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Balanced Urban Development: Options and Strategies for Liveable Cities

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Balanced Urban Development: Options and Strategies for Liveable Cities

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MISTRA URBAN FUTURES

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Preface

The current world population is about seven billion, split almost evenly between rural and urban. Projections are that by 2050 the global population will increase to about ten billion. It is likely that the bulk of the increase will occur in urban population, perhaps due to migration from rural areas. The massive migration is and will be posing huge challenges with regard to water security, energy security, food security, transportation, housing, education, health services, protection from natural disasters, social tranquillity, economic opportunities and health of ecosystems. These challenges will be daunting for any government – local, state and national. Already, migration of people from rural areas to urban areas is occurring at an accelerating pace, particularly in developing countries, such as Brazil, China, Egypt, India and Mexico. For the lack of space, urban development is moving into the countryside, eliminating much of the best farmland surrounding cities, and peri-urban areas are rapidly sprouting. In many countries, some of the highly valued natural resource assets, such as biodiversity, native vegetation, peri-urban agriculture, wetlands and waterways, occur in peri-urban landscapes. In view of the impacts of climate change, energy costs, rising world population and changing patterns of food consumption, the value of these assets will increase even further.

The aim of any government body is to strive for balanced urban development (BUD). However, BUD may mean different things to different people and different sectors. There is no universal definition of BUD. It is therefore important to have a dialog on this very critically important issue. In many countries, the way urban areas have come up, there are limited options left for BUD. The local and state governments do not have well-developed strategies to achieve BUD or have limited opportunities to develop new and innovative strategies for BUD. The motivation for this book therefore stemmed from the desire to provide a discussion of BUD and options and strategies for achieving it.

Introducing the theme of this book in Chap. 1, the subject matter of the book is divided into nine parts. Part II deals with peri-urbanisation comprising five chapters. Chapter 2 discusses lessons learnt from re-ruralising in the USA, Europe and Global South; what is being done to keep the countryside (peri-urban areas) green is treated in Chap. 3. Chapter 4 discusses rural design connecting urban and rural futures. The role of archaeology and urban dynamics in developing more resilient and sustainable cities in the peri-urban interface is presented in Chap. 5. One consequence of urbanisation is the generation of pollutants and their transport by run-off. Chapter 6 deals with the decontamination of urban run-off.

Part III, comprising three chapters, deals with peri-urban culture and social economy. Chapter 7 discusses the case of Lisbon, Portugal, to illustrate the social and economic dimensions of urban areas. Taking the case of Udaipur City in Rajasthan, India, Chap. 8 discusses the changing economic scenario of peri-urban areas. Chapter 9 deals with the stakeholder viewpoints on urbanisation, with particular reference to Ma Oya River in Sri Lanka.

Peri-urban land use planning is the theme of Part IV that comprises three chapters. Chapter 10 discusses the role of peri-urban land use planning, with particular reference to Melbourne, Australia, whereas Chap. 11 discusses how to engage peri-urban stakeholders in natural resource management which is a challenge in any landscape. Chapter 12 deals with a master plan for urban farming in western Sydney from planning to implementation. It highlights the challenges the plan will face, including legislative and regulatory processes and environmental and social factors, and provides insights into planning-to-reality of the farming plan.

Urban water security is the theme of Part V that comprises four chapters. Chapter 13 discusses urban water bodies, such as wetlands, that act as coolers for urban environment and natural filters for water purification. Chapter 14 deals with groundwater crisis, with particular reference to Delhi, India, and reflects on the sustainability of this valuable resource. Using the case of peri-urban communities of southeast Nigeria, Chap. 15 discusses safe water supply determinants, and Chap. 16 deals with risks of groundwater and aquifer contamination due to hydraulic fracking.

Part VI deals with the recycling of wastewater and its use for irrigation. It contains three chapters. Chapter 17 deals with the use of recycled wastewater for irrigation of open spaces, such as lawns, golf courses and parks. Chapter 18 discusses challenges and opportunities, based on global experiences on the use of wastewater for irrigation. It makes a strong argument for the employment of modern technologies to mitigate detrimental environmental consequences of wastewater irrigation. Discussing a case study of Udaipur City, Rajasthan, India, Chap. 19 deals with the impacts of wastewater reuse on peri-urban agriculture.

Urban agriculture and food security constitute the subject matter of Part VII containing four chapters. Chapter 20 deals with urban agriculture in Cuba, with regard to legal structures in response to food security crisis. Chapter 21 discusses news ways to identify high-quality agricultural lands and use them as a decision-making tool, whereas Chap. 22 discusses planning and design of food-efficient neighbourhoods. Using Kampala, Uganda, as a case study, Chap. 23 discusses the role of peri-urban areas in the food system.

Part VIII treats the impact of climate change and adaptations and contains four chapters. Chapter 24 discusses a project in Victoria, Australia, that identifies, analyses and evaluates climate change risks and develops an adaptation plan to prepare for likely impacts of climate change. Chapter 25 emphasises the role of awareness through education and training to understand climate change impacts and develop plans to cope with these impacts, using a case of Pakistan. Chapter 26 considers the effect of climate change on food production with particular reference to urban agriculture and the associated impact on food security. It also considers the value of urban agriculture to the health and nutrition of developing and developed countries. Chapter 27 discusses the adaptive capacity of Indigenous People living in coastal urban and peri-urban areas to climate change.

Legal, policy and institutional challenges are described in Part IX that contains three chapters. Chapter 28 argues for voluntary collective action to be essential for natural resource governance in peri-urban settings, where a complex behavioural and institutional matrix and the net balance of incentives and disincentives, supports and impediments determine the likelihood of effective action. The chapter explores the dynamic nature of the challenge of collective action in a peri-urban setting. Real estate is a major driver of the economy in many countries of the world and is one of the main barriers to the development or implementation of zoning and planning regulations that would make urban agriculture more than a fortuitous and temporary use of space. Taking the case of Beirut, Chap. 29 deals with gentrification versus territorialisation in reference to peri-urban agriculture. Chapter 30 discusses the role of mega urban regions as economic integration regions in Southeast Asia.

The last part, Part X, deals with integrated urban development. Beginning a discussion of lessons learnt from the journey of engagement for the sustainability of water resources in peri-urban landscapes in Chap. 31, it goes on to discussing the development of future management options for Hawkesbury River in Chap. 32. Case studies from New South Wales discussing the development of plans for reducing mosquito hazards in peri-urban landscapes are presented in Chap. 33. Chapter 34 presents and demonstrates the use of an information modelling platform for assessing alternative urban development scenarios. It also illustrates the application of the platform to a peri-urban development in the city of Melbourne, Australia.

It is hoped that peri-urban planners and managers, municipal council representatives, local governments and state governments, as well as students, researchers and consultants of water and land use planning, environmental management, peri-urban agriculture, food security, water security, energy security and ecosystems management, will find this book to be useful.

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We would like to take this opportunity to thank all the chapter authors for their contribution in the book.

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Basant Maheshwari has wide-ranging research experience in urban and peri-urban water management, planning and sustainability. Over the past 10 years, his work has involved transdisciplinary approach to water research and has focussed on understanding how water, landscape and people at the interface of urban and rural fringe (peri-urban) interact and influence the environment and sustainability. His work in recent years focussed on modelling and analysing the surface and groundwater resources for long-term water resource planning at regional level and examining the implications of social, economic, cultural, policy and institutional aspects of water resources management. He has over 180 publications, including more than 75 journal articles in peer-reviewed, international journals. He was recipient of the 2010 Collaboration and Leadership Award from CRC for Irrigation Futures and fellow of ISAE.

Vijay P. Singh Ph.D., D.Sc., P.E., P.H., Hon. D.WRE, is distinguished professor and Caroline and William N. Lehrer distinguished chair in water engineering at Texas A&M University. Professor Singh has been recognised for four decades of leadership in research, teaching and service to the hydrologic and water resources engineering profession. He has published his research in more than 710 refereed journal articles, 300 conference proceedings papers, 80 book chapters and 70 technical reports. He has authored or co-authored 21 books and has edited another 54 reference books. He has been the recipient of 63 national/international awards from professional organisations. He is a recipient of the Arid Land Hydraulic Engineering Award, Ven Te Chow Award, Torrens Award, Norma Medal and Lifetime Achievement Award all given by ASCE and Ray K. Linsley Award and the Founders Award given by the American Institute of Hydrology. He has been awarded two honorary doctorates one by the University of Waterloo, Canada, and the other by the University of Basilicata, Italy. He is a fellow of ASCE, EWRI, AWRA, IE, ISAE, IWRS, IASWC and IAH and a member of AGU, IAHR, IAHS and WASER. He is member/fellow of ten engineering/science academies.

Bhadranie Thoradeniya is a senior lecturer at the Division of Civil Engineering, Institute of Technology, University of Moratuwa, Sri Lanka. Her research interests and teaching experience over 30 years in the subjects related to water and land are underpinned by the M.Sc (Distinction) degree she obtained from the UNESCO-IHE, the Netherlands, in 1995. Over the years her research has focused on social, economic and environmental aspects of water resources development and specifically on stakeholder involvements in engineering projects. Currently she is leading an international research team on a project aiming to ascertain the impacts of water quality on livelihood of the dry zone farming communities of Sri Lanka. She has authored and co-authored several conference and journal articles and book chapters.

Part I
Introduction

Chapter 1
Balanced Urban Development: Is It a Myth or Reality?

Basant Maheshwari, Vijay P. Singh, and Bhadranie Thoradeniya

Abstract A major challenge we face globally is that cities are growing rapidly and most of this growth is inevitably is occurring in peri-urban areas. The concept of balanced urban development is complex and is linked to liveability of urban areas along with water, food and energy security. Increasingly, liveability is becoming important for urban planners and governments at all levels. There are many environmental, economic, political and social challenges if the goals of achieving sustainable, liveable and productive urban regions are to be achieved. The concept of sustainable development and liveable cities symbolise the big visionary ideas for urban planning and balanced development but implementation of these popular visions can encounter a host of conflicts due to a range of interests and stakeholders involved. The process of achieving balanced urban development may require learning from the past successes and mistakes to identify what makes a good practice for balanced urban development and guide local governments, planning agencies and developers to plan and design future cities that are highly liveable. At present there is insufficient policy focus on the challenges of the peri-urban areas of growing mega-urban regions around the world, because they are not recognised as an integral part of the functional activities that drive the growth of these urban areas. Thus, policies for peri-urban regions have to be given priority at both national and global levels, if 'globally just urban places' are to emerge.

Keywords Liveable cities • Urbanisation • Peri-urban fringe • Balanced urban development • Food security • Water security • Land management • Urban agriculture

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1.1 Introduction

A major challenge we face globally is that cities are growing rapidly, with current forecasts indicating strong growth in the urban fringe well into the future (Cohen 2006). Most cities around the world play an increasingly dominant role in the national economy in terms of both production and consumption but the urban growth, particularly in developing world, so rapid in the 10–15 years that it is putting a question mark on the capacity of most cities to provide adequate services and amenities for their residents. Our local, state and federal governments are faced with the complex task of creating future urban areas that are sustainable and liveable. Most of the future urban growth will occur in peri-urban areas that are complex to manage and have significant impact on the liveability of cities. Urban growth is inevitably linked to peri-urban areas, the zones of transition from rural to urban land uses located between the outer limits of urban and regional centres and the rural environment. The boundaries of peri-urban areas are porous and transitory, as urban development extends into the rural and industrial land. Irrespective of how the boundaries move, there will always be peri-urban zones.

There are growing concerns about water and food security to meet increases in population in urban areas. The pressure of urbanisation is enormous in the Asia-Pacific region which includes six of the world's most populous countries, viz., China, India, Indonesia, Pakistan, Bangladesh and Japan, and include over 55 % of the world's total population (CISS 2013). The population growth and ensuing urbanisation, particularly in this region, has obvious implications for water and food security and liveability of cities. For cities to be liveable and sustainable into the future there is a need to maintain the natural resource base, food production and the ecosystem services in the peri-urban areas surrounding cities. The development of peri-urban areas involves the conversion of rural lands to residential use, closer subdivision, fragmentation and a changing mix of urban and rural activities and functions. Changes within these areas can have significant impacts upon ecohydrological functions, environmental amenity and natural habitat, supply and quality of water and water and energy consumption. These changes affect the peri-urban water and land management and food production.

By the middle of 2009, the number of people living in urban areas exceeded the number living in rural areas and according to the UN estimates, by 2050, two out three people in the world will live in urban areas (United Nations 2009). Therefore, peri-urban development as a consequence of urbanisation is inevitable. There are challenges of water availability for urban irrigation, for drinking and a number of other uses. The future liveability of urban areas is very much linked to water availability along with a number of other factors. There is some sort of 'revolution' taking place around cities and towns around the world to build new suburbs partly to accommodate more people but it is also encouraged by government policies and financial assistance (e.g., the first home buyers grant in Australia) to maintain a "healthy" economy.

The growth of urban areas is now dominated by vertical expansion around the main city areas and horizontal expansion in surrounding areas, mainly into peri-urban zones (McGee 2009). We still do not fully appreciate how the liveability of cities is impacted by land and water use changes and consequent changes we cause in natural vegetation and wildlife through urbanisation. The growth also has influence on peri-urban food production and range of other services. The urbanisation process presents unprecedented complex environmental, social, economic and political challenges, especially in terms of keeping urban areas greener and cooler and thus more liveable. Although, there are some differences in terms of local conditions and scales, the problems of urbanisation are similar for cities and towns across different countries.

1.2 What Makes a City Liveable?

Liveability is becoming important now-a-days for urban planners and governments at all levels. The definition of liveability varies depending upon the purpose of why it is being considered in the first place and by whom, yet the common goal of liveability is that how we direct our actions, planning and designs that will make a place enjoyable to live in (Ruth and Franklin 2014; de Haan et al. 2014). The idea of a liveable city is to bring community together for healthy living, enhance their interaction among themselves and surrounding environment and promote their productivity and wellbeing in a sustainable way. Liveability is often related to the values and preferences local community places for amenity, wellbeing aspect and sense of place or belonging. However, it must be noted that the meaning of liveability may vary, depending upon the needs of the community and local environment and place-related factors. The main purpose of balanced urban development is to improve liveability, and for this we need to plan for an appropriate access to drinking water and sanitation, healthy waterways and efficient and environmentally friendly transport networks. When urban development is well balanced with different needs, it will provide opportunities for businesses and commerce to grow, create jobs and facilitate affordable housing and living for different levels of society. Furthermore, such development will result in access to surroundings that appeal to local residents, provide ample opportunities for strong social and cultural networks, and foster a sense of place and belonging (Goldberg et al. 2012).

1.3 Urbanisation is Inevitable

Urban expansion is accelerating with projections that cities will accommodate more than 70 % of the global population by 2050 (United Nations 2011). The growth of urban areas will be dominated by vertical expansion of mega cities and horizontal expansion in surrounding areas into peri-urban zones. It is not fully appreciated that what occurs in peri-urban areas affects both the urban areas and surrounding rural communities. The urbanisation process presents unprecedented complex environmental, social, economic and political challenges. Although there are diverse local conditions and scales, the problems of expanding cities have similarities worldwide, e.g., loss of productive agricultural land, changes in the hydrology of the place due to more areas under hard surfaces and loss of natural habitat.

In the period up to year 2050, the growth of urban population will occur primarily in the developing countries of Asia and Africa (McGee 2009). This region could contribute up some 60 % of urban increase in this period. The growth of urban places will be dominated by two spatial processes. First, the growth of central cities in mega-urban regions, and second an ongoing process of horizontal urban expansion into surrounding hinterlands creating peri-urban regions that will contain-up to 70 % of mega-urban regions population by 2050. This latter process presents many environmental, economic, political and social challenges if the goals of achieving sustainable, liveable and productive urban regions are to be achieved.

1.4 The Role of Water in Peri-Urban Landscapes

Water is a vital input to the liveability of cities but there are many other factors related to population growth, competition for land and water resources, globalisation and climate change that need to be overcome for enhancing and sustaining the liveability. When we see green space, it is pleasing to the human eye and indoor and outdoor areas that contain green spaces benefit community in a range of ways, including promoting physical activities, relieving mental stress, cooling environment through transpiration, and biodiversity (Schebella et al. 2012). For maintaining green space, urban irrigation is critical and the provision of water that is secure and fit-for-purpose is essential. In addition to significant changes in the local water cycle, with urbanisation, there are also water policy and regulatory aspects that impact the water sources available for irrigation, the places that are irrigated and the management of irrigated spaces.

Provision of green spaces is increasingly considered important and promoted as part of planning process in many urban growth areas. Functional green space is a core element of liveability and therefore maintaining healthy vegetation, which often requires irrigation, is essential for aesthetics, sport and exercise activities, natural environment conductive to relieve everyday stress as well as a range of other benefits (Fig. 1.1). Therefore, the role of water in maintaining soil moisture, thus to support green space vegetation, is becoming more important in urban growth areas.

Water Sensitive Urban Design (WSUD) systems is another approach that is being considered in many new growth areas to cope with future water scarcity. The water supply systems that incorporate rainfall harvesting and reuse need to provide reliable water supplies to support green spaces. The planning and design of urban areas need to consider strategies for water supply during periods of low rainfall and drought to maintain irrigation, when the value of green space to maintain liberality

Fig. 1.1 Public open spaces will be quite important in the future and so will be maintaining them green, especially during the periods of drought

becomes greater. In future, potable mains water may be limited for urban irrigation and so the use of recycled water may play an important role in securing water for urban irrigation in new growth areas. To ensure sustainable use of this water for irrigation, the chemical quality of the recycled water and the soil chemical properties need to be technically assessed in terms of suitability for soil and plants to maintain sustainable landscapes.

To sustain future urban areas liveable, we need to emphasise the following points related to water for future urban planning and policy making:

- Irrigation is central to future successful peri-urban development;
- Provision of secure and fit-for-purpose water for irrigation is essential;
- Capacity building of the irrigation and water industry is important in developing viable and sustainable solutions; and
- Greater advocacy by the irrigation industry of the specific requirements of irrigated green space will assist in informing planners and developers of the specific needs of sustainable sites.

1.5 Key Challenges of Sustaining Future Urban Areas

The planning in the past has focused on community character and sense of place, but there was little attention to protecting the environmental, social equity, and place-based economic development (Berke 2002). The current rate and complexity of urban expansion often results in ad-hoc and fragmented policy and planning at the city or state level. There is no clear vision or policy related to urban water, especially related to the rainwater harvesting, reuse of water and the overall need to keep new urban areas greener in the longer term.

The planning strategies and processes, during the urbanisation process, are often more focussed on subdivision of land, building roads and some basic necessities but urban irrigation is something that is added at the end. There is a need for holistic thinking about how we are going to sustain urban irrigation. It is important to base urban irrigation as part of liveable city agenda integrating perspectives from natural and social sciences, economics, government, industry and community.

The key question we need to ask ourselves in relation future peri-urban areas is 'how do we want to 'do' sustainable urban development successfully? Urban irrigation is an essential component of green space and by giving it due consideration during urban development will result in holistic environmental planning and eco-friendly living. The common green space will be critical in the future if future urban designs are focussed on high density housing (Fig. 1.2). It is important that decision-makers are made aware of how urban irrigation and green space benefit the community through health and wellbeing.

The International Conference on Peri-Urban Landscapes: Water, Food and Environmental Security (www.periurban14.org) was held in Sydney from July 8–10, 2014. Various issues and challenges, including governance were addressed at the Conference, and it was attended by over 150 policy makers, researchers, planners, government officials, NGOs, private sector specialists and community groups from 16 countries. The conference concluded that peri-urban development as a consequence of urbanisation is unstoppable, and that it requires special and urgent policy and governance attention to meet the challenges of water, energy, food, environment and liveability of cities we face now and into the future. The conference identified a number of key challenges and actions for policy and planning future urban areas.

- The rate and complexity of urban expansion often results in ad-hoc and fragmented policy and planning with inequitable investment across the effected landscapes and unsustainable development.
- Vertical expansion of housing cannot alone meet the demand for urban expansion, and so there will be continued pressure on non-urbanised lands.
- Given their transitional status and rapidity of change, peri-urban areas face unique challenges. In particular, there is a need to address multi-dimensions of poverty in emergent urban societies.
- Unless governments take immediate actions to address the resulting challenges, current and future generations will suffer massive escalating economic costs, ecological degradation, political disruption and cultural dislocation.

Fig. 1.2 New development areas such as the one shown in this picture from Western Sydney are now focussed on smaller backyards and so the public open spaces will be integral to urban living

- Governments must address the complex challenges posed by expanding cities as an essential element of UN Post 2015 sustainable development and poverty alleviation goals. We welcome the recent inclusion of a specifically urban goal in the draft list and urge further work to ensure it has practicable and appropriate content.
- All levels of government need to work with the private sector and communities to develop integrated strategies and plans, based on local engagement and transparent decision making.
- Global and local investments in built and ecological infrastructure and services should be directed to ensure equity between people occupying urban and peri-urban landscapes.
- Regional planning strategies and processes should be based on trans-disciplinary research and integrate perspectives from natural and social sciences, economics, government, industry and community.
- National and international indices of “liveability” and “sustainability” should be developed to guide future urban planning strategies and measure effectiveness of urban development.

1.5.1 Knowledge and Capacity Building Actions for Future Cities

- Governments and knowledge providers must come together to generate, maintain and enhance knowledge bases on ecological, socio-economic, political and cultural dimensions to build baseline conditions and test future development scenarios.
- The education and planning sectors must address the shortcomings of existing planning processes and management by developing innovative curricula and delivery mechanisms for professional and community actors.
- Governments, R&D bodies, NGOs and donors are urged to make significant investments in research and development to support and integrate hard evidence into sound decision making.
- Emerging tools and techniques need to be customised and implemented to tackle these challenges. There should be an integrated approach, for example, the 'Circles of Sustainability' method used by the United Nations Global Compact Cities Programme, Metropolis and other organizations.

1.6 The Process of Balanced Urban Development

The concept of sustainable development and liveable cities symbolise the big visionary ideas for urban planning and balanced development but implementation of these popular visions can encounter a host of conflicts due to a range of interests and stakeholders involved (Godschalk 2004). The process of balanced urban development requires transdisciplinary approach and engagement of a range of stakeholders (Fig. 1.3). In broad terms, the balanced urban development is concerned with three key themes: place, people and planning. The aim is to help policy makers, local governments, developers and service providers through development of the various planning tools and models that help to analyse and visualise different options and scenarios. The overall goal of the balanced urban development is to deliver liveable, sustainable, resilient and affordable areas.

Urban development can impact health and wellbeing of people in the medium and longer-term. During the process of achieving balanced urban development, we can learn from the past successes and mistakes to identify what makes a good practice for balanced urban development and guide local governments, planning agencies and developers to plan and design future cities that are highly liveable.

Engaging community in the planning, design and development of future growth areas is equally important. In particular, we need to put in place planning processes that will effectively engage stakeholders and will assist them to understand constraints and options for the future development and have their input in what the new residential areas will look like and function as liveable places. This will particularly help in better economic, social and environmental outcomes, while minimising the need for costly redevelopment in the future.

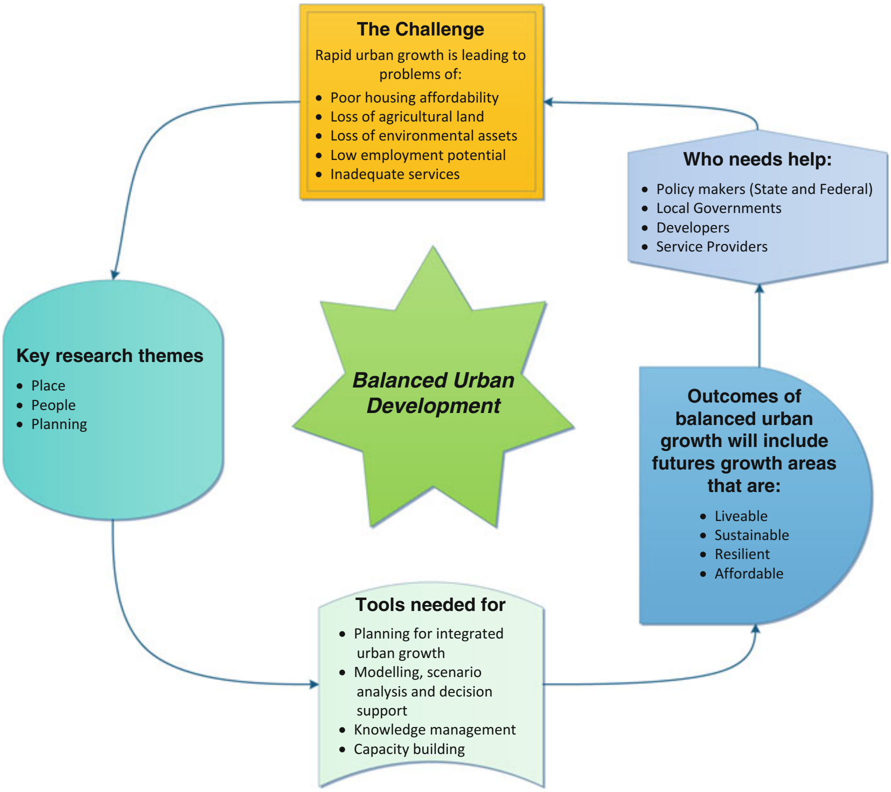

Fig. 1.3 The process of balanced urban development

Developing liveable cities does not stop at planning, design and establishing the new urban areas but the ongoing monitoring, refinement and learning need to continue in the future. Liveability of a place can change due to range of factors over time and so what is liveable now may not be so in the future. Therefore, it will be important to regularly collect data that will assess liveability, community health, wellbeing and the range of factors that contribute to a better quality of life in a given urban areas.

Another important area related to liveability is the social infrastructure and community interactions and their impact on access to quality health, educational, social, cultural, business and recreational facilities in the area and overall in promoting social interaction and a sense of community place and belonging. For sustainable development, we need governance, policy mechanisms and investment and infrastructure approaches that will facilitate resilience in future cities, not only from the point view of economic but also from environmental, social and cultural points of view. The future liveable cities must also have climate change adaptation and risk management strategies, particularly taking care of natural disasters, such as flooding and wildfire.

From food security point of view, the process of balanced urban development also needs to explore opportunities to maintain and develop existing agricultural enterprises, together with the spin-offs for landscape value and environmental amenity. The process need to examine alternative approaches to the protection of agricultural land of strategic significance and the options for improving the profitability of agriculture in areas that are inappropriate for urban development, such as floodplains. Biodiversity and ecosystems services are equally important in the development process. Both biodiversity and ecosystems services are quite complex and can be impacted by growth of new urban areas and may impact the broader catchment health, including impacts on flooding, fire hazard, erosion, water quality, salinity and biodiversity and the cost of delivering services over longer distances and broader areas.

1.7 Concluding Remarks

At present there is insufficient policy focus on the challenges of the peri-urban areas of growing mega-urban regions around the world, because they are not recognized as an integral part of the functional activities that drive the growth of these urban areas. Policies tend to focus on making the central city more globally connected and internationally competitive, often absorbing a large proportion of national budgets for urban development. There is a need to create more balanced budgetary allocation, so that challenges of peri-urban regions can be met. Further, there is a need for more innovative research that can be fed into the formulation of peri-urban policies that will make cities liveable and sustainable, while they are secure in terms of water, food and energy. Thus, policies for peri-urban regions have to be given priority at both national and global levels, if 'globally just urban places' are to emerge.

References

Berke PR (2002) Does sustainable development offer a new direction for planning? Challenges for the twenty-first century. J Plan Lit 17(1):21–36

CISS (2013) Food security in Asia – a report for policymakers. Centre for International Security Studies, University of Sydney, Sydney, 32p. http://sydney.edu.au/arts/ciss/research/food_security.shtml. Accessed 15 Aug 2015

Cohen B (2006) Urbanization in developing countries: current trends, future projections, and key challenges for sustainability. Technol Soc 28(1–2):63–80

de Haan FJ, Ferguson BC, Adamowicz RC, Johnstone P, Brown RR, Wong TH (2014) The needs of society: a new understanding of transitions, sustainability and liveability. Technol Forecast Soc Chang 85:121–132

Godschalk DR (2004) Land use planning challenges: coping with conflicts in visions of sustainable development and livable communities. J Am Plan Assoc 70(1):5–13

Goldberg A, Leyden KM, Scotto TJ (2012) Untangling what makes cities liveable: happiness in five cities. Proc ICE Urban Des Plann 165(3):127–136

McGee T (2009) The spatiality of urbanization: the policy challenges of mega-urban and Desakota Regions of Southeast Asia. UNU-IAS Working paper no. 161. www.as.unu.edu/resource_centre/161%20Terry%20McGee.pdf

Ruth M, Franklin RS (2014) Livability for all? Conceptual limits and practical implications. Appl Geogr 49:18–23

Schebella M, Weber D, Brown G, Hatton MacDonald D (2012) The importance of irrigated urban green space: health and recreational benefits perspectives. Goyder Institute for Water Research, technical report series No. 14/2, 30p

United Nations (2009) Urban and rural areas 2009. Department of Economic and Social Affairs, Population Division. http://www.un.org/en/development/desa/population/publications/urbanization/urban-rural.shtml

United Nations (2011) Population distribution, urbanization, internal migration and development: an international perspective. Department of Economic and Social Affairs, Population Division, Publication no. ESA/P/WP/223, 363p

Part II
Peri-Urbansation

Chapter 2
Re-Ruralising the Urban Edge: Lessons from Europe, USA & the Global South

Helen Armstrong and Abby Mellick Lopes

Abstract Major cities of the world are characterised as either growing cities, such as in Asia and Australia, or shrinking cities as in Europe and North America. Growing cities are destroying their rural edge while shrinking cities are creating a new rural urbanism, often in their urban centre. This chapter describes the instrumentality of design and its enabling function in achieving new typologies for peri-/inter-urban rural land with key drivers being state-of-the-art technology and mapping techniques. Peri-urban economics require new land-tenure models and innovative forms of agriculture that synthesise agriculture, nature conservation, infrastructure and communities. The chapter also looks at small-scale community innovations including a number of initiatives in Penrith, Western Sydney, such as *Out & About in Penrith* which explored community activities in local open space, Penrith as *a Regional City Garden* with diverse models of urban agriculture and the *Cooling the Commons* project which explores the role that forms of urban agriculture might play in adapting urban environments for liveability in a climate-changed future. Findings from these projects reveal the potential of mobile infrastructure and temporary urbanism for Western Sydney.

Keywords Urbanisation • Re-ruralisation • Urban edge • Urban economics • Land tenure • Urban environment

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2.1 Introduction

This chapter draws from a range of international projects in the peri-urban and urban areas, both large and small, that are addressing the loss of food-producing land such as the planning and design work occurring in the Netherlands where the debate about urban development is focussed on how to achieve new forms of rural/urban/natural landscapes. There are also important lessons to be learned from the shrinking cities of Europe and North America where a new rural urbanism is emerging; either encouraged by government such as the *Farmadelphia* Program in Philadelphia or informally as in Detroit and Berlin. Similarly in the German towns of Hamburg, Frieburg and Tübingen, the rural tide is turning with new models for collective farming in the zschischenstadt or urbanised countryside (Sieverts 2003).

2.2 Four Ways to Revive Sydney's Peri-Urban Agriculture

What role should planners and designers in Australia play to address the loss of food-producing lands? We suggest this problem can be addressed in four distinct ways.

First, many peri-urban farms are market gardens developed by migrants in the 1950s–1960s. The farmers are now elderly and understandably see rezoning their farms for residential development as a retirement income. Respect for this equity issue requires innovative planning for land tenure, related to productive land that allows owners to realise their land's development value without changing the rural use. This can be achieved through transfer of development rights (TDR) (Armstrong 2005). Parallels exist with built heritage, successfully addressed through TDR which enable owners of heritage buildings to realise similar capital returns to those who own non-heritage buildings by transferring their development rights to other locations. Western Sydney's designated Growth Centres are ideally placed for such transfer of development rights to save productive peri-urban land.

The second issue relates to reversing 'Rural Residential' zoning. Many local government areas are pressured by the electorate to rezone agricultural land to 'Rural Residential'. This is the least supportable way to use such valuable productive land as it merely satisfies the desires of affluent exurbanites seeking so-called 'lifestyle living' in the rural areas outside cities. Conversion of prime farming land in the Sydney region into rural residential lots has been at the forefront of political and development conflict about appropriate planning for peri-urban lands (Sinclair et al. 2003).

European designer/planners offer alternative models for 'Rural Living' that allow for continued productive farming associated with new clustered residential areas. This involves innovative land tenure and inventive forms of governance drawn from the organizational strategies associated with cooperatives. There are interesting examples in the Netherlands, Hamburg and Zurich, such as the award-winning proposal by the landscape designers, ceto-o/kunzt + herbert, for 'Fischbeck Mississippi', Hamburg (Aufmkolk 2003) and the Tübingen-Südstadt's community plan developed to contain the pressure for urban sprawl using orchards, city farms and ecological infrastructure for water purification. This community plan won a European Urban and Regional Planning Award (*ECOCITY Tübingen-Derendingen* n.d.). Zurich has new consumer-led cooperatives for the production of local, seasonal and organic food ensuring the peri-urban stays productive. The Netherlands sees its new Agroparks as providing numerous benefits of spatial clustering such as closing the cycle with community waste and reducing transport requirements (Smeets 2011).

These cooperatives have prompted the European Commission to instigate a research project 'Towards sustainable modes of urban and peri-urban food provisioning' called SUPURBFOOD and financed by the European Commission's 7th Framework Program for Research and Technological Development as a 3 year project from 2012 to 2015. The project is analysing agri-food dynamics, policies and governance arrangements in different European city regions and looking at how observations from the Global South, such as short food chain delivery, water, nutrient and waste management and multifunctional agriculture in urban and peri-urban areas, can be applied to European city regions (*Supurbfood* n.d.). In Asia, Beijing is actively promoting multi-functional recreational agriculture in the peri-urban zones, using land use planning as well as allocating parts of the municipal budget for investments in the peri-urban region (*Supurbfood* n.d.).

The third issue involves making productive land attractive to new farmers. The recent market growth of water products, ecosystem services, and niche marketing of gourmet products are emerging opportunities for rural economics.

Finally, the fourth issue; the development of new urban agriculture associated with hybrid urban forms which conflate architecture, landscape, infrastructure and high tech farming in innovative ways. Thomas Sieverts (2003), the Berlin-based planner, called the peri-urban lands the 'Zwischenstadt' or 'in-between lands', suggesting that urban-rural landscapes can be a new form of city characterised by mutual penetration of built forms and rural landscapes. For over a decade he has been asking why not develop a new cultural landscape in which food production, recreation, and ecological balance create new relationships with built-up areas? It would appear that such hybrid urban forms are emerging and many of them are exploring innovations associated with temporary urbanism.

2.3 Lessons from the Global South

Planners in Casablanca, the largest port in Africa and an emerging megacity, are responding to Sieverts' question. Peri-urban agriculture in Casablanca has been the focus of a large international research team funded by the German Federal Ministry of Education and Research (BMBF) looking at Sustainable Development for Megacities of Tomorrow in order to develop energy and climate efficiency (*Urban*

Agriculture, Casablanca (UAC) n.d.). They have been working together to observe how urban agriculture can contribute to sustainable, climate-optimised, urban development. Their focus has been on the integration of the existing agricultural use in Grand Casablanca into urban development and on its transformation from typical rural land use into multifunctional green infrastructure. The teams have used reflexive action research to explore synergetic rural-urban linkages and new livelihoods in peri-urban areas (Giseke 2011).

The environmental implications of these new hybrid urban agricultural forms now include issues related to food security under climate change. Assessment of climate change and urban/peri-urban agriculture was recently initiated in nine cities across Africa and South Asia in order to understand the complex interplay of climate change, urban agriculture, and urban food systems. This is being funded by the European Commission, with co-funding from UNEP and additional support from USAID.

The extensive programs being initiated in Europe and involving Africa and Asia are big steps. There are also small steps involving community actions in the shrinking cities of North America and Europe.

2.4 Lessons from the Shrinking Cities

Detroit, epitomising the extensive low-density suburbanised American city, is now designated as a 'shrinking city'. The extent of abandonment due to de-industrialisation has resulted in sprawling anarchy. Yet out of the ashes something optimistic is happening that is far removed from the models used by planners or architects. The inner ring of worker-housing surrounding the remnant central business district has become a new form of rural land. The city is now a mosaic of deteriorating urban structures and new rural spaces. The new rural areas, made up of many hundreds of urban farms, intersect strangely with the decaying infrastructure of an abandoned big city. These community-initiated farms, facilitated by the Detroit Agriculture Network, are resulting in a different urban paradigm where an outer suburban ring surrounds a re-ruralised core of new farmland and forests occupying the former inner-city. Although most of the farms are on squatted land, the success of the community enterprises has encouraged the city administration to develop 'Land Banks' where for one dollar, residents can receive the title to land, providing they maintain the land and pay taxes. So successful has the community enterprise been, that investors are now seeking to be part of the new urban agriculture (Guss 2010).

Philadelphia is another shrinking city. The increasing number of derelict spaces and vacant buildings in the urban fabric prompted the city to hold a design competition for Philadelphia's 'voids' in 2005. The winning entries addressed water management and environmental rehabilitation, but one entry, particularly empowering for the community, was an urban farming proposal called FARMADELPHIA by the designers, Front Studio. The FARMADELPHIA proposal involves a city-wide conversion of vacant lots into farmlands where each block maintains responsibility for the management and harvesting of crops. Within a far-reaching 7 year agricultural plan for the city, sequenced crop are proposed, starting with easy to grow perennial crops such as corn, raspberry bushes, mustard greens, herbs and so on and progressing through to well-managed permaculture (*Farmadelphia* 2006).

Ruralising the urban is also being explored as a hybrid between recreation and cultivation in the form of new models for city gardens such as Gleisdreieck Park in Berlin which involve community engagement and responsible citizenship. Harking back to the medieval system of interlocking duties and obligations of all, from the city institutions to the homeless, these city gardens are proposed as the locus of local food production, new forms of bartering, innovative environmental design, resilient and flexible examples for twenty-first century communities.

In Western Sydney, Penrith planners have been exploring the idea of a regional city garden. As the largest of the three river cities in Sydney, Penrith is a city at the nexus of the Cumberland Plains, the Blue Mountains and the emerging Penrith Lakes. Penrith planners are looking at ways to contribute to responsible urban living in the twenty-first century by forging local and regional partnerships with peri-urban farmers and other developing industries. Drawing from city garden and peri-urban research and consultative workshops, a proposal for a regional city garden was developed as a major focal site in the 'Penrith Lakes' area with supplementary loci throughout the region that can consolidate community partnerships and showcase local products, including those from local farms. The educative role of Penrith City Garden was intended to operate through smaller thematic gardens, including innovative peri-urban agriculture enterprises as well as collaborative research projects with Hawkesbury Harvest and the University of Western Sydney.

Using the principles of eco-urbanism, particularly open-endedness, complexity and resilience when subjected to dynamic change, these regional city gardens develop Sieverts' ideas where the landscape acts as multiple 'Soft Systems', including urban water features that undertake water treatment, phyto-remediation on derelict sites, energy harvesting, green roofs and walls, and designed landscapes that accommodate climate change by employing increasingly sophisticated use of rain water to address unpredictability.

Another innovative example of urban agriculture was proposed for the White Bay-Rozelle Bay precinct just west of the Sydney CBD, currently lying derelict. The innovation lay in the concept of urban agriculture as a temporary use involving flexible infrastructure that can exploit abandoned industrial sites. The proposal included 'light' and 'dark' agriculture. The 'light' concept, proposed for the empty hardstand previously used for container storage on Glebe Island, was an urban orchard under a giant flexible glasshouse; while 'dark agriculture' was proposed for the long nondescript maritime storage shed on the western edge of White Bay.

The proposed glasshouse was a glazed space-frame over a sub-tropical and citrus orchard adjoining glazed vertical farms and assisted by the old silos, which were reworked into a complex system for water purification using recycling water, as well as sites for storage of produce. Surrounding the diamond facetted glasshouse, a shrubby wind-blown embankment of hardy bush-food contrasted with the moist sub-tropical environment inside. 'Dark' agriculture in a large abandoned shed, consisted of enclosed layers of agriculture systems needing less and less light; on top, a system known as valcent vertical hydroponics took advantage of roof lighting, below this were omega carousel gardens with internal lighting, and below this commercial mushroom farms in the dark. These were all modular enabling rapid assembly and disassembly. A key to the feasibility of these proposals lay in the economics of temporary use (Armstrong 2011).

2.5 The Value of Temporary Uses

Temporary use of urban space has progressively become the focus of innovative planning (La Varra 2005). A European urban forum, Urban Catalyst, has developed a unique archive for planners, municipalities, developers and others from their investigations into temporary uses in residual urban areas. They note that conventional architecture and urban planning are increasingly unable to find answers to the radical transformation occurring in cities. To address this, Urban Catalyst's interdisciplinary network has developed strategic planning tools which integrate temporary uses into long lasting urban developments. These are now available in the publication, *URBAN CATALYST- THE POWER OF TEMPORARY USE* (Oswalt et al. 2013); a compilation of more than 10 years of research and practice in the field of temporary use as a catalyst of urban development in Europe. Urban agriculture with its annual crop cycle is well suited to temporary and flexible infrastructure.

The British-based urban theorists, Bishop and Williams (2012) have provided an overview of numerous temporary urban projects in Britain and North America in their book *The Temporary City*. Of the 68 projects they describe, most are related to creative interventions or community agriculture and gardening initiatives. Community horticulture projects also feature in the four case studies described in *Urban Tactics*, *Temporary Interventions + Long Term Planning* (Killing Architects 2012).

In Australia, the concept of temporary use has been well-developed by the Pacific Islander community in Brisbane who manage a mobile yam plantation. They approach various authorities with vacant land and request the right to use it for a community plantation for 3 years. They carry insurances and use their own water truck so that they do not require assistance from the authorities who own the land and the owners are not liable for accidents etc. Usually a number of families plant and cultivate the plantation, often sharing banana or guava trees with other families. The yams are harvested and shared while some are kept for next year's planting. When the land is required, the trees are transplanted to the next site, leaving the temporary site as it was (Armstrong pending publication).

Another successful model of temporary use, this time in local parks, has been explored by Penrith City Council: the Mobile Play-van (Sofoulis et al. 2008). The Council's mobile Play-van is stocked with a changing array of children's play equipment, furniture, toys and art materials. Experienced Council community workers take the Play-van on scheduled visits to local and pocket parks and neighbourhood centres, bringing opportunities for adult and child social engagement. Play-van visits transform even the bleakest looking environments into hives of positive social activity. The service has a community facilitation role, providing educational and community service information as well as a role in alleviating social isolation. Aside from mothers, many grandparents, single dads and involved neighbours accompany the young children. The Play-van has a role in getting people into the habit of going to parks; some stay on after the van has gone. Many councils offer a Mobile Play-van service; however the transformative value of the service is magnified in a low-density city like Penrith, which is not served particularly well by public transport infrastructure.

The Play-van service demonstrates that open spaces do not have to offer the same facilities to the same groups of 'average' users every hour of the day; nor do different groups of users necessarily need different open spaces. Instead, park uses and facilities can be temporary, allowing the park to become an attractor for different social and cultural activities at different times. Thought of in this way, the park is not a static space but a dynamic event (Sofoulis et. al. 2008).

In this context, parks and open space in Western Sydney can include community agriculture in interesting ways, such as the National Gallery of Victoria's successful Urban Commons (*Urban Commons* n.d.) and the Nomadic Green in Berlin which is a mobile garden in the Kreuzberg district set up as a not-for-profit open organic garden dedicated to exchanging knowledge and work through growing vegetables. By growing vegetables in rice bags, plastic crates and milk containers they have created a dynamic system where they can bring the plants with them if a change of location is needed. The garden was started as a pilot project in the summer of 2009 by Nomadic Green (*International Network for Urban Agriculture* 2009).

The concept of mobile urban agriculture has also been explored by Atelier d'architecture autogérée (*aaa*) described as a studio for self-managed architecture. Based in Paris and co-founded by architects, Constantin Petcou and Doina Petrescu (2012), *aaa*'s projects are experiments in the temporary reuse of leftover urban space using catalysts in the form of enabling infrastructure that local residents gradually transform into self-managed spaces (*International Network for Urban Agriculture* 2009). The success of their 'Ecoboxes', a series of vegetable gardens made from recycled materials, has prompted urban horticulture ideas to be extended further in the project called 'Passage 56'. This involved the transformation of a disused passageway into a productive farm/garden whose ecological footprint through recycling, composting and use of solar panels was minimal. Tactically, *aaa* learned from these projects that it is easier to use space with easy access, such as disused laneways or vacant land, to avoid being blocked by various authorities. Rather than buying land, *aaa* negotiate for short and long term use, focussing on interstices and urban spaces which are not currently subject to financial speculation. They also realise that mobility of the structures is a key to allaying municipal concerns about permanent appropriation of land. Their urban agriculture project called 'Agrocité' began in 2012 in Colombes, a suburban town near Paris. As an agrocultural unit, Agrocité comprises an experimental micro-farm, community gardens, educational and cultural spaces and a series of experimental devices for compost heating, rain water collection, solar energy production, aquaponic gardening, phytoremediation. 'Agrocité' can be thought of as a '*Civic Agriculture Unit*, *which consists of a micro-farm aimed at collective and familial use*'(*Urban Tactics* n.d.).

The project at Colombes is divided into three areas; one for activities related to nature and agriculture, one for community gardening and one for an 'AgroLab' experimenting with intensive organic agricultural production. It also has a shared greenhouse for plants and seedlings, equipment for collecting rainwater, phytopurification, solar energy and biogas, aquaponics crops, and agricultural short circuits. Despite being such an elaborate project, the components can be disassembled and moved to other locations if required.

2.5.1 Temporary Use as a Strategy for Urban-Rural Reimagining

These examples provide valuable lessons for how new ways of imagining the dynamic relationship between rural and urban spaces might be enabled. Temporary uses can initiate, introduce and elicit social creativity, as well as provide an environment for 'social dreaming' (Dunne and Raby 2013) while garnering support for interventions prior to more fixed and permanent 'solutions' taking place. In the following we elaborate on some design considerations based on the projects we have explored in this chapter that may productively inform strategies for temporary agricultural and horticultural use in cities and suburbs on the urban edge.

2.5.1.1 Cultural Sensitivity and Shared Vision

Communities are complex and dynamic and already involved in using peri-urban landscapes in ways that need to be acknowledged and understood prior to urban agriculture initiatives taking place. Collaborative and reflexive forms of community engagement and co-design, including creative mapping strategies, elicit the creativity of non-designers, generate shared future visions and promote ongoing community involvement.

As the previously discussed examples of mobile and temporary urban agriculture show, successful initiatives are often community-led and operated enterprises. Co-design processes might facilitate engagement with peri-urban communities to respond creatively to emerging opportunities for rural economics that may not have been previously considered.

2.5.1.2 Identifying Shared Values and Needs

Culturally specific designs can exacerbate territoriality, while designs for shared age, life stages and interests can foster social cohesion. There is an opportunity for urban agriculture to contribute to the development of social and practical skills, and foster intergenerational communication. Knowledge exchange, experimentation and social learning as exemplified by the R-Urban project, need to be seen as a critical part of re-ruralising the urban edge.

2.5.1.3 Identifying Enabling Infrastructure

As shrinking cities such as Detroit and Philadelphia show, derelict and abandoned sites, vacant lots and voids are being reimagined for their regenerative possibilities. Such 'in between' spaces, as well as existing roof and wall surfaces, become enabling infrastructure as 'platforms' for creative communities (Manzini 2005). Mobile infrastructure like the Play-van facilitate temporary use, and enterprises such as the Nomadic Green and *aaa* projects reveal the potential for the sustainable reuse of discarded materials and products in flexible applications.

2.5.2 Temporary Urbanism in the Peri-urban Riverlands of Western Sydney

Drawing on the model provided by *aaa* (Paris), the R-Urban project, and learning from the previous Penrith projects, the MURRS group (Mapping Urban Resilience in Riverland Sydney) seeks to explore a local dialogue with the concept of urban 'resilience' through a hybrid collective approach using Action Research to explore both human and non-human factors.

Initially the team are establishing local government partners in order to undertake a series of mapping processes that explore human and non-human aspects of the agreed local context. Blacktown City Council, a local government area east of Penrith City and including large areas of peri-urban land, has expressed interest in mapping their numerous pockets of left-over spaces that are too small for development with a view to community urban agriculture projects. Blacktown City also has large areas of land already subdivided and partially developed. The MURRS team are exploring partnerships with developers where temporary community projects, including vegetable gardens and workshops for temporary shade houses, could animate the currently vacant land awaiting development.

In recent times Urban Heat Islanding (UHI) has emerged as a significant concern for Western Sydney's future (Western Sydney Regional Organisation of Council 2008). UHI results from the replacement of vegetation with heat-absorbent surfaces, increasing ambient temperatures and extreme heat days. This unanticipated consequence of hard urban development provides further impetus for the exploration of new forms of urban agriculture. In addition to providing substantial cooling benefits (Susca et al. 2011), urban vegetation provides protection from heat stress (Loughnan et al. 2012), potentially alleviating reliance on energy-intensive air conditioning; as well farming and gardening supporting social participation in open spaces, which has substantial wellbeing benefits. In '*Out & About in Penrith*', the lack of shade was revealed as a strong inhibitor of the use of open public space (Sofoulis et al. 2008). The creation of 'cool commons' is a creative challenge for the growing city.

2.6 Conclusion

The peri-urban productive lands in coastal areas of Eastern and South-Western Australia, including the rich volcanic land of Northern New South Wales and South East Queensland and the alluvial soils of Western Sydney, are continuing to be appropriated by urban sprawl. To address this loss, lessons can be learned through the current planning and design work occurring in the shrinking cities of Europe and North America where a new rural urbanism is growing. In this chapter we have outlined four ways in which this rural urbanism is retrieving lands for urban agriculture. Findings from these projects reveal the potential of mobile infrastructure and temporary urbanism for adapting urban environments to enhance liveability in a climate-changed future. The MURRS group is exploring partnerships that could exploit the potential of these lessons in creating opportunities for 're-ruralising' the urban edge in Western Sydney.

References

Armstrong H (2005) Rural lands protection toolkit. Cultural Landscape Research Unit, Queensland University of Technology, Brisbane
Armstrong H (2011) Re-enchanting the industrial in the city. In: Abbate A, Polakit K, Kennedy R (eds) Proceedings of the 3rd international subtropical cities conference. 8–11 Mar 2011, USA
Armstrong H (pending publication) Marginal Landscapes
Aufmkolk G (2003) cet-o/kunst+Herbert-"Mississippi" in Hoppenstedt. In: Adrian (ed) Event landscape? Birkhauser, Berlin, pp 98–103
Bishop P, Williams L (2012) The temporary city. Routledge, London/New York
Dunne A, Raby F (2013) Speculative everything: design, fiction and social dreaming. MIT Press, Cambridge
ECOCITY Tübingen-Derendingen (n.d.) http://www.upv.es/contenidos/CAMUNISO/info/U0511244.pdf. Accessed 12 April 2016
Farmadelphia (2006) http://frontstudio.com/selected-work/explorative/farmadelphia.htm. Accessed 11 Aug 2015

Giseke U (ed) (2011) Urban agriculture Casablanca: design as an integrating factor of research. TUB publication, Berlin
Guss A (2010) Detroit shrinking, proposals for urban farming grow. https://www.myhealthwire.com/news/food/183. Accessed 11 Aug 2015
International Network for Urban Agriculture (2009) Nomadic green. http://www.inuag.org/tags/nomadic-green. Accessed 11 Aug 2015
Killing Architects (2012) http://www.killingarchitects.com/. Accessed 12 April 2016
La Varra G (2005) Post-it city: the other European spaces. In: Koolhaas R, Obrist H (eds) Mutations. ACTAR, Barcelona
Loughnan M, Coutts AM, Tapper NJ, Beringer J (2012) Identifying summer temperature ranges for human thermal comfort in two Australian cities. In: 7th international WSUD conference, Melbourne. 21–23 February 2012
Manzini E (2005) Creative communities and enabling platforms. An introduction to a promising line of research and actions on sustainable production and consumption. In: Doyle D (ed) Taking responsibility. Hedmark University College Publishing, Allkopi, Norvegia
Oswalt P, Overmeyer K, Misselwitz P (2013) Urban catalyst – the power of temporary use. Shrinking Cities Publication DOM Publishers, Berlin
Petcou C, Petrescu D (2012) Atelier d'architectureaugérее. In: Tyszezuk R, Smith J, Butcher M (eds) Atlas geography architecture & change in an independent world. Black Dog Publishing, London, pp 64–71
Sieverts T (2003) Cities without cities: an interpretation of the zwischenstadt. Spon Press, London
Sinclair I, Bunker R, Holloway D (2003) From the outside looking in-planning and land. http://www.ruralplanning.com.au/library/papers/soac03.pdf. Accessed 11 Aug 2015
Smeets PJAM (2011) Expedition agroparks: research by design into sustainable development and agriculture in the network. Wageningen Academic Publishers, Wageningen. doi:10.3920/978-90-8686-719-6
Sofoulis Z, Armstrong H, Bounds M, Mellick Lopes A, Andrews T (2008) Out & about in penrith, universal design and cultural context: accessibility, diversity and recreational space in Penrith, June 2008. Centre for Cultural Research, UWS with Penrith City Council. Available via http://www.uws.edu.au/__data/assets/pdf_file/0008/46367/Out__and__About_Final_Report_with_Appendices.pdf
Supurbfood (n.d.) EU 7th framework program for research and technological development. www.supurbfood.eu. Accessed 11 Aug 2015
Susca T, Gaffin SR, Dell'osso GR (2011) Positive effects of vegetation: urban heat island and green roofs. Environ Pollut Environ Pollut 159(8–9):2119–2126. doi:10.1016/j.envpol.2011.03.007. Epub 2011 Apr 8
Urban Agriculture, Casablanca (n.d.) Urban Agriculture as an Integrative Factor of Climate-Optimised Urban Development, Casablanca. http://www.uac-m.org. Accessed 12 Apr 2016.
Urban Commons (n.d.) Products. http://www.urbancommons.com.au/. Accessed 11 Aug 2015
Urban Tactics (n.d.) R-URBAN – participative strategy for development, practices and networks of local resilience. http://www.urbantactics.org/projects/rurban/rurban.html. Accessed 12 Apr 2016.
Western Sydney Regional Organisation of Council (2008) Agenda for sustainability and wellbeing for Western Sydney. WSROC, Blacktown. Accessed 11 Aug 2015 http://202.60.92.134/~wsroccom/reports/agenda-for-sustainability-and-wellbeing-for-western-sydney-may-2008

Chapter 3
Nimbyism and Nature: Whose Backyard Is It Anyway?

Jennifer Scott, Marnie Kikken, Michelle Rose, and Penny Colyer

Abstract The Ku-ring-gai community have long expressed a strong desire to keep their suburbs green. When asked, most people comment that they moved to the area to live in a bushland setting. Given this enduring set of values, it is interesting that Council spends a great deal of time fielding complaints from residents about nature's miscreants, those birds, animals and plants that fail to respect property boundaries or intrude into the lives of residents in the bushland interface areas. This paper examines one such dilemma challenging public land managers; when people and nature come into conflict. The issue in question is that of a long standing flying fox camp in Ku-ring-gai and the problems arising from the close proximity of these animals to local residents. It is a debate that has passionate proponents on both sides.

The flying fox management issue provides an insight into the juxtaposition between people who want to live close to nature but on strictly human terms. The strategies proposed to keep the peace between the residents and the champions of the flying fox is an instructive environmental management example that is likely to become increasingly common as pressure on the remaining natural resources in urban areas continues to rise.

Keywords Suburbs • Bushland • Nature • Land manager • Environmental management

3.1 Introduction

The Ku-ring-gai Council Local Government Area (LGA) is located to the northwest of the city of Sydney and is regarded as part of the city's North Shore region. The LGA covers 84 km^2 and contains distinctive physical features such as deeply incised and forested gullies, with Sydney Blue Gum vegetation dominating the ridgelines.

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The area receives an annual average rainfall of 1,118 mm per annum and contains 2 critically endangered and 5 endangered vegetation communities, 1 threatened population and 18 threatened species (Biodiversity Strategy 2006).

Trees, specifically Sydney Blue Gums, are considered iconic and give the local area a distinctive character. The Blue Gum High Forest and Sydney Turpentine Ironbark vegetation communities (assemblages of flora associated with the trees) have been classified critically endangered with less than 1 % of the original pre European settlement forest area remaining (Biodiversity Strategy 2006).

The Ku-ring-gai Biodiversity Strategy (2006) p.7 states '*Within our LGA the bushland-urban interface is a major factor defining our character and influencing biodiversity'*.

After thousands of years of occupation of the area by Garingai people, Europeans first settled in the area around 1810. Given the high rainfall and productive clay soils, the area served to provide fresh fruit and vegetables to the Sydney market. During the early part of the twentieth century, Ku-ring-gai became popular with wealthy city dwellers looking for a rural retreat that was close to, but also a world away from, the dirty polluted atmosphere of the city. The Ku-ring-gai community today remains one of the least disadvantaged communities in Australia (SIEFA Index 2012).

The urban footprint of Ku-ring-gai dominates the higher contours with housing extending into bushland areas along ridge lines to the north and south of the main ridge that divides the municipality in half. With a major road artery and railway line located on the top of the main ridge, urban development is intensifying along the length of this corridor. Three national parks surround the LGA and 120 bushland reserves are managed by Council within the area. Around 13,000 homes are directly located on the bushland interface and as a consequence bushfire is an ever present danger.

The Ku-ring-gai Community Strategic Plan expresses the Vision for 2030 as '*Ku-ring-gai will be a creative, healthy and liveable place where people respect each other, and conserve the magnificent environment and society for the children and grandchildren of the future'*

Efforts to conserve the natural resources of the area continue, although external funding and support for such programs is currently declining. At the same time there are those in the community that find living so close to nature arduous for one reason or another. Some residents believe that their property is their property and trespassers, whether they are human or not, should enter only upon invitation. In some cases this may not have always been their opinion. Advancing age, ill-health and other changes in life circumstances can alter a person's attitude to the bushland from one of inspiration to exasperation. New residents, particularly those from overseas can be intimidated by the bush and its creatures as they are completely alien to them.

Within the community there is a wide range of views regarding conservation; from the entitlement of a reasonable person to enjoy their property to a deep green commitment. The behavioural characteristics of many wild species are not always consistent with the needs and expectations of some land owners.

This paper explores the tension between residents and wildlife on the urban bushland interface in Ku-ring-gai. As the urban footprint expands and intensifies so does the pressure on the survival of species and their habitats in remnant bushland. The management of the flying fox and their camps in the Ku-ring-gai municipality and elsewhere has generated a broad range of responses in the community, both positive and negative. The subsequent policies and strategies introduced by various land managers to control the impacts of flying foxes on residents contain instructive lessons for the wider management of urban wildlife. Ku-ring-gai Council gathered data from other land managers to review the success of flying fox management strategies already attempted. The information coming from this investigation along with extensive community and stakeholder consultation provided the basis for Ku-ring-gai's own approach to the management of the flying fox and its habitat.

3.2 The Benefits of Bushland

Being near bushland brings a sense of calm and substance, a place where the hectic pace of life can be shut out. The air seems fresher and the scent of the bush invigorating as the trees and other plants play host to a myriad of insects, birds and animals.

Many people elect to purchase property in Ku-ring-gai because they enjoy the 'natural' feel of the area. Apart from the inherited and contemporary societal values associated with living in close proximity to nature, other more tangible benefits can be linked to bushland. These benefits have been expressed in Council's Community Vision and include enhanced property values; educational values; market values such as income from fees charged for film locations; seed banks; and recreational activities, to name but a few that enrich the lives of the local community.

Communities with extensive tree canopy are generally cooler in summer (Brown et al. 2013) and quieter for the most part. While these benefits are acknowledged both unofficially and officially, the contention for some living in specific bushland locations demand Council's time and attention.

3.3 The Disbenefit of Bushland

Trees cause a great deal of angst and sometimes rightly so. The Ku-ring-gai area has a long history of severe storms characterised by gale force winds and hail. Storms have on occasions (such as 1991 in North Turramurra) caused millions of dollars of damage and taken the lives of local residents.

Storm damage to homes, infrastructure, cars, roads, parks, gardens and businesses often occurs as result of falling trees and their limbs. Thousands of trees can come down in a severe storm, taking months to clear away and dispose of. The costs are not only financial but also physical and psychological. The 1991 storm generated a clean-up bill of $670 M (Ku-ring-gai Council 1991) which in 2014 dollars would be well over $1B. Street trees contributed to the damage bill but so did trees located in bushland reserves, close to homes, gardens, pools and other infrastructure.

The other local issue of great concern regarding trees is bushfire. Ku-ring-gai also has a long history of impact by bushfire and some in the community believe that a canopy tree close to their home makes their home more vulnerable to radiant heat. Extensive research has demonstrated that the loss of most homes in bushfire is from ember attack as it is the major source of ignition (Blanchi and Leonard 2005; NSW RFS 2011). Regardless, some in the community continue to believe the only way to reduce the risk of losing their home in a bushfire is to remove the trees.

Fire and storm dominate the conversation around trees and their associate risks. However other nuisances are associated with living in close proximity to bushland, for example, leaf drop blocking gutters and littering swimming pools, animals such as lizards and snakes taking up residence in gardens and birds stealing food from unsuspecting pets. While these issues may seem trivial, to those people who have to endure them it is very serious. Some people feel trapped in their homes during magpie mating season, gardens get taken over by weeds for fear of stepping on a snake and pool owners give up trying to keep their pool clean having been defeated by the mass of leaf litter falling most days.

Living in close proximity to wildlife habitat s can be exhilarating to some and obnoxious to others with both ends of the spectrum populated by relatively small percentages of the interface community. Both extremities make good sense in their arguments for and against the conservation of these natural areas and the constituent wildlife. Land managers are required to tread a wary path between the two factions. With no easy answers available and a strong incentive to avoid win/lose outcomes, land managers continue to search for win-win solutions.

3.4 The Flying Fox

In recent times one species has demanded a great deal of attention, both within Ku-ring-gai and across Australia. This species highlights some of the challenges of managing habitats and animal populations in close proximity to the community. Managing flying fox populations on the urban interface has required considerable time, research and investment to be directed to it. An examination of the issues and the strategies may yield some important lessons for public land managers when facing the challenges of managing urban interface spaces and species.

Grey-headed flying foxes (*Pteropuspoliocephalus)* are large migratory bats that occupy forests and woodlands in the coastal lowlands, tablelands and slopes of southeast Australia from Bundaberg (Queensland) to Geelong (Victoria). They are present continuously in coastal lowlands in the northern part of their range and in metropolitan areas such as Brisbane, Newcastle, Sydney and Melbourne, where artificially diverse food occurs because of plantings.

Grey-headed flying foxes feed primarily on blossoms and fruit in canopy vegetation and supplement these with leaves. Their diet includes over 100 species of native flowering trees and fleshy-fruited trees and vines.

The modern flying fox diet now includes fruit of introduced plants such as garden and orchard trees, street trees, introduced palms and some noxious weeds. Grey-headed flying foxes forage over extensive areas with one-way commutes of over 50 km recorded between camps and foraging areas, although commuting distances are more often less than 20 km.

Flying foxes play a vital role in our ecosystems, particularly in pollination and seed dispersal of flowering and fruiting trees. Because they move freely among habitat types during their foraging trips they transport and disperse pollen and seeds of diet plants across fragmented, degraded and urban landscapes. Seeds have a greater chance of growing into mature plants when they germinate away from their parent plant. Seed dispersal also helps to expand the gene pool within forests which in turn promotes forest resilience to future impacts to the local environment (Qld EHP 2014).

The Grey-headed flying fox is listed as Vulnerable under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Females give birth to only one live young each year, which is one of the reasons their population is very vulnerable. This legislation protects these animals and it is illegal to harm or try to move them without the appropriate consent.

Within the Ku-ring-gai area an important maternal colony of Grey-headed flying-foxes roosts in the Ku-ring-gai Flying-fox Reserve (KFFR). The bushland reserve is adjacent to an urban residential area and bounded by approximately 100 properties.

Covering an area of 15.34 ha, the KFFR contains a variety of wildlife habitats. In addition to flying foxes the reserve supports other threatened species such as the Powerful Owl and Sydney Turpentine Ironbark Forest (an Endangered Ecological Community under the *NSW TSC Act* and *EPBC Act*) (Fig. 3.1).

In 1991, an urban residential property development was approved in close proximity to the Ku-ring-gai flying fox camp. A Reserve area was identified and a Conservation Agreement entered into between Ku-ring-gai Council and the New South Wales Government in response to concerns the maternal colony was likely to be under threat. The Agreement ensured the continued protection and preservation of native flora and fauna, in particular the Grey-headed flying fox colony and all elements of its habitat within the reserve (Ku-ring-gai Flying fox Reserve Management Plan 2013).

The Reserve is significant for the flying foxes as it provides a roosting and maternity habitat, access to food in both urban landscapes and native forests and a stopover habitat for migrating animals, whilst supporting a resident population. The Reserve is also a site for long-term research, including the longest population monitoring of any flying fox camp in Australia (Ku-ring-gai Flying fox Reserve Management Plan 2013).

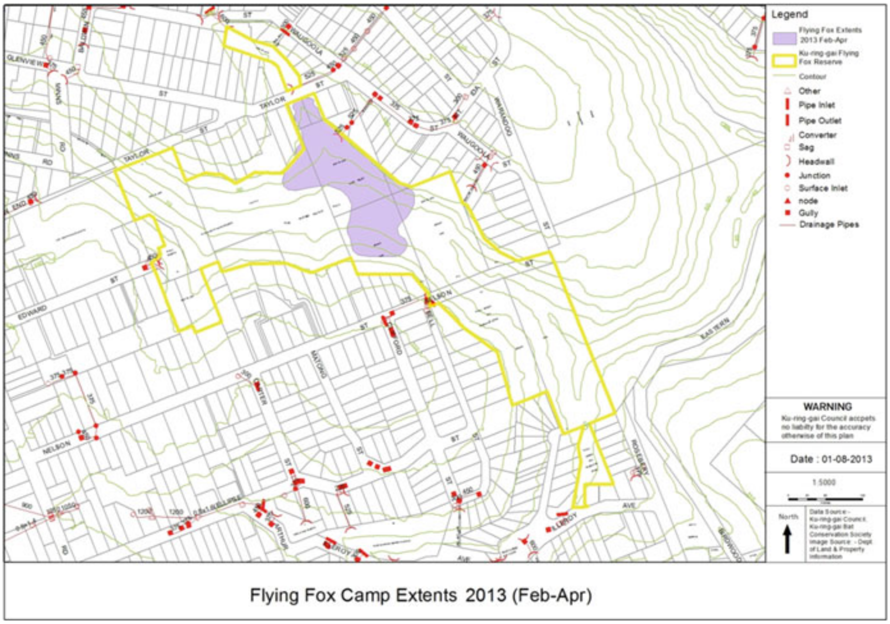

Fig. 3.1 Map of Ku-ring-gai Flying Fox Reserve (Ku-ring-gai Flying Fox Plan of Management 2013)

Since the 1980s the Ku-ring-gai Bat Conservation Society and other researchers have monitored flying fox numbers in the Reserve. This data has been incorporated into a national database to better understand trends in flying fox movements and to detect any decline in numbers.

Ku-ring-gai data shows annual and seasonal variations in the KFFR camp population from zero to around 80,000 animals. During winter numbers may fall to only a few hundred with no flying foxes recorded on eight occasions. During the summer months numbers swell to around 20,000–40,000 peaking in the March breeding season. Numbers of 70,000 or more animals have been recorded only twice – in 2000 and 2009. The local data indicates a trend of decreasing average numbers in Grey-headed flying foxes between 1998 and 2012. This trend is consistent with the increase in the number of camps in the Sydney Basin from 7 in 1989 to 22 in 2013.

Historically the flying fox colony has moved periodically around the KFFR, in response to seasonal conditions and as an adaptation to roost tree damage. At times when the flying fox colony inhabits the deeper areas of the Reserve the impacts to residents have been negligible. However, since 2009 the flying fox colony moved into an area very close to properties adjacent to the KFFR, as depicted in Fig. 3.2 below.

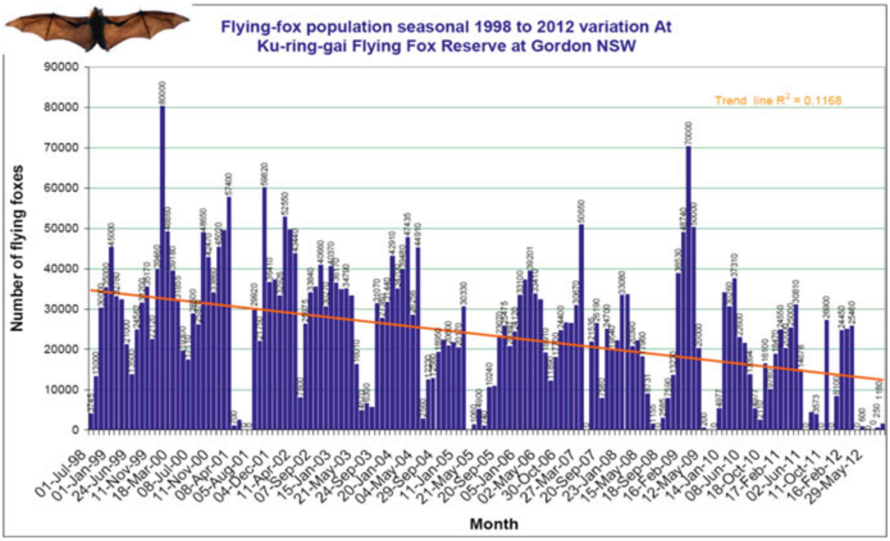

Fig. 3.2 Flying Fox numbers over time in the Ku-ring-gai Flying Fox Reserve (Ku-ring-gai Flying Fox Plan of Management 2013)

3.5 Ku-Ring-Gai Flying Fox Management

While Council is the land manager of the KFFR, the community has played a vital role in the Reserve's management. The Ku-ring-gai Bat Conservation Society has provided valuable advice and assistance with on-ground works since 1985. In recent years, the number of issues from residents adjacent to the Reserve has risen as a result of the noise, smell and droppings impacting them when the flying foxes have shifted closer to the Reserve edge.

The KFFR has a specific management plan prepared in accordance with the Ku-ring-gai Flying-fox Reserve Conservation Agreement. In response to the ongoing lifestyle, health and wellbeing impacts on residents adjacent to the KFFR, the 2013 Ku-ring-gai Flying-fox Reserve Management Plan attempts to strike a balance between management actions to conserve the threatened species and ecological communities within the Reserve and management actions to reduce the impacts of the flying foxes on residents. Such balance had to occur within a prescribed management framework, largely determined by State and Federal legislation (for example, the *Threatened Species Conservation Act 1995* and the *Environment Protection & Biodiversity Conservation (EPBC) Act 1999*) and the conditions of the Conservation Agreement.

The 2013 plan was prepared in consultation with the Ku-ring-gai Flying fox Reserve Advisory Group, consisting of representatives from Council, the Ku-ring-gai Bat Conservation Society, residents and relevant government agencies.

In developing the management strategy for the KFFR, Council and the Advisory Group critiqued a number of potential management actions (which were derived from other land managers who had already attempted many different strategies with varying success) against a set of criteria, including the terms and conditions of the Conservation Agreement, relevant legislation, research, Council plans and policies, the Reserve's physical constraints, funding, staff resources, community support and volunteer capacity. Council also consulted numerous stakeholders and residents adjacent to the KFFR during the public exhibition period of the 2013 KFFR Management Plan.

3.6 Learning from the Experience of Other Land Managers

Many Councils in NSW and other states manage bushland reserves containing flying fox camps. Flying foxes do not always choose to camp in bushland reserves and occasionally move into town areas where park and street trees provide a source of food and shelter. In these instances the impact of these animals is more obvious and immediate and more likely to bring the animals into closer contact with a larger number of people. At least in reserves there is a 'buffer' between the flying foxes and people, although in Ku-ring-gai this buffer can be quite small depending on the exact location the flying foxes choose to roost each season.

Given the protection afforded to the flying fox under law, there are limited options available to land managers to control the impacts of flying foxes on local communities.

Roberts et al. (2011) discuss the remedies utilised to reduce the impact of flying foxes on the community. These have included minimising disruption to the camps and nudging-dispersal-relocation techniques. Numerous agencies have attempted to re-locate flying foxes with varying degrees of failure as the animals demonstrate a strong fidelity to camps that is not easily broken. If they do move it is not as a group (Eby and Roberts 2011).

The outcomes of 17 recent Flying fox dispersal attempts were systematically reviewed (Roberts and Eby 2013) and a set of common outcomes were identified to guide their use in Australia. Camps varied in size from several hundred animals to over 200,000. This review identified that:

- in all 17 cases, dispersed flying foxes did not abandon the local area;
- in 16 of the 17 cases, dispersals did not reduce the number of flying foxes in a local area;
- dispersed flying foxes did not move far (in approximately 63 % of cases the flying foxes only moved <600 m from the original site, contingent on the distribution of available vegetation. In 85 % of cases, new camps were established nearby);
- in all cases, it was not possible to predict where replacement camps would form;
- conflict was often not resolved. In 71 % of cases conflict was still being reported either at the original site or at other unacceptable locations years after the initial dispersal actions;

- repeat dispersal actions were generally required (in all cases except extensive vegetation removal); and
- the financial costs of all dispersal attempts were high, ranging from tens of thousands to millions of dollars, for active dispersals (for example, using noise, smoke etc.).

Roberts and Eby (2013) note that these patterns only varied where abundant financial and human resources were available (for example, Royal Botanic Gardens – Melbourne and Royal Botanic Gardens – Sydney); or specific landscape characteristics existed (for example isolation from neighbours in Batchelor, NT); or the connection through a habitat link to an 'acceptable' location as in the Royal Botanic Gardens – Melbourne).

It appears that the potential for unintended consequences, the lack of ability to pre-determine or control the new location of replacement camps and the high costs involved make relocation an unviable option.

3.7 Viable Management Options for the Ku-Ring-Gai Flying Fox Reserve

3.7.1 Council Management Actions

Management actions implemented in the 2013 Ku-ring-gai Flying fox Reserve Management Plan, aimed at reducing the impacts of the flying foxes on residents adjacent to the Reserve, include: the re-location of a flying fox release cage (as part of the KFFR rehabilitation and release program) to a nearby Reserve; canopy replenishment in the core of the KFFR; strategic tree removal and treatment works in the KFFR, close to residential housing; formalised community engagement processes and elevated community engagement efforts during periods of greatest community concern; and continued consultation with relevant agencies, organisations, councils and flying fox experts on management options for the Reserve. Unfortunately, the activities conducted to date have had little success in alleviating the impacts on residents adjacent to the Reserve.

Hence, in November 2014 a range of management options aimed at nudging or dispersing flying foxes from properties adjacent to the KFFR were re-assessed based on their economic, social and environmental costs/benefits, and in their ability to, as stated in the recently released Flying Fox Camp Management Policy 2014 – Consultation Draft (NSW OEH 2014) be "legally defensible in balancing community concerns and neighbourhood amenity with environmental outcomes". The management options assessed were:

- Improving roost habitat in the KFFR core, away from residents
- Private property tree removal
- Selective roost tree removal/pruning within 10 m of a dwelling wall, pool, deck or other living space in the most affected areas

- Selective roost tree removal/pruning within 10 m of the KFFR boundary in the most affected areas
- Creation of 10 m vegetation buffer zone from the KFFR boundary in the most affected areas
- Creation of 25 m vegetation buffer zone from the KFFR boundary in the most affected areas
- Creation of 50 m vegetation buffer zone from the KFFR boundary in the most affected areas
- Use of noise to disperse and re-locate flying-foxes

This assessment revealed that the key factors in determining the likely success of any nudging/dispersal attempts can be identified as follows:

- whether the conflict is likely to be resolved in the broader community and not just around the original site, that is, the problem is not transferred from one undesirable location to another, or several, other undesirable locations;
- whether the financial and human resources required are proportionate to the scale of impact being experienced within the community;
- the likelihood and scale of any unintended (but detrimental) social and environmental impacts;
- the specific landscape characteristics, that is, are alternative camp locations isolated from urban settlements and is there a habitat link to ‘acceptable’ locations?;
- the welfare outcomes for the flying foxes; and
- the availability of food sources – flying foxes are unlikely to leave a local area when a camp is dispersed as long as food remains available.

In light of the above, in the case of the KFFR, the physical, legislative, environmental and financial constraints, as well as the potential unintended social consequences deem any management actions to nudge or disperse the camp location, beyond further strategic tree removal to alleviate the most direct impacts of the flying foxes, not appropriate or feasible. As a result, Council recently resolved to fund selective roost tree removal/pruning within 10 m of the KFFR boundary in the most affected areas.

3.7.2 Encouraging the Community to Adapt

The local community is divided on the best way to deal with the flying fox. Apart from the physical discomfort experienced by some, resident concerns extend to the health risks arising from the proximity to flying foxes. Council provides information on the prevention and treatment of diseases transmitted to people through bites and scratches from flying foxes. Encouraging people directly involved with the flying fox to be vaccinated against diseases transmitted through bites and scratches is the first priority. Educating the residents on their risk exposure from living in proximity to a flying fox is aimed at alleviating their concerns relating to this aspect.

In extreme situations residents can consider the benefits of retro fitting properties, including acoustic insulation, pool covers and high pressure water pumps for cleaning down surfaces quickly and effectively.

With no good alternative responses yet available, Council manages the KFFR with conservation and habitat protection as main objectives. It is thought that by doing so, this will contribute to the overall health of the species and conform to the Conservation Agreement and the species 'threatened' status.

3.8 Discussion

As with any community debate land managers need to juggle a number of responsibilities. Legislation often dictates the type of responses that can and cannot be considered. Nimbyism and justice in decision making on environmental issues is usually topical. The label of Nimbyism has been used by some in the past to disempower the arguments regarding an unwanted and arguably unwarranted development. In particular the Nimbyism label can be applied intentionally to disengage the views of those in the community negatively affected by a development from the decision making process. It is unsurprising then that dissatisfaction with land managers occasionally features in newspapers across the country. While the case of flying fox management is a different context to that of a development, there are certain similarities. Both sides of the case (want flying foxes; do not want flying foxes) have passionate proponents with valid viewpoints that need to be reconciled to a conclusion. Some residents enjoy the presence of these animals while others suffer them unwillingly.

Fairness in such dichotomous and emotionally charged situations is a hard road to tread. Chances are that nobody will be satisfied with a compromise except possibly the flying foxes. As Smith and Scott (2006) notes urbanisation generates pressures from a combination of expanding population and increasing demands on natural areas. Inevitably tensions grow and conflict follows.

Institutional arrangements for the conservation of remnant habitat areas and endangered species come under close scrutiny from time to time. This scrutiny is particularly fierce from those whose properties adjoin the natural areas where wildlife activity impacts upon the peace and enjoyment of home owners. Councils are generally the target of any complaints in situations where the Council is the land manager.

Ku-ring-gai residents reportedly (North Shore Times 28/08/13 Danielle Nicastri) endure 'a living hell' created by the noise and odour from the nearby flying fox camp. One resident claims in the article that '*you cannot hold a conversation in our back yard, we cannot swim in our pool and we haven't had friends stay over or have a BBQ because of the bats*'.

Clearly their complaints have substance as anyone who visits the local flying fox camp during times of activity will attest to. Ku-ring-gai Council's Councillors and the General Manager have described the resident's situation as 'horrific' (North

Shore Times, 28/08/13 Danielle Nicastri) and have since responded with strategies designed to reduce the impact of noise inside homes by removing roosting habitats adjacent to houses.

Flying fox activity regularly appears in the news at locations traversing the length of the Australian east coast. Flying fox numbers swell and decline up and down the coast for reasons not yet well understood. The Royal Botanic Gardens in Melbourne elected to encourage the flying foxes out of the gardens to limit damage to trees and public areas. The Royal Botanic Gardens in Sydney has attempted to do the same. Some Ku-ring-gai residents worry it will mean more flying foxes on their door step while others believe that increasing the pressure on these animals will see emerging diseases such as Hendra virus take a stronger hold on the weakening condition of the flying foxes over time. According to the NSW DPI (2014) '*..hungry bats may have been carrying Hendra virus, and stressed animals tend to shed more virus'*. Directing resources towards flying fox habitats to keep the animals healthy may reduce the probability of viruses, such as Hendra, causing problems in the future.

Flying fox supporters join together in societies (such as the Ku-ring-gai Bat Conservation Society) to promote the welfare of the flying fox. In Cairns, the ABC News (29/04/14) reported that the Council attempted to relocate a flying fox camp out of the main street by trimming trees and removing the roosting sites. Local protestors claimed that these actions would do nothing to solve the problem but rather make it worse. '*it causes stress to the colony and possibly to individuals and if there is some relocation occurring then this can be to a more problematic area'* one protestor claimed.

According to those supporting the flying fox in Ku-ring-gai, '*before 1989 there were seven flying fox camps around Sydney… located on the edge of cleared land where animals had easy access to both bushland and urban gardens. In 2013 there are now twenty two camps …. And some [camps] are now occupied through winter'* (Friends of Bats newsletter, June, 2013). It is proposed that misguided attempts to modify habitats and scare flying foxes onto other locations has had the effect of fragmenting the camps into a series of smaller camps (Friends of Bats newsletter, June 2013). Arguably this has increased the number of people coming into close contact with the species, increasing the number of complaints and pressure for further control attempts to no good effect for either the flying foxes or local residents.

Millions of dollars in public funds has been spent across the country in attempts to move flying foxes to more desirable locations. According to Roberts et al. (2011) relocation attempts have been '.ad hoc*, and lacking of systematic documentation, costing and monitoring' and* flying foxes have relocated to *'new sites that have been unanticipated and in undesirable locations'.*

Presently there is no foreseeable change in the legal status of flying foxes and current research and experience suggests that there are no viable management options in sight to alleviate the most severe impacts of the flying foxes on residents living in close proximity to camps. In most cases those negatively affected by the noise and odour have little choice but to improve the resilience of their homes and properties in an attempt to lessen the effects of living in close proximity to the flying foxes.

3.9 Lessons Learnt

The experience of managing land devoted to the conservation of the flying fox in urban Australia has been complex and lengthy. Several lessons emerge from the research into flying fox management that could be helpful in the management of other species that affect properties neighbouring bushland areas. The following lessons have informed Council's management approach within the KFFR:

- Interfering with habitats or attempts to modify the natural behaviour of the flying fox inevitably exacerbates the problem through unintended consequences. Attempts by the Sydney Royal Botanic Gardens to move flying foxes out saw the flying foxes end up in Centennial Park. Attempts by Cairns City Council to move the flying foxes out of trees in the main street saw the animals move into trees at a local school. In both cases the magnitude of the problem was amplified by bringing more people into closer contact with the animals;
- Community education: the most popular community education events run by Ku-ring-gai Council concern local wildlife particularly when it involves species that are controversial and have a human impact such as flying foxes, ticks, bandicoots and bush turkeys. People can happily co-exist with the flying fox habitat nearby when they better understand the values associated with flying foxes, the general magnitude of impact and options available to manage any negative impacts;
- Modification of the built environment: a far more practical, effective and efficient management measure is to strengthen the resilience of homes, properties and lifestyles to the impact of wildlife;

As Roberts et al. (2013) note it is the magnitude of the perceived problem that is important. This needs to be understood before responding. For example, if noise, smell and faeces from a camp affect only a small number of residents, then smaller, local-scale mitigation options should be applied. In this way the unintended consequences of the management action will be minimised and be less likely to result in a worsening of the problem.

It is the unintended consequences of management actions that need to be thoroughly investigated and understood. For example altering the flying fox habitat or the animal's natural behaviour may inadvertently foster the incidence of zoonotic disease by increasing the stress on animals who are already experiencing pressure for resources from urbanisation of habitat areas.

Biodiversity integrity and human health have long thought to be inextricably linked (Pongsiri et al. 2009). Strategies to manage wildlife impacts on urban populations need to be mindful of the bigger picture surrounding the immediate context of these decisions. Increasing pressure by further degrading biological resources to the point where the system declines could have a range of significant consequences. Conserving the integrity and diversity of biological resources can assist in maintaining resilience to emerging diseases. The response to the problems created by urban development encroaching on conservation areas must prioritise minimal disruption to the service and functions of the natural systems for any successful resolution to emerge.

References

Biodiversity Strategy (2006) 2006 Ku-ring-gai Biodiversity Strategy, May

Blanchi R, Leonard J (2005) Investigation of bushfire attach mechanisms resulting in house loss in the ACT bushfire 2003. Bushfire CRC

Brown H, Katscherian D, Carter M, Spickett J (2013) Cool communities: urban trees, environment and health. World Health Organisation and Curtin University. http://ehia.curtin.edu.au/local/docs/CoolCommunities.pdf. Accessed 8 May 2014

Eby P, Roberts B (2011) Managing flying fox camps in New South Wales: background and recent experiences, Griffith School of the Environment, Griffith University Qld

Ku-ring-gai Council (1991) The Storm, a joint publication by Ku-ring-gai Council and Playbill Pty Ltd, November

Ku-ring-gai Council (2012) Management and restoration of flying-fox camps – guidelines and recommendations, Ku-ring-gai Council

Ku-ring-gai Flying fox Management Plan, Ku-ring-gai Council (2013)

Ku-ring-gai Flying Fox Reserve Plan of Management (2013) Ku-ring-gai Council

NSW DPI (2014) Hendra virus – frequently asked questions. NSW Department of Primary Industries, Agriculture. http://www.dpi.nsw.gov.au/agriculture/livestock/horses/health/general/hendra-virus/faqs#Why-are-there-so-many-more-cases-of-Hendra-virus-now-than-in-the-past?. Accessed 8 May 2014

NSW OEH (2014) Flying-fox camp management policy 2014 – consultation draft, NSW Office of Environment and Heritage

NSW RFS (2011) Development assessment and planning – best practice guide to bushfire protection, upgrade of existing buildings. Version 1/25 Feb 2011

North Shore Times (2013) Residents near the Ku-ring-gai flying fox reserve in Gordon are being driven batty by the noise, by Danielle Nicastri, North Shore Times, 28 Aug 2013. http://dailytelegraph.com.au/newslocal/north-shore/residents-near-the ku-ring-gai-flying-fox-reserve-ingordon-are-being-driven-batty-by-the-noise/story-fingr8h9d-1226705947931. Accessed 10 May 2014

Pongsiri MJ, Roman J, Ezenwa V, Goldberg TL, Koren HS, Newbold S, Ostfield R, Pattanayak S, Salkeld DL (2009) Biodiversity loss affects global disease ecology. BioScience 59:945–954. ISSN 0006-3568, electronic ISSN 1525-3244. © 2009 American Institute of Biological Sciences.

Qld EHP (2014) The importance of flying foxes. Queensland Department of Environment and Heritage. https://www.ehp.qld.gov.au/wildlife/livingwith/flyingfoxes/importance.html. Accessed 14 May 2014

Roberts B, Eby P (2013) Review of past flying-fox dispersal actions between 1990–2013. Unpublished report

Roberts BJ, Eby P, Catterall CP, Kanowski J, Bennett G (2013) The outcomes and costs of relocating flying-fox camps: insights from the case of Maclean, Australia. In: Law B, Eby P, Lunney D,

Lumsden L (eds) The biology and conservation of Australasian Bats. Royal Zoological Society of NSW, Mosman. 2011 pp 277–287
SIEFA Index (2012) The socio-economic indexes for Australia, Census of Population and Housing, Australia, 2011 (cat. no. 2033.0.55.001)
Smith G, Scott J (2006) Living cities – an urban myth? Rosenberg Publications, Sydney

Chapter 4
Connecting Urban and Rural Futures Through Rural Design

Dewey Thorbeck and John Troughton

Abstract Urbanisation has been accelerating around the globe as people move from rural areas to urban areas for economic advancement creating urban development that sprawls into the countryside, eliminating much of the best farmland surrounding cities. By 2050 there may be another 2.5 billion people on the planet with 100 million more in the United States and Australia's population may increase by 13 million or more. Urban design and planning has attempted to shape urban development as cities have expanded, but it has done so primarily from an urban perspective. Areas of transition from rural to urban and land uses at the urban/rural edge in the peri-urban landscape require the lens of spatial arrangement from both urban and rural perspectives to shape, manage, and preserve the ecosystems that people depend upon.

Keywords Urbanization • Rural design • Urban development • Peri-urban landscape • Ecosystem

4.1 Introduction

Urban is defined as having the characteristics of a city, whereas rural is defined as a combination of natural and human landscapes – in reality they are both much more complex with integrated natural systems. Urban design and rural design are similar in that both embrace quality of life. However, rural design is fundamentally different in seeking to understand and embody the unique characteristics of open landscapes and ecosystems where buildings and towns are components of the landscape, rather than defining infrastructure and public space as in urban design (Thorbeck 2012).

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Connecting Urban and Rural Futures through Rural Design discusses how rural design and the problem-solving process of design and design thinking that can help resolve land-use issues in the peri-urban landscape and how the quality of life and the economies of people living and working in both rural and urban areas can be improved in the process?

Rural areas around the world are undergoing profound demographic, economic, cultural, and environmental change creating considerable challenges and stress for their residents and on the ecosystems upon which they depend for their livelihood and quality of life. Critical global issues such as climate change (that is currently having a large impact in Australia), renewable energy, water resource protection, food security, and healthy human development will dominate international and local rural policy for years to come as citizens and governments try to manage change. The peri-urban landscape is of particular concern because urban expansion has historically been done at low density requiring large amounts of land causing infrastructure and public services to be provided at great cost.

4.2 Rural Design

Rural design is an emerging design discipline that was started at the University of Minnesota in 1997 when Dewey Thorbeck founded the Center for Rural Design (CRD). Since that time the CRD has been involved in a wide range of rural projects that impact the quality of life in rural areas, primarily in the State of Minnesota. These projects and experiences working with rural citizens implied that the principles of rural design could be applied anywhere and were documented in Thorbeck's book *Rural Design: A New Design Discipline* (Thorbeck 2012). The book is now being translated and published in China by PHEI.

Rural design is the design discipline that brings design thinking and the problem-solving process of design to rural issues at both the macro and micro levels while making connections between urban and rural futures. Rural design is a way to understand the dynamic behaviour of natural and human systems, and to unify and conceptualise the complex and dynamic reality of sustainability in integrating humans, animals, and the environment in both rural and peri-urban areas. We are living in a time of rapid change and rural design is needed to make connections between urban and rural futures at the urban/rural edge, and in the process it can help minimize the negative impacts of change while increasing the positive impacts with economic resiliency, social interaction, and appreciation for diversity in art and culture (Fig. 4.1).

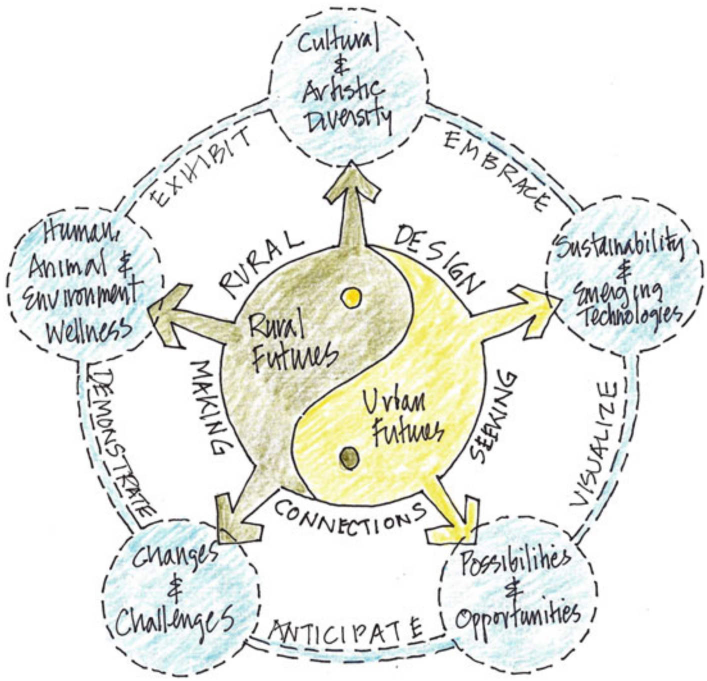

Fig. 4.1 Rural design is a connector of urban and rural futures

4.3 Rural Design for Urban Agriculture

Urban agriculture is gaining strong worldwide support to integrate agriculture into urban landscapes. It has a long history emanating from the Garden Cities movement in the nineteenth century and has evolved today into a new vision for the role of agriculture in urban contexts to enhance quality of life by retaining the land's capability to contribute to sustainable societies and cultures. Urban agriculture is an emerging design opportunity to think about and shape common open space to provide for food security, water resources and maximize the value of open landscapes in urban expansion. However, most of the design ideas focusing on urban agriculture that have recently emerged illustrate a very narrow point of view as architecture that incorporates plants in an urban setting. Urban agriculture is more profound and inclusive requiring a perspective of both urban and rural design. It is that connection between the high density city core and the rural landscape, defined as a transect, that needs to be rethought to fit twenty-first century living. A proposed project that the CRD is working on in Minnesota will look at that issue to redefine the connections between urban, per-urban, and rural (Fig. 4.2).

The design process used for this study (involving the University of Minnesota's CRD and Metropolitan Design Center, and planning staff from Dakota County) will provide policymakers a wide range of options as how to shape urban and rural

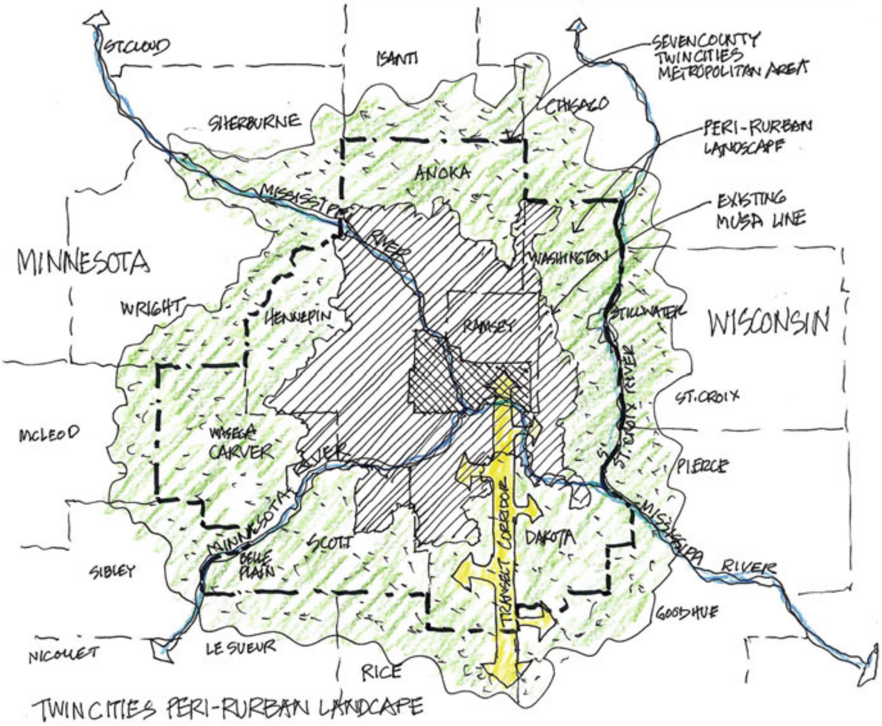

Fig. 4.2 Twin cities metropolitan region and its peri-urban landscape and the planning transect

landscapes to increase water resources, provide for food production, protect natural amenities, and identify development rules that will enhance sustainability, provide housing and public infrastructure at lower long-term cost while improving quality of life.

This idea was first discussed in a paper about urban development with a creative commons. The creative commons is local open space that facilitates neighbourhood development and social progress through inclusivity, creativity and entrepreneurship (Troughton and Walsh 2011). The paper argues that the creative commons can become a dynamic substrate for urban agriculture by challenging how food and plant production, and associated activities, can be programmed and managed in many ways for generations to come. It can create a source of plant and food knowledge available to everyone, but above all it becomes a community asset. This can be shown as the design approach and as an actual plan (Figs. 4.3 and 4.4).

Rural design provides a methodology to shape rural and urban landscapes before climate change and concerns for food production and security and water resources become critical for a rapidly expanding world population. Using community engagement, design-thinking, and the lens of spatial arrangement in shaping the human and natural landscapes, rural design can incorporate agriculture into existing cities and along the urban/rural edge for food as well as opportunities for recreation,

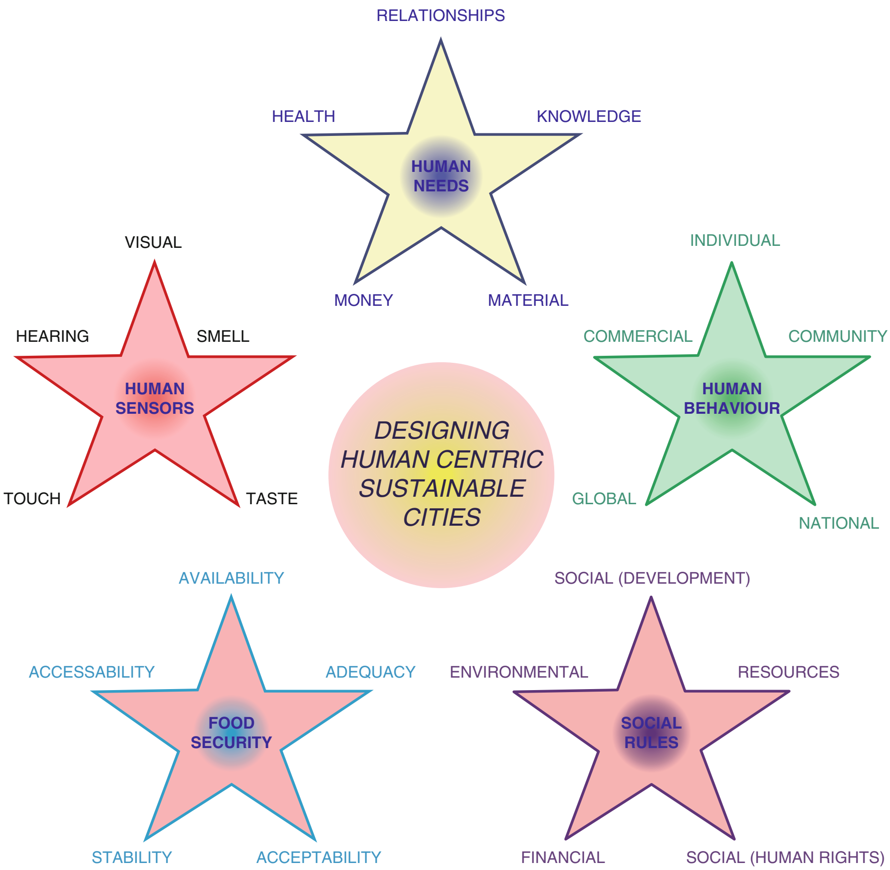

Fig. 4.3 Illustrating the design approach

economic development, and environmental understanding. Rural design is a process to nurture collaboration and cooperation amongst rural and urban communities to shape the landscape to make connections and provide an integrated system of human communities, plants and animal production that meets the needs of people, the economy, and the environment in the present without compromising for the future. This is particularly true at the urban/rural edge and the peri-urban landscape (Fig. 4.5).

Design thinking and the problem-solving process of design is a strategic resource and source of creativity, innovation, and entrepreneurship to find ways that limited land and water resources in peri-urban landscapes can be better shaped and utilised. They are a process that can be taught and utilised by human communities to analyse issues, seek solutions, and select a preferred pathway to a better future that does not necessarily require design professionals to generate the solution. Rural design is not a science, but a methodology for holistically crossing borders and connecting issues to nurture new design thinking and collaborative problem solving. It recognises that

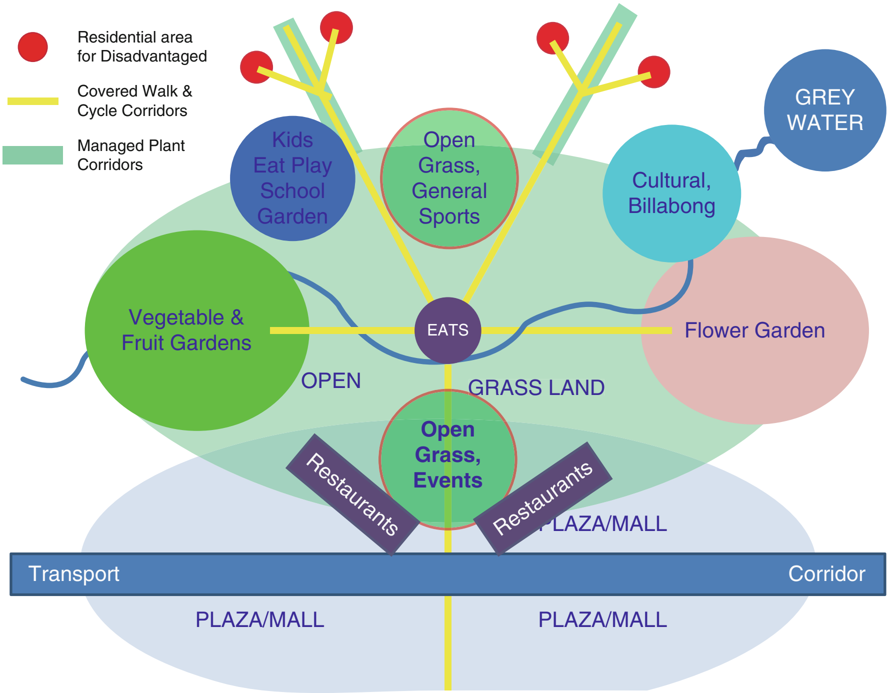

Fig. 4.4 Illustrating an actual plan

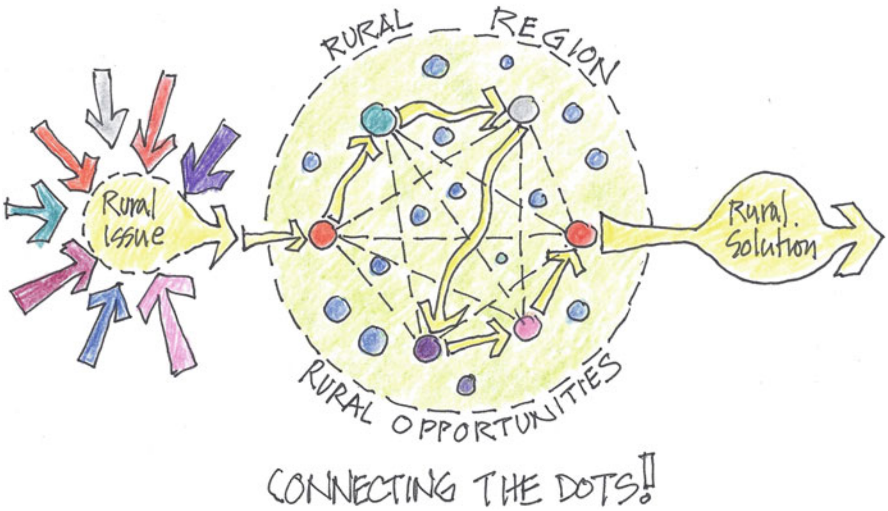

Fig. 4.5 Rural design crosses borders and connects the *dots*

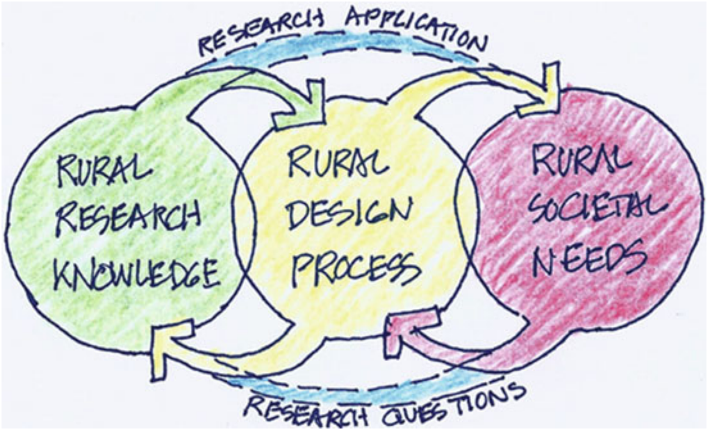

Fig. 4.6 Rural design linking science to society

human and natural systems are inextricably coupled and engaged in continuous cycles of mutual influence and response. As a process rural design brings science to society and in doing so it can identify new research questions (Fig. 4.6).

The 2014 International Conference on Peri-Urban Landscapes: Water, Food and Environmental Security was an exciting opportunity to dialogue about connections and how science and society can more fully interact for social, economic, and environmental sustainability. The authors of this book chapter believe that the Second International Symposium on Rural Design being planned to be held in Australia in the near future (the first was held at the University of Minnesota in January 2010) can be an important follow-up to provide a strong evidence-based argument for political and policy changes impacting urban expansion at national, state, regional, and local levels in Australia and worldwide.

Rural Design can integrate knowledge across disciplines, and while not directly engaged in research, rural designers can translate and apply research knowledge to the design process, helping bridge the gap between science and society, while improving the social, economic, and environmental conditions of human communities on Earth, as articulated by this diagram of the rural design process (Fig. 4.7).

4.4 Case Studies of Rural Design

The following are two case study examples of where rural design thinking and the architecture expressing that thinking illustrate new approaches to linking urban design and rural design together while crossing borders. They reflect a desire to connect urban and rural design to provide a product for the market with an architecture that relates to place and climate – embracing the concept of one healthy planet that integrates through design human, animal, and environmental wellness – as a way to understand and appreciate the importance of connecting all life on Earth.

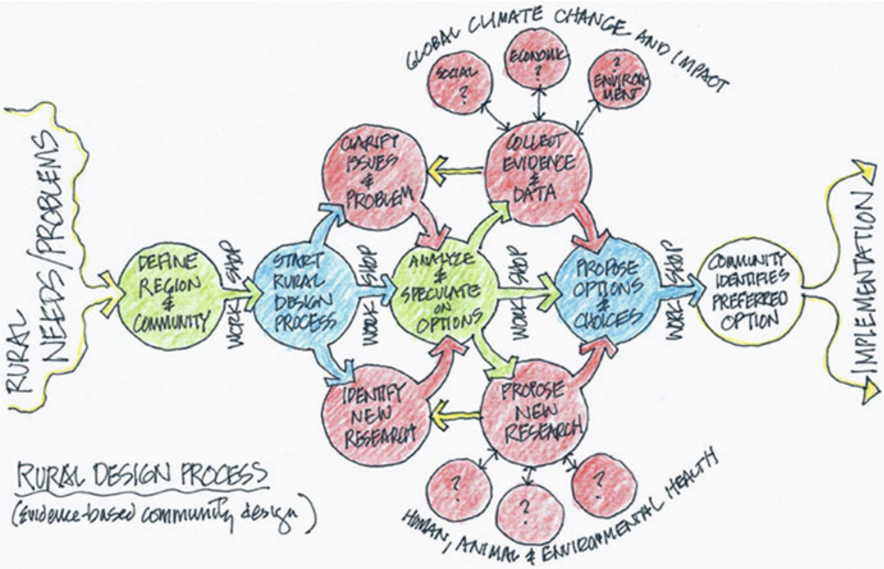

Fig. 4.7 Rural design process

The first project (Fig. 4.8) is a woolshed designed by Australian architect Peter Stuchbury. The Deepwater Woolshed was designed and constructed for the New South Wales landscape and designed around the functional flow of humans and sheep with an adaptable structure that can adjust to change with a structure of appropriate durability. The award winning building has a beautiful design that will protect it from the winds and is cooled by water during extreme heat. It is one of the rare examples of good architects working in the rural landscape on agricultural buildings that illustrate a rural point of view rather than an urban point of view as typically done.

The second project is a large installation of glass greenhouses in the peri-urban landscape of New Zealand (Fig. 4.9) for more effective minimization of environmental risks, while improving plant and labor productivity. The project is a good example (of a project that has been constructed rather than a project that is proposed) of functional and cost effective urban agriculture that is being utilised more and more in the peri-urban landscape around cities worldwide. The modern CO_2 enriched glasshouse maximises the use of non-productive land, increases the production per unit of land area by as much as ten times and dramatically increases the efficiency of water and fertilisers. Also, it is an architecture that can be recycled.

Development like this may change the face of food security for ever and the technology will spill over into urban and city farms with the ability to use any urban nook and cranny to make existing cities green and produce food for its citizens.

Fig. 4.8 Deepwater woolshed in New South Wales, Australia

Fig. 4.9 Glass greenhouse in the peri-urban landscape of New Zealand

4.5 Concluding Remarks

There are very few existing studies of the complex food systems that provide food products to cities and the impact on the environment that those food systems impact. Those cities along the sea coasts may be the most vulnerable because of rising sea levels due to climate change. The real question is how can urban populations worldwide make plans for effective and reliable food sources without some form of urban/rural partnerships?

The answer will require the involvement of private sector businesses engaged in agricultural, food, forestry, energy and water to work with the public sector at local, regional, national, and international levels incorporating long-term resilience with development goals. Food and nutrition security is jeopardised by climate change, limited water resources, and the relative lack of accessibility that the increasing global population has to secure safe food and nutrition (Foster and Gets Escudero 2014). This important study identified a critical concern for balancing production and consumption making it clear that urban and rural populations must work together for mutual benefit.

Design thinking is a problem-solving process and a methodology to bring the evidence of science to help resolve urban, rural, and peri-urban societal needs. Research issues are by nature interdisciplinary and require a dialogue between citizens and the academy for scholars to understand the issues and respond with research and effective solutions. The research, however, must recognise that human and natural systems are inextricably linked and engaged in continuous cycles of mutual influence and response and this requires an understanding of both urban and rural to fully respond to global issues of potable water supplies, energy and food supplies, and the ecosystems services that human and animal communities depend upon.

Urban design and rural design have many similarities in that both embrace those unique characteristics in design thinking that acknowledges social and cultural values to enhance quality of life. Urban design has been taught in university design schools for some time, but rural design is an emerging new design discipline that needs to be developed in higher education around the world.

Rural design and urban design are design methodologies to address peri-urban issues and resolve peri-urban needs. To be effective and relevant for this task, the methodology must be founded on solid research, and its practice must be based on validated data that will result in transformational changes. Using the lens of spatial arrangement in shaping landscapes and methods of community engagement, rural design helps citizens manage change and in the process it can help organise peri-urban landscapes and rural regions for recreational, agricultural, cultural, economic, and ecological purposes to enhance quality of life – urban and rural.

Rural design, when applied with research evidence connected to peri-urban place, provides:

- Design thinking information to policy makers of the spatial, ecological, and ethical impact of various alternatives and the choices they make;
- A methodology to resolve land-use issues at a variety of scales, including climate change and water management, and crossing borders while encouraging collaboration and cooperation;
- A process for geographic information systems and other communication technologies to enhance urban and rural citizen knowledge to enhance economic development and business opportunities;
- A community-based design process to empower citizens in shaping their futures;
- An opportunity to bring new technologies to create synergism and entrepreneurship through systemic and holistic linkages and connections;

- An understanding of regional quality of life and unique sense of place in the peri-urban, urban, and rural landscapes;
- A way to understand, connect and resolve rural and urban land-use issues worldwide for a better and prosperous quality of life for people, animals, and the environment.

We are living in a time of rapid change and the problem-solving process of design is needed to make connections between urban and rural futures at the urban/rural edge, and in doing so it can minimize the negative impacts of change while increasing the positive impacts with economic resiliency, social interaction, and appreciation for diversity in culture and arts. Urbanisation and the sprawl into the rural landscape is also increasing people's contact with the natural environment creating concerns for new forms of zoonotic disease transmission from animals to humans that could greatly impact civilization. A sustainable future will require cooperation and collaboration between the private sector in the flow of goods and services and the public sector in defining land uses and infrastructure systems. This will require high level leadership from involved men and women to break down barriers and cross borders to find optimal solutions for the benefit of both urban and rural populations.

References

Foster T, Gets Escudero A (2014) Landscapes for people, food, and nature. World Bank, Washington, DC

Thorbeck D (2012) Rural design: a new design discipline. Routledge, New York

Troughton JH, Walsh S (2011) International urban design conference: resilience in urban design. Internal Publication

Chapter 5
Archaeology and Contemporary Dynamics for More Sustainable, Resilient Cities in the Peri-Urban Interface

David Simon and Andrew Adam-Bradford

Abstract Understanding of urban fringes or peri-urban interfaces (PUIs) as zones characterised by rapid transitional change and sprawling urbanisation has increased markedly over recent years. Archaeological evidence also illustrates the pivotal role that peri-urban zones once played in the survivability of ancient urban centres. Over the last three decades, urban growth and associated transitional changes have accelerated in most regions, producing major challenges to the development of resilient cities capable of absorbing climatic, economic and environmental shocks. Globalised processes of industrialisation and market interdependence have remoulded urban fringes, bringing increased environmental impacts, including the loss of natural resources and environmental buffers now recognised as essential for urban resilience. Furthermore, ongoing global environmental change (GEC) and increasing socio-economic inequality are generating new priorities as peri-urban zones consolidate, erode and shift outwards. Given the inadequacies of existing frameworks, we advocate a hybrid approach to PUI planning and design that draws on integrated, agropolitan-type perspectives embedded within a resilient, locally appropriate regional-urban focus within broader socio-spatial and geo-economic systems. Diverse historical and contemporary examples inform the discussion of the PUI planning and design and the identification of policy recommendations for a hybrid planning approach based on adaptive capacity and resilience.

Keywords Hybrid planning • Peri-urban interface • Urban fringe • Urban sustainability • Urban resilience

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5.1 Introduction

> The growth of peri-urban areas around cities, particularly as urban growth outpaces infrastructure development, is one of the most prominent current changes to urban structure. In Asia, this is occurring on a dramatic scale: in Jakarta and Bangkok, some 77 % and 53 % of urban growth by 2025, respectively, is expected to be in peri-urban regions, while in China, some 40 % of urban growth by 2025 is expected to be in peri-urban areas as far as 150–300 km from core cities. In Asian cities, lateral spread is occurring along transport corridors, creating a form of 'regional urbanisation' … The growth of … as well as the development of peri-urban areas – are occurring in Latin America and the Caribbean and in the transitional countries. Peri-urban informal development is a key pattern in sub-Saharan Africa, particularly on customary land (UN-HABITAT 2009: 153).

This chapter is <u>not</u> intended as a review of the vast and diverse literature on the transitional zones on the periphery of larger urban areas known variously as the urban-rural fringe, peri-urban area or interface (PUI), urban edge or periphery. That task has been undertaken elsewhere (e.g. Mbiba and Huchzermeyer 2002; Simon et al. 2004; McGregor et al. 2006; Simon 2008). Our objectives here are fourfold: to draw a few key insights from the state of the art; to develop further the understanding that, empirical diversity notwithstanding, such interface zones occur worldwide across both space and time; to explore the implications of global environmental change (GEC) for PUIs and those dependent upon them for their livelihoods; and to propose a novel, hybrid approach to planning in PUIs appropriate to their characteristic range of activities and dynamic changes in order to promote urban resilience.

The terminology used for these interface zones reflects different urban research and planning paradigms, urban planning and management traditions in different parts of the world, the duration and particular form of urbanisation, theoretical and disciplinary differences, and analytical purpose. For instance, urban planners seeking to delimit the spatial extent of a city or to determine appropriate urban politico-administrative boundaries are interested in finding tangible 'clean breaks' in the built-up area to distinguish what lies within the boundaries from that without. By contrast, systems analysis, national infrastructural or logistical planning, and research on mobility/migration and livelihoods tends to emphasise spheres of influence, functional relationships and movement spaces and associated flows, all of which transcend such boundaries and emphasise continuities and connections across physical, agro-ecological and politico-administrative entities. Simon (2008) has examined these different traditions and emphases, showing that there are common threads around the world despite different combinations and the differing relative importance of various underlying factors and processes.

The traditional notion of a rural-urban dichotomy is now widely recognised to be simplistic and that, for most purposes, a continuum is more appropriate and, indeed, compatible with the highly diverse rural-urban gradients, rates of transition, combinations of factors, and functional or land-use complexities encountered in different regions. Many interfaces are not linear but have diverse and complex spatial forms, including edge cities, urban archipelagos, *desakota*/extended metropolitan regions, and the like. Furthermore, the rapid globalisation of economies, populations and urban design and governance approaches through corporate endeavour, aid and development programmes, planning/management education and training, and the recent proliferation of city twinning, partnership and network arrangements have substantially reduced some of these traditional differences.

It is now becoming increasingly necessary to transcend the traditional historico-spatial analytical and 'planning ghettos' that, for instance, have largely restricted the flourishing research and increasingly sophisticated understanding of PUI interactions and their livelihood implications to the global South. Economic change, not least the suddenness and depth of the credit crunch and consequent global recession since 2008, together with ecological and environmental concerns for sustainability, local resilience and self-reliance, and increasing vulnerability to the impacts of GEC, strongly suggest that peri-urban dynamics, environmental sustainability, livelihoods and food security are becoming central concerns worldwide. Therefore, many of the traditional concerns of peri-urban 'development' research and planning in the global South can and should provide lessons for (post-) industrial cities in countries of the Organization for Economic Co-operation and Development (OECD) and the transitional economies struggling to adjust to rapidly changing circumstances in the context of rigid or outdated planning legacies on the urban fringe or in the *Zwischenstadt* (e.g. Audirac 1999; Jones 2000; Bunker and Houston 2003; Sieverts 2003; Busck et al. 2006; Gallent et al. 2006; McFarlane 2006; Qviström 2010, 2013; Ravetz et al. 2013). Most existing forms of urbanism are morphologically, functionally and environmentally unsustainable under current conditions. They also face profound challenges in overcoming the obstacles to becoming more resilient cities capable of absorbing climatic, economic, environmental and demographic shocks while also addressing structural inequities and injustices.

There has been renewed recent interest in urban history over the very long durée (e.g. Taylor 2012), deriving at least partly from new archaeological work referred to below and also from a desire to understand urban environmental legacies that might be relevant to current sustainability and resilience concerns, including landmark contributions by Douglas (2013) and Elmqvist et al. (2013a). In this context, it is also noteworthy that such research has to date not generally identified historical analogies with present-day issues at the urban fringe or through peri-urban interfaces or transition zones. That is the first objective of this chapter, as an aid then to transcend the diversity of current institutional and planning settings and processes in order to identify appropriate principles for addressing the dynamic challenges of such zones to promote adaptive and transformative urban sustainability and resilience.

5.2 Historical Perspectives on the PUI

As indicated in preliminary terms a few years ago (Simon 2008), recent archaeological advances, facilitated by new remote sensing and associated technologies, reveal that ancient civilisations in various parts of the world had urban systems with features consistent with characteristics of present-day PUIs. New evidence continues to emerge and, to date, such published findings relate to the Khmer complex centred on Angkor in present-day Cambodia, Mayan sites in Meso-America and the Upper Xingu region of the Amazon basin in Brazil (Evans et al. 2007; Heckenberger et al. 2008; Mann 2008; Smith 2010, 2012; Fletcher 2012; Isendahl 2012; Barthel and Isendahl 2013; Isendahl and Smith 2013) but there is every reason to anticipate comparable evidence in future relating to complex ancient urban cultures of the Middle East, South Asia (not least Pollonaruwa and Anuradhapura in Sri Lanka), sub-Saharan Africa, Europe and the Mediterranean rim and elsewhere. The greater Angkor area covers some 3,000 km^2, over one third of which was covered by an urban complex of settlements integrated by an extensive hydraulic system (Fig. 5.1). Settlement densities varied within and beyond the boundaries of the known complex, itself centred on several key temples and major reservoirs. The hydraulic networks were quite possibly developed to ensure reliable food production in order to support the increasing concentrations of people living in these growing conurbations in the face of fluctuating rainfall and other environmental conditions (Evans et al. 2007). Indeed, there are speculations in the literature that a failure of food production, perhaps due to lack of maintenance or destruction of key hydraulic facilities during conflicts or natural disasters, may have been implicated in the collapse of these societies, along with the more commonly proffered explanations relating to environmental changes, including in prevailing temperatures and rainfall.

Similarly, recent evidence shows that pre-Hispanic Maya grew a significant proportion of their food within an ‘agro-urban landscape’ at Xuch (Isendahl 2012: 1123) and elsewhere, which had distinct hallmarks of what we would today recognise as peri-urban:

> The general distributional pattern of architecture at Xuch follows the familiar low-density settlement model and suggests that the settlement may have extended over as much as 20 km^2… despite the civic-ceremonial core being only mid-sized in comparison to other regional centres. At the centre of the agro-urban landscape is a large pre-Hispanic rainwater reservoir, which played an important economic, political and symbolic role in the physical transformation and social construction of landscape (Isendahl 2012: 1117).

In a synthetic paper drawing on their respective previous work, Isendahl and Smith (2013) compare Mayan and Aztec urban forms and are the first archaeologists within this new literature to draw attention explicitly to the distinctive peri-urban nature of many residential areas. Following Smith (2010), they also challenge the ‘recentism’ of much current urban agriculture literature and argue that these ancient urban forms were highly sustainable over several centuries; indeed Mayan cities collapsed only when their socio-ecological system was reorganised. The authors also specifically posit the importance of learning from such historical lessons for present day urban sustainability initiatives.

The pre-industrial and pre-colonial walled cities of West Africa provide further evidence of integrated indigenous approaches to regional land management and territorial development that supported pre-colonial urban cores through a highly organised and co-ordinated peri-urban interface. The walled cities of Hausaland and

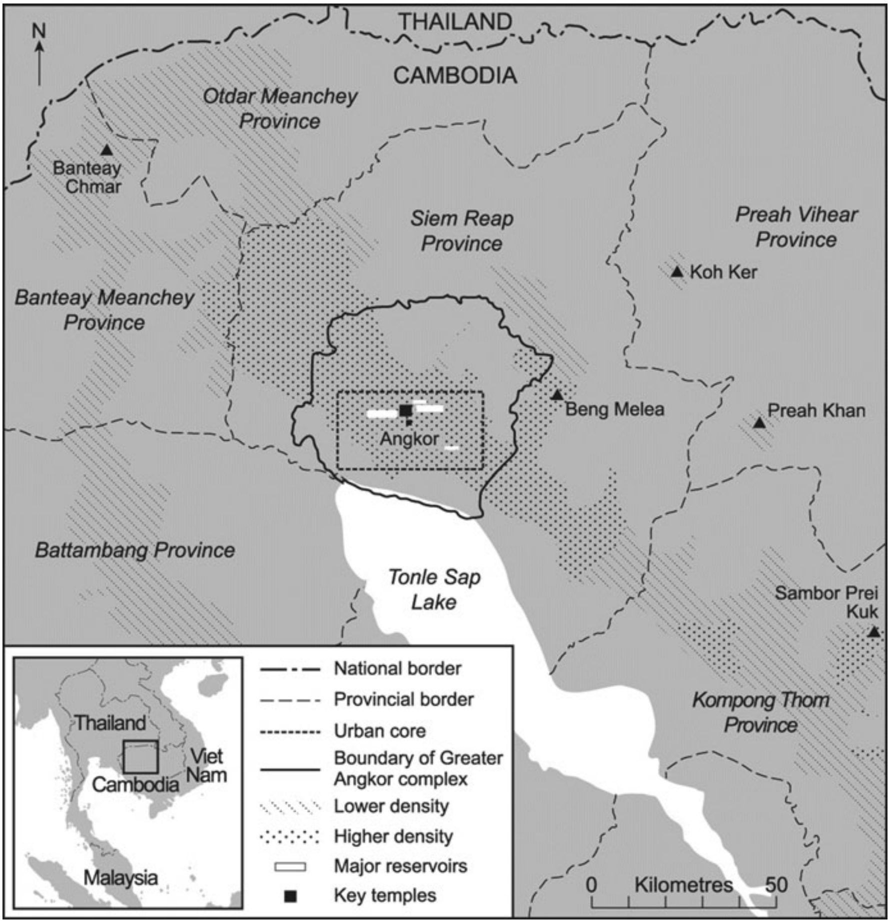

Fig. 5.1 Approximate extent of temple-and-pond-based agricultural settlements of the Angkorian and pre-Angkorian periods on the basis of an analysis of Landsat imagery and the spatial coverage of recent archaeological maps (Source: modified after Evans et al. 2007, Fig. 5.3)

Yorubaland provided the urban inhabitants with a degree of physical defence, particularly as these areas had high populations so that competition for resources and control of trade often resulted in regional conflict. Moreover, labour-intensive urban infrastructures such as city walls necessitated organised communal labour, which in turn was dependent on a meticulously planned and integrated peri-urban interface for food and subsistence. For example, in the Benin City area, much of the extraordinary network of interlocking earthworks allowed demarcation of sufficient land to ensure that each enclosed settlement had land for cultivation and extended fallow, while surrounding ‘wild forest’ resources were also planned and allocated to different settlements within the urban core (Connah 2000).

The import of this still localised but mounting evidence from different (sub-) tropical regions is threefold: first, it is enhancing our understanding of agro-environmental underpinnings and sustainability of historical urbanisms across space, time and cultural domains. Secondly, it is highlighting that features like a PUI, which have been associated particularly with present-day urbanism driven by mechanised transport and industrial globalisation, have been features of complex and sometimes large-scale urbanism since ancient times in diverse political ecologies, cultural realms, social formations and technological systems. Thirdly, these ancient peri-urban areas may provide valuable lessons for current efforts to develop sustainable, resilient cities with greater security of food supply and livelihoods. In a sense, they represented early examples of how a 'basic-needs strategy' sustained urban populations though a forerunner of a generic 'agropolitan' approach, to borrow a term first utilised in the mid-1970s by John Friedmann and Mike Douglass to describe their anti-growth-pole vision of rural urbanisation, and to which we return below.

5.3 The PUI: A Contemporary Perspective

In North America, Western Europe, Australia and Japan, PUIs are characterised by distinctive urban-rural boundaries with clearly demarcated planning zones that illustrate the conventional urban and rural planning divide (e.g. Audirac 1999; Jones 2000; Bunker and Houston 2003; Busck et al. 2006; McFarlane 2006). In these regions, early urban environmental challenges were met through reactive urban planning strategies that consolidated a superficial urban-rural dichotomy and gave rise to rigid urban planning doctrines based on homogeneous land use zones and were later to be exported through colonial influence and associated bodies of practice such as town and country planning. In the United States of America (USA), far more attention is still devoted to the quintessential post-World War II urban phenomena of suburbanisation and sprawl than peri-urbanisation (Teaford 2006). Hoggart (2005: 5) highlights that in the United Kingdom (UK), 'the land-use planning system keeps vigorous checks on the incursion of 'urban land-uses' into 'the countryside''. By contrast, in France, Germany and Spain, Hoggart discerns elements of consistency in socio-cultural and landscape changes near urban fringes, as well as in districts that are more distant from the city, but a town and country planning divide has remained, although there are now examples of more nuanced approaches, and Hoggart calls for new methods to address complexity based on a 'hierarchy of (often urban-centred) 'functional regions'' (Hoggart 2005: 6). His is a somewhat different perspective from that of the literal in-betweenness of the *Zwischenstadt* phenomenon and process identified and problematised by Sieverts (2003). Changing demographic structures and economic conditions affect the relative pressures to redevelop urban brownfield sites versus greenfield expansion on urban fringes (Simon 2008), but also highlight the importance of restoring 'working greenspaces' (especially for urban agriculture and woodland management) within mature, slow-growing or stable cities in Japan and other post-industrial countries as contributions to enhanced urban sustainability (Yokohari and Bolthouse 2011). Qviström (2010, 2013) identifies a legacy of incomplete peri-urban interventions in Western countries (his term) by numerous sectoral and spatial planning agencies, including local authorities, that create a 'crowded policy space' where discursive selectivity obscures other storylines that may be vital for the promotion of landscape integrity, sustainability and resilience. He demonstrates this with a detailed case study of a small Swedish town, whereas Busck et al. (2006) reveal considerable land conversion from agriculture to urban uses in peri-urban Copenhagen over the 1984–2004 period. This also demonstrates a far more dynamic PUI than much of the European literature implies. Modest change towards characteristically mixed peri-urban land-use is evident in various other places, including Vancouver (Fig. 5.2).

Interestingly, a tangible trend is now emerging in Europe for urban fringe research to be framed explicitly in peri-urban terms (e.g. Busck et al. 2006; Rosol and Schweizer 2012; Cabannes and Raposo 2013; Qviström 2013, Ravetz et al. 2013). This might herald a welcome move towards more compatible analytical perspectives worldwide, since they emphasise the dynamics of European PUIs rather than the essentially static picture painted by most previous authors with very few notable exceptions like Sieverts (2003). Of particular note in this context is that

Fig. 5.2 Typical mix of smallholder agriculture and new upper middle class housing in Vancouver's southern peri-urban interface (© David Simon)

Cabannes and Raposo (2013) address urban and peri-urban agriculture (UPA) in a manner hitherto associated largely with the global South, examining the extent to which such practices in allotment gardens and other spaces in Lisbon and London assist in integrating migrants socially and in biodiversity enhancement. Their findings again point to the importance of local contextual specificities, with cohesion maintenance within particular migrant communities outweighing integration with the host population. Interestingly, their paper, and that by Rosol and Schweizer (2012) examining an experimental organic peri-urban co-operative farm as a model of solidarity economics, form part of a collection explicitly examining the extent to which UPA everywhere forms part of a global movement (Atkinson 2013).

In much of the global South, PUIs are characterised by dynamic transformations and rapid urbanisation, largely as a consequence of global processes of colonisation, industrialisation, independence, and a rapidly expanding and globalising market economy which continues to reshape and remould the urban fringe. In India, for example, development and environmental issues impacting along the urban-rural interface predate independence in 1947 and were already firmly on the policy agenda as Gandhi himself researched, practised and advocated cottage industries and rural self-sufficiency in an attempt to stem rural-urban migration and reduce the growth of urban slums that were commonly located in the PUI. After independence, urbanisation accelerated, producing even greater social and environmental impacts. In some early peri-urban research, Saini (1989) highlighted the development and environmental issues in metropolitan Delhi's urban-rural interface and stressed the importance of 'peripheral community development' as urban sprawl consumed vast tracts of arable land and natural resources.

Such work has now been followed by considerable output from multiple peri-urban sites in the Americas, Asia, and Africa, reaching similar conclusions, although the rates of peri-urban landscape change are generally greater and environmental contamination is higher, while slum expansion is now almost ubiquitous. While research conclusions may highlight that the fundamental issues remain the same, the rate and intensity of peri-urban change have gained considerable pace, bringing irreversible environmental changes to the PUI (McGregor, et al. 2006; Simon 2008; see also Fig. 5.3). Such rapid change has resulted in considerable loss of biodiversity and natural resource buffers that once provided important sources of subsistence, fibre and fuel to urban populations, while also providing even greater ecological systems services in relation to regional ecology and local climatic conditions. With the loss of such important ecological functions and protection, urban areas and particularly their PUIs are more vulnerable to natural hazards such as heavy rainstorms, flash flooding and landslides and also to less frequent but equally devastating tsunamis and earthquakes (Elmqvist et al. 2013b).

Much of this vulnerability stems from the expansion of urban areas into marginal lands such as the many urban settlements found on steep slopes or onto flood plains. In both cases, changing land uses and the associated removal of vegetation and increase in areas covered by impermeable construction materials have profound impacts on the local ecology, such as reducing rainwater infiltration, destabilising soils and slopes, and increasing urban runoff. In the context of disaster risk reduc-

Fig. 5.3 Rapid urbanisation of Kumasi's PUI in Ghana (© David Simon)

tion, these very same PUI areas that are characterised by complex and dynamic mixes of socio-economic inequality and social and physical vulnerability are also subject to diverse planning omissions and ambiguities. This situation arose because these intermediate locations often straddle urban and rural administrative boundaries and are thus neglected by both urban and rural planning and governance institutions and political processes because PUIs rarely have specific, appropriate institutions or contain politically powerful interests (McGregor et al. 2006).

5.3.1 Global Environmental Change and the PUI

The bidirectional relationships between urbanisation and global environmental change (GEC) are now attracting increasing research efforts in recognition of the fact that urban areas generate up to 75 % of a country's greenhouse gas emissions and other contributions to GEC. Moreover, since humankind is now predominantly an urban-dwelling species, it is in urban areas that many of the impacts of GEC will be most widely felt (e.g. Sánchez-Rodríguez et al. 2005; Leichenko and Solecki 2006; Parnell et al. 2007; Simon 2007, 2010; Rosenzweig et al. 2011; Simon and Leck 2015a, b). Although the importance of the PUI to urban livelihoods, resource utilisation, leisure activities and ecosystem services has been recognised

(Sánchez-Rodríguez et al. 2005), very little attention has yet been devoted to empirical research on GEC implications for such zones (see Olwig and Gough 2013; Lwasa et al. 2014, 2015).

As explained above, PUIs are undergoing rapid change as cities expand and new areas on or beyond the urban periphery are drawn increasingly into their spheres of activity and influence. Yesterday's adjacent rural area is today's PUI and tomorrow's outer suburb. It is important to ascertain just how the processes of land-use conversion from rural to urban uses and of livelihood changes contribute to GEC and, in turn, render PUIs increasingly vulnerable to its impacts. Given the rapidity of such changes, it is very likely that PUIs represent a focal point for environmental changes contributing to GEC and, in turn, areas where many residents are poor and vulnerable to the impacts of GEC. Loss of farmland and hence food supply, conversion of natural land cover to tarmac and concrete, increasingly intense run-off of surface water after rain, increasing abstraction of groundwater, extraction of resources for construction, infrastructure and other industries are among the more important changes.

Conversely, sea level rise, saltwater intrusion into fresh water aquifers, increasing mean temperatures, damage to housing, commercial and industrial premises and infrastructure are specific risks, most of which are felt particularly acutely in PUIs as a result of the loss of natural barriers that provide protection and underpin resilience. Importantly, the impacts of GEC are already being felt, a trend that will increase in intensity. GEC comprises two distinct but overlapping elements: the increasing intensity and probably also frequency of extreme events, with shorter recovery periods between them, and slow-onset but (semi-)permanent changes, e.g. rising sea levels and changing atmospheric conditions. These intersect in ways that have profound importance for urban areas in both coastal zones and in drought-prone inland areas. There is already sufficient evidence to demonstrate that GEC can no longer be dismissed as being only a long-term phenomenon that will merely become a problem for future generations; some changes are already occurring (e.g. Fall et al. 2005; Adger et al. 2009; Bicknell et al. 2009; Simon 2010, 2014; Rosenzweig et al. 2011; Simon and Leck 2015a, b).

Mitigation can often be achieved relatively quickly through simple restrictions and incentives to accelerate behavioural changes to reduce the impact of current activities and reduce vulnerability to GEC impacts. Adaptation is generally longer term and involves strategic decisions and political will. However, there is no necessary tension between these sets of response; indeed, well targeted measures can contain elements of both mitigation and adaptation simultaneously. Conventional urban planning is rigid and restrictive in nature, unsuited to the rapidity of changing conditions or the flexible and facilitatory orientation required in changing times. Conversely, 'spontaneous' or informal 'popular' planning by low-income communities in shantytowns will also not be able to cope with the magnitude of changes and levels of resourcing required. Coping with GEC impacts and 'climate proofing' cities therefore require innovative, hybrid, flexible and adaptive approaches that are appropriate to the dynamic nature of PUIs. As elaborated below, these should embody some of the appropriate principles underlying the sustainability of ancient agro-urban systems examined above.

5.4 Hybrid Planning and Design for the PUI

5.4.1 From Integration to Hybridity

A common priority in order to address environmental issues on urban fringes worldwide is the facilitation of future strategic/integrated urban planning across the numerous local authority boundaries (including different categories of local authority) (Simon 2008; Rosenzweig et al. 2011). The indigenous urban planning and agricultural design strategies found in the pre-colonial Aztec and Mayan cities of Meso-America, the Angkor complex in present-day Cambodia and walled cities of Hausaland and Yorubaland in present-day Nigeria illustrate the benefits of an integrated and strategic approach at the urban-regional level. In such a context, planning addressed the allocation of resources along the urban-rural continuum, while design was practised through traditional wisdom – comprising an amalgam of indigenous knowledge, religious values and/or customary practice – which provided the techniques used for allocating natural resources in accordance with local land tenure systems. Crucially too, many of these systems were underpinned by an acute appreciation of the importance of water and local hydrological cycles. Elaborate and integrated agro-hydrological systems were developed across the urban and peri-urban zones to store, distribute and safeguard water and to maximise its harvesting and conservation.

In indigenous Nigerian cities, forms of intensive food production such as stall-fed livestock were maintained within the walls, thus providing some security if the city was under siege. Manures were then used outside the walls on intensively maintained vegetable plots. Further away from the city, staple crops would be grown with rainfed dryland agricultural techniques; access to dryland forestry was also available in these locations. Good crop storage facilities within the city enabled the residents to keep food stocks for both human and livestock feed during conflicts and sieges (Connah 2000). Through this system, natural forests were conserved, agricultural land managed with a rotational fallow verging on precision, and even urban organic waste was recycled, thus closing an important peri-urban nutrient recycling loop (Connah 2000). In such a context, planning and design were delivered as an integrated approach and at a strategic level – the urban-rural continuum or the urban-regional area. While it would be impossible and naively nostalgic to attempt to recreate such conditions today, the importance of applying an integrated approach to the urban-rural continuum is paramount, particularly in the light of the rapid changes now being experienced in these transitional zones.

By contrast, today's densely populated and dynamic PUIs in fast-growing urban contexts are usually poorly integrated into their urban systems. They straddle different governance systems as explained above, and experience instability and often uncontrolled resource extraction and waste dumping. Water resources are neglected and often heavily contaminated, with food production in steep decline. Changing this equation – and the underlying short-termist view of local landowners, residents and governance institutions – towards longer-term, more integrated and sustainable approaches will be complex and challenging but essential for the PUIs and their urban cores. Under such conditions the planning response required is not just integrated but rather a hybrid approach that allows urban planners and municipal authorities to draw on a range of urban and rural land planning and risk reduction methodologies and tools to address specific issues at the urban-regional level but within a global context. Such a planning approach will inevitably move resources from the current national planning focus back to a regional level but should have due regard to global economic markets and environmental processes. In essence, this decentralisation of the planning processes, or 'devolution of power', is aimed at increasing the flexible and facilitatory orientation of planning (and design) at the urban-regional level in a similar manner to that previously proposed in the early conceptions of agropolitan development.

5.4.2 Agropolitan-Type Approaches

A nostalgic return to pre-colonial or pre-industrial urban conditions, when agriculture still frequently featured as an important urban activity, is neither feasible nor desirable. But we do argue that revisiting such models is relevant and appropriate for contemporary urban and peri-urban planning and design, especially in view of current urban sustainability imperatives. In cities subject to political, economic and ecological conditions such as increasing oil prices, erratic seasonal rains in surrounding rural areas, war and conflict, coupled with limited urban sanitation, water shortages and food insecurity, the emphasis on city-regional planning is likely to re-emerge as a strategy to reconnect cities with the natural resources obtained from, and ecosystem services (however valorised or quantified) provided by, peri-urban areas. However, this will need to happen in a manner that maximises the effective and efficient use of natural resources while minimising resource depletion such as tree, vegetation, soil, water and nutrient losses.

Such regional planning strategies – an agropolitan approach – were first articulated by Friedmann and Douglass in a UN Centre for Regional Development symposium in 1975 as a critique of the inequalities being generated by traditional growth pole strategies. Friedmann (2002: 138–9) describes it as a counter-model of rural development:

> Favoring rural townships, the model could as easily have been dubbed "the urbanisation of the countryside." Given prevailing densities in many parts of Asia, which were generally higher than suburban densities in the USA, agropolitan development seemed to us to have reasonable prospects in the densely populated regions of South and East Asia. The problem was twofold: how to bring urban infrastructure, services, and nonfarm jobs to rural areas and how to give local people a more effective voice in the use public funds for local development.

The ideas were disseminated more widely in Friedmann and Weaver's seminal text, *Territory and Function*, in which they advocated 'a basic-needs strategy for territorial development' (1979: 193), labelled an agropolitan approach to development. This they defined broadly as a 'self-generated process of dynamic change from within agricultural communities to the larger processes of central guidance by the state', with the strategy involving substantial devolution of power to small territorial units within the overall system of societal guidance (Friedmann 1985: 155). Friedmann and Weaver (1979: 206) highlighted the importance of sound 'political leadership' for such approaches, remarking that 'agropolitan development is thus more likely to evolve in response to particular historical opportunities than as a result of technocratic planning'. This was the case in Cuba during the 1990s, where reactive planning policies were introduced to address sustainable agriculture and food security in an era of oil scarcity (Wright, 2009). Without such political leadership, success was likely to be limited: 'The political choice, then, would seem to be between planning for equality and political self-determination at the lowest levels of territorial governance or planning for inequality and political autocracy' (Friedmann 1985: 155).

Although conceived in the context of spatial and politico-economic inequalities characterising urbanisation in the global South, its tenets have global relevance. In a generic context, if planning for equality and political self-determination has remained elusive, then more nuanced or alternative strategies with specific components addressing inequality are required, and such approaches can be found in disaster risk reduction and integrated watershed management strategies, both of which provide the planner with hybrid options that are highly relevant to the PUI, but most importantly involve a substantial devolution of power to smaller territorial units such as an urban region or a watershed. These are also very relevant to the implementation of mitigation and adaptation in the context of global environmental or climate change, not least the biophysical parameters of adaptive capacity for existing socio-ecological systems.

5.4.3 Disaster Risk Reduction and Integrated Watershed Management

Two distinct but nevertheless related planning approaches gaining increasing attention in academic, policy and practitioner circles are disaster risk reduction (DRR) and integrated watershed management (IWM). DRR uses planning and policy tools to address issues of vulnerability and build capacity and resilience to natural hazards and anthropogenic disasters (Pelling and Wisner 2009). Vulnerability has been defined as the lack of capacity to anticipate, cope with, resist and recover from the impact of a hazard (Wisner et al. 2004; Pelling and Wisner 2009). IWM, which has a longer tradition, has been practised in various guises such as 'comprehensive river basin planning', which dates back to the 1930s and its pioneering model, the Tennessee Valley Authority (TVA). This early planning approach sought to tackle the industrial and urban expansion challenges of the period through watershed linkages and the integrated management of water and land resources (Friedmann and Weaver 1979).

IWM has undergone several transformations, and although DRR is a more recent concept, it too has been moulded to suit specific local conditions at different scales. These evolutionary changes in both fields have sought to develop 'self-generated processes of dynamic change' by a 'substantial devolution of power to smaller territorial units' within an overall system, thus we now see the emergence of community-based disaster risk reduction (Twig 2004) and participatory watershed management (McGregor et al. 2006; Gregersen et al. 2007), both of which can be suitably characterised by using elements of Friedmann and Weaver's (1979) approach. However, the related connection between the two planning approaches is effected through the medium of water: as Gregersen et al. (2007: 2) highlight, 'water flows downstream, ignoring all political boundaries en route' and 'most of the things that people do to their land and water upstream affects the water quantity, timing of flow and quality downstream and, as a consequence, downstream land productivity in its various forms.'

This applies equally in the context of disaster risk reduction as land use changes in the watershed can have profound implications for vulnerability as experienced by others (rural, urban and peri-urban) located downstream. This has clear ramifications in the context of rapid peri-urban change, particularly where marginalised lands are settled, and compounds vulnerability issues stemming from agricultural productivity in surrounding rural areas as well as urban water scarcity and food insecurity. In such scenarios, the watershed approach could be a crucial planning and policy tool for effective and efficient management of natural resources, particularly in regard to reducing disaster risk and maintaining future food security in expanding populous urban cores, where high quality agricultural land is often a primary focus of conversion to other, more urban land uses. The watershed approach is equally important in the tackling of 'wildland' fires in the PUI, as water resources can form effective physical barriers for mitigation and fire breaks, and natural water storage features become water reservoirs for fire fighting operations. Wildfires regularly cause extensive devastation, affecting both poor and rich, in the USA, Australia, Europe (including Portugal, Spain, France, Italy and Greece); and South Africa (Goldammer 2005; Ye 2005). The vulnerability stemming from problems associated with wildland fires is particularly acute when the PUI is characterised by extensive forestry and tree-based systems as opposed to lands predominantly used for agricultural purposes. The demand for, and high value profits from, suburban development set in woodland areas exacerbates these issues which is one reason that wildfires often occur on the fringes of Australian, European and North American cities (Goldammer 2005; Ye 2005), although such risks and vulnerabilities are not unique to high-income countries; for example, wildfires have also devastated many peri-urban areas in Indonesia (Tacconi et al. 2007).

5.4.4 Urban and Peri-urban Natural Resource Management

The ecosystems services approach is another analytical tool suited to urban and peri-urban natural resource management. Four categories of ecosystem services are commonly used: provisioning services (e.g., food/water/minerals/pharmaceuticals/

energy); regulating services (e.g., carbon sequestration/waste decomposition and detoxification/purification of water and air/crop pollination/pest and disease control); habitat services (e.g., nutrient dispersal and cycling/seed dispersal/primary production) and cultural services (e.g., cultural, intellectual and spiritual inspiration/recreational experiences/ecotourism/scientific discovery) (ten Brink 2011; Elmqvist et al. 2013b). Planning and designing at a wider urban ecosystem scale have the potential to bring 'macro' scale benefits, including improved urban sanitation; disaster risk reduction through better urban flood management and slope stabilisation of steep hillsides; protection and rehabilitation of fragile and vulnerable habitats, including riverbanks and wetlands which act as natural sponges and wildlife havens; and reductions in the urban heat island effect.

The ecosystem services approach is used to detail the multiple benefits of appropriate urban and peri-urban natural resource management and conservation, including in part what is now increasingly known as 'greening the city', thus clearly linking urban ecosystem services to climate change mitigation and adaptation as well as promoting urban-regional resilience. Examples from urban case studies already experiencing high climatic variability (Fall et al. 2005; Bicknell et al. 2009; Pelling and Wisner 2009; Simon 2010, 2014; Gotz and Schäffler 2015; Leck and Roberts 2015) illustrate future scenarios and the importance of adopting appropriate urban and peri-urban environmental policies now to foster climate change adaptation and build urban-regional resilience. Dodman et al. (2010) demonstrate the power of community-led adaptive strategies to reduce disaster risk in the face of environmental change. One potentially problematic aspect of the ecosystem services perspective is the temptation to attach monetary values to the various services, linked to the payment for ecosystem services (PES) approach favoured by some international agencies. Although intended to ensure that these biophysical functions are not undervalued, the result is often that only services to which monetary values can be attached are regarded as valuable, and/or that ability to pay becomes the basis of entitlement, thereby introducing potentially serious inequalities of access.

Although distinctive in some ways, urban and peri-urban political 'hot-spots' provide further illustrations and interesting potential scenarios of how climate change-induced events may impact in peri-urban interfaces in future, triggering rapid population displacements and regional food insecurity. Recent examples include Afghanistan, Sudan's Darfur region, occupied Palestinian territories, Somalia and South Sudan, in all of which political conflicts are impacting on agricultural processes or flows in ways which broadly anticipate the negative conditions and consequences that are likely to emerge from climate change. The sustainable agriculture and food security lessons that were learnt in Cuba during the early 1990s' era of oil scarcity provide the classic example of this phenomenon. Following the collapse of the Soviet Union and subsequent cessation of subsidised imports of Soviet oil and oil-based agrochemicals, Cuban farmers could no longer irrigate and fertilise their fields as previously practised during the subsided Soviet era (Wright 2009). The effects of these two agricultural constraints provide a possible foretaste of climatic-induced events, for example the effects of limited irrigation are similar to those of increased rainwater variability (no longer having the right amount of water at the right time on the field). In relation to soil fertility, the effects of a sudden lack of fertilisers are similar to those likely to emerge during warmer climatic conditions, including increased soil degradation and a higher carbon decomposition rate in soils, ultimately leaving agricultural plots nutrient deficient and prone to erosion.

Sustainable PUI management clearly involves a high degree of integrative planning using an urban-regional approach that draws from a multitude of urban and rural planning approaches to transcend the traditional town and country or urban and rural dichotomies of social construct, political entity and planning paradigm. While this combination of planning methods and design tools lies at the core of a hybrid planning and design approach, it also draws strongly on urban and peri-urban natural resource management, not in the context of a utopian vision of urban self-reliance but rather as a means to promote urban and peri-urban resilience and sustainability through enhanced food security, conservation of natural resources and use of ecological protection to reduce disaster risk in urban and peri-urban areas. An example of how linkages can be made between the conventional disaster management cycle and (peri-)urban agriculture is illustrated in Fig. 5.4. Here, agriculture is being used as the conduit for a range of capacity-building measures, including disaster preparedness and risk reduction through enhancement of community cohesion. This provides the foundation since strong community networks can then be utilised to implement a range of specially related disaster risk reduction measures such as early warning and evacuation response plans which require a high degree of community organisation in order to work effectively. Urban agriculture sites can also be used for zoning vulnerable and fragile areas such as steep slopes and the

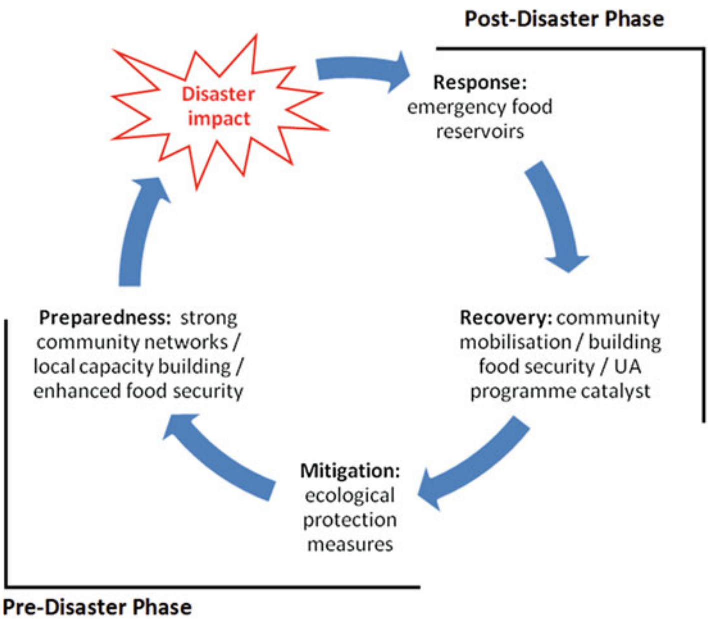

Fig. 5.4 Conventional disaster management cycle with urban agriculture linkages (Source: Adam-Bradford et al. 2009)

sides of urban and peri-urban river systems, while increased food security forms a key component of urban resilience (Adam-Bradford et al. 2009).

The linkage between agriculture and resilience is again central in the concept of 'stabilisation agriculture', a term coined by Phillip Harris at the Centre of Agroecology and Food Security,[1] Coventry University in 2010. Stabilisation agriculture focuses on enhancing the ecological and social resilience of agricultural communities to withstand and respond to adverse conditions in countries affected by natural and human-induced disasters. In the pre-disaster phase, agroecology can, for example, be used as a land management tool in disaster risk reduction programmes, while in the post-disaster phase the aim of stabilisation agriculture is the swift re-establishment of primary food production systems that are more resilient than previous systems. The six main components of stabilisation agriculture include:

(i) Integrating and mainstreaming agroecology through programmes, policies and institutions, for disaster risk reduction (DRR).
(ii) Agroecology for refugee camps and settlements.
(iii) Urban agriculture for dispersed refugees and host communities in urban areas.
(iv) Facilitating transitions: a) food aid to food production; b) refugees to returnees and; c) combatants to farmers.
(v) Sustainable management of abiotic stresses in agriculture, such as drought, salinity, contaminated land and climate change.
(vi) Sustainable management of biotic stresses in agriculture, such as invasive plant species and insect plagues.

Stabilisation agriculture embraces an integrated and participatory approach to the management of agriculture in disasters and emergencies in both rural and urban settings. As a result, programme 'beneficiaries' are transformed into pro-active agents of change, through processes that empower local communities, including refugees, internally displaced persons (IDPs) and host communities. Integration is achieved at the programme, policy and institutional level, thus building capacity for local governments, non-governmental organisations (NGOs) and UN agencies, to support communities to scale-up and facilitate stabilisation agriculture interventions (Adam-Bradford et al. 2009; Sutton and Cheese 2011).

Many of these stabilisation agricultural components are highly relevant in the PUI context, particularly because in post-disaster scenarios, the PUI often experiences acute population influxes, exacerbated land degradation and resource depletion as is currently occurring in peri-urban areas of Somalia, as Tilstone (2011: 2) highlights in her analysis on addressing climatic-induced disasters in pastoral areas,

> It is becoming clear that unless local capacities are built, and underlying vulnerabilities reduced in this increasingly unpredictable environment, the potential of pastoralism to support millions of people – on land suited to little else – will be undermined. Governments and development agencies will be faced with the far more intractable problem of sustaining even larger numbers of unskilled peri-urban dwellers in remote and low potential areas.

[1] Known as the Centre for Agroecology, Water and Resilience since 2014.

Future interventions will require extensive capacity building so that individuals and local authorities can make better-informed decisions which can then be supported through public and donor investment (REGLAP et al. 2011). In drylands, such as the Horn of Africa, integrating the PUI in long-term planning will be crucial for sustainability and resilience. The control and access to land, protecting communal land rights, and the traditional decision-making bodies that should determine development priorities, all require urgent attention if natural resource-based livelihoods are to be protected, and developed, in the PUI (REGLAP et al. 2011). In the context of dryland recovery and development, REGLAP et al. (2011: 47) highlight the requirement for 'building community capacity to determine development priorities, control natural resources and monitor the use of funds', along with appropriate education and investment in pro-poor infrastructures including financial services, market infrastructure, secondary roads, telecommunications and information provision. Such integrated approaches will be critical for the peri-urban spaces in these regions and this will require a determined hybrid planning approach to ensure the PUI functions sustainably rather than becoming the next environmentally degraded informal settlements dependent on external aid.

Even in non-disaster PUI situations, complex, fast-changing and often ambiguous land tenure systems are characteristic (McGregor et al. 2006; Adam 2014), yet relatively secure access to cultivable land without risk to personal safety is a prerequisite for any form of agriculture. Along with coherent and integrative institutional governance, this is frequently unavailable in dynamic PUIs, which merely highlights the contrast between the integrated and sustainable precolonial systems and the harsh realities of most present-day contexts outside of the OECD countries. However, the diversity of conditions belies easy generalisation and even within tropical Africa, for instance, the extent and nature of urban and peri-urban agriculture and forestry (UPAF) vary from negligible to substantial and commercial. A recent meta-study has indicated the conditions – consistent with the analysis above – under which it can not only help to alleviate the poverty of practitioners but also contribute to urban food security and mitigation and adaptation to climate change (Lwasa et al. 2014, 2015) if farmers are themselves able to adapt their practices to changing environmental conditions (Odewumi et al. 2013) (Fig. 5.5).

Integrated approaches are likely to evolve in response to particular historical opportunities rather than as a result of technocratic planning (Friedmann and Weaver 1979: 206). Clear examples are the reactive urban agriculture programmes including the 'Dig for Victory' campaign in Britain during the Second World War, and more recently in 'Operation Feed Yourself' implemented in Ghana during the 1970s, and the 'Special Period in Peace Time' implemented in Cuba during the 1990s. Momen (2009) provides a recent example from Nepal, demonstrating how a municipality has fostered a more integrated approach to rural-urban linkages and micro-enterprise development that has helped reduce exploitative socio-spatial relations. Contemporary examples include two programmes now being implemented in peri-urban areas of Somalia: the Somalia Resilience Program (SomReP) funded by the Danish International Development Agency (DANIDA) and the Building Resilient Communities in Somalia (BRCiS) programme funded by the UK

Fig. 5.5 Peri-urban riverbank agriculture, Ibadan, Nigeria, with flood erosion evident (© David Simon)

Department for International Development (DFID). These programmes each comprise two different consortia of international non-government organisations targeting peri-urban areas with a focus on pastoralism, agro-pastoralism and peri-urban livelihoods. In response to weak local institutions, these projects are adopting a multi-sectoral approach that includes capacity building, community mobilisation and participatory planning, with the aim of building resilience into these rapidly expanding peri-urban areas.

As argued above, successful integrated and locally appropriate planning was once practised in contexts such as the pre-industrial and pre-colonial walled cities of West Africa, and the low-density urban-based complexes of Angkor in Cambodia and the classic Aztec and Mayan cities of Meso-America. While such settlements and urban patterns were embedded within very different global contexts and stable land tenure regimes, the level of integration and the technical sophistication of the planning and design involved clearly offer way markers when considering the challenges facing the sustainable and participatory management of urban and peri-urban areas in an era marked by rapid urbanisation and globalisation, climate change uncertainty, unequal access to energy, increased geo-political tensions in water-scarce regions, and declining agricultural productivity in many rural areas.

Food security, environmental integrity and heritage conservation are widespread challenges across the spectrum of peri-urbanisation processes worldwide. Ayutthaya, the historic capital of Thailand before its relocation to Bangkok 50 km further south, provides an acute example of globalisation-related pressures in economically dynamic regions of the world-economy. This growing urban region now forms a peri-urban part of the Bangkok Extended Metropolitan Region, which attracts some 90 % of foreign direct investment into Thailand. The rapid expansion of transnational corporate manufacturing, and the infrastructural, housing and population pressures associated with it, have created profound challenges for the conservation of the old ruined capital, which is a UNESCO World Heritage Site, as well as for the maintenance of environmental services and rice production in what is a highly productive and intensely cultivated rice-growing basin of global importance. Current governance and planning institutions are fragmented and grossly inadequate to this task (Maneepong and Webster 2008). Although these authors advocate a strengthening of high-level governance institutions as a result, we suggest that traditional top-down mechanisms alone will not succeed without active community engagement and an integrated approach adopting the holistic principles outlined above. Such integrated and multidimensional approaches also entail practical implications for research and any subsequent intervention in the PUI.

Similar concerns apply in China, where Beijing's substantial expansion since the early 1980s has shifted its PUI progressively outwards. The current PUI is experiencing complex dynamics linked to ongoing marketisation, an increasingly dichotomised land tenure system and the establishment of new middle income communities, often drawn from the ranks of migrants from other regions (the so-called *yi zu* 'ant people' who lack local registration and benefits under what remains of the *hukou* permit system). They face discrimination and often remain on temporary jobs despite being well educated and holding responsible skilled jobs. Perhaps linked to this, novel forms of collective and 'incomplete ownership housing' village organisation are emerging, while – as elsewhere – development management remains fragmented and hence ineffective (Zhao 2012).

Mounting evidence indicates clearly that effective peri-urban management requires high levels of local participation and ownership (McGregor et al. 2006; Dodman et al. 2010). Hence research methodologies are crucial aspects of planning and design and should incorporate a well-informed community focus through participatory action research or co-production. While participatory technology development works best in promoting the interests of the poor and marginalised in the PUI, such interventions must remain affordable and based upon self-help. Community participation and mobilisation are also crucial to promoting sustainability, a prime requirement for PUI work, particularly in regard to environmental sustainability. Conducting such research requires frameworks for each distinct scale of research focus, as different data will be required to inform the way forward at multiple scales, hence interventionist and pro-poor strategies must be carefully researched and executed.

5.5 Concluding Remarks

We have argued that current institutionalised planning paradigms and practices almost invariably fail to address the essential dynamic processes of change that characterise PUIs worldwide. This reflects an abiding dichotomy within all-too-rigid planning systems based on often numerous politico-administrative territorial units which are deemed to be either predominantly urban or rural. Conventional land-use zoning and related standards and regulations also remain outdated and fail to keep pace with ongoing changes. By contrast, recent archaeological evidence from different regions is demonstrating that sophisticated and integrated urban systems comprising extensive areas that we would identify as agricultural PUIs existed over long periods of time. These sustained urban populations and gave them resilience.

In today's complex and rapidly changing world, fragmented urban planning cannot succeed. Instead, strategic or integrated urban planning across local authority categories and boundaries is needed in order to provide coherence and a holistic approach to functional urban areas. Such systems need to remain flexible and more permissive in order to cope with the dynamics of change and unorthodox combinations of activity that characterise PUIs almost everywhere. Most existing systems remain rigid and restrictive in orientation. Hence the hybrid planning approach advocated here requires the integration of multiple approaches and perspectives, including agropolitan development, disaster risk reduction, environmental change mitigation and adaptation, integrated watershed management, ecosystem services and stabilisation agriculture.

Commitment to peri-urban or urban fringe issues by individual local authorities that are either urban or rural in nature or statutory classification is often low because such areas lie on their territorial and often political margins. One rationale for integrated functional-area planning is to overcome this marginality. Equally, the generally inadequate levels of capacity and resourcing for local or metropolitan governance institutions at the urban fringe represent a handicap that must be addressed. In many parts of the world, urban expansion over time means that different land tenure (e.g. forms of communal and individualised) and planning systems may exist within a single urban area, presenting often intractable strategic and practical/routine problems. In the absence of coherent strategies to address this, creeping de facto individualisation of tenure in communally-based areas often widens socio-economic disparities, thus greatly complicating the existing challenges of how to address the conflicting resource needs and demands of rich and poor households, often with diverse cultural and class priorities, within individual localities and across an urban area. As a result, post-structural approaches have been applied to urban planning for some time – arguing the need for flexible, responsive and hybrid planning that blends traditional and modern, indigenous and 'international' architectural styles, technologies and urban idioms in locally appropriate ways. As Acevedo and Carreira (2011: 66) conclude in their analysis of such challenges in Medellín, Colombia,

> It is not a matter of *development* or *stagnation*; rather, it is a process in which traditions and uses modify, re-interpret and re-create those models imposed under the development ideal. When the dynamics between what is *planned* and how this is *used* by real people and local communities are understood as a totality, it would be possible to create more versatile and adequate responses to the challenges of a dynamic society moving towards a global order.

This applies no less directly to the dynamic mixture of people, activities and land uses that comprise the PUI, which is very much part of the urban 'totality'. However, the novelty of what we are proposing here is underscored by the very limited coverage of peri-urban areas in the *Global Report on Human Settlements 2009*, the theme of which was 'Planning Sustainable Cities' (UN-HABITAT 2009). While PUIs are mentioned briefly in a number of places, this comprised mainly general statements about the rapidity and predominant informality of growth and urbanisation there, and the challenges that this presents for coherent urban planning and the installation and upgrading of services and infrastructure. The principal focus of the report remained resolutely urban and although its arguments for substantive changes to rigid, modernist, blueprint-style planning based on outdated norms, regulations and standards were well made, there is little firm planning advice for those concerned with PUIs and they appear somehow still to be conceived of as a separate suite of evolving spaces, in that, for instance, "[n]ew and incremental approaches to service and infrastructure delivery, in partnership with local communities, will have to be found" (p. 203) (see the final summary for some of the policy recommendations this raises). This could equally well be said of unserviced area within cities. Surprisingly, integration of PUIs with the growing cities that spawn them and with which they are increasingly functionally bound up, is not advocated and the planning advice is equally vague and equivocal:

> A further issue is whether the planning of peri-urban areas calls for local or regional planning action, and which level of government is best placed to deal with such areas. A combination of regional and local planning approaches may well be required (UN-HABITAT 2009: 203).

Such issues and dynamic, even contradictory, pressures are not restricted to mega-conurbations or even just large cities that interface between local, national, regional and global economies. They apply globally across the urban spectrum in terms of better integrating urban areas into their peri-urban and regional hinterlands. The precise dynamics of change in the PUI of individual urban areas are contingent but planners and city managers are very often reduced to little more than spectators. Conventional wisdoms can be inverted; contradictions and discontinuities abound. For instance, as Klaufus' (2010: 135) comparative study of remittance economies and the growth of Quetzaltenango (Guatemala) and San Miguel (El Salvador) concludes,

> Intermediate Central American cities face rapid urbanisation on the fringes. Whereas uncontrolled urban growth used to be associated with informal self-provision of houses, suburban disorder is now attributed to fully serviced residential projects for a new middle class, built on ecologically vulnerable land. Target groups are remittance-receiving families or other people with access to foreign currency These gated communities are spatially segregated from the rest of the city, sometimes even designed as parallel cities. The construction of private water supply systems causes a reduction in groundwater levels, while deforestation in higher areas where urbanisation projects are developed causes flooding in lower urban areas.

In the very different context of peri-urban Zanzibar island in Tanzania, Myers (2010) illustrates the heterogeneity of 'place making' by individuals and households, often defined in terms of their personal relationships with elements of the state. These in turn have specific historical roots, and the diverse and even conflicting interests militate against efforts at coherence or even alternative, bottom-up and more sustainable planning than what has resulted from the failed modernist legacy. Yet, in peri-urban Maputo, where the state still technically owns all land, fragmentation is also occurring although technically illegal informal markets appear to operate quite efficiently (Kihato et al. 2012).

These few examples attest to the diversity of situations and processes which are remaking peri-urban spaces everywhere through territorial disintegration and urban fragmentation, generally on the basis of wealth and political power through growing marketisation, whatever the formal legal situation. This indicates the strength of the challenges to be overcome if the integrative and holistic approaches we advocate and which we believe to be essential to achieving greater urban and peri-urban sustainability, equitability and resilience are to become practicable in dynamic, fast-growing contexts. Equally, recent literature from various parts of Europe and elsewhere in the OECD suggests that many peri-urban interfaces there are far more dynamic than portrayed in earlier literature and that similar issues and concerns over ambiguities and weaknesses of governance frequently exist. To some extent, at least, the increasing adoption of peri-urban nomenclature and approaches in European literature symbolises an effort to break down intellectual and geopolitical ghettos and open up these dynamic spaces of fragmented place making for mutual learning.

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References

Acevedo B, Carreira AM (2011) Hybrid cities: narratives of urban development and popular culture, the case of medellín (Colombia). In: Sonda G, Coletta C, Gabbi F (eds) Urban plots, organizing cities. Ashgate, Alershot

Adam AG (2014) Land tenure in the changing peri-urban areas of Ethiopia: the case of Bahir Dar city. Int J Urban Reg Res 38(6):1970–1984

Adam-Bradford A, Hoekstra F, van Veenhuizen R (2009) Editorial: linking relief, rehabilitation and development: a role for urban agriculture? Urban Agric Mag 21:3–10

Adger WN, Lorenzoni I, O'Brien K (eds) (2009) Adapting to climate change: thresholds, values, governance. Cambridge University Press, Cambridge

Atkinson A (2013) Urban and peri-urban agriculture: part four; introduction. City 17(3):361–364

Audirac I (1999) Unsettled views about the fringe: rural-urban or urban-rural frontiers? In: Furuseth O, Lapping M (eds) Contested countryside: the rural-urban fringe in North America. Ashgate, Aldershot, pp 7–32

Barthel S, Isendahl C (2013) Urban gardens, agriculture and water management: sources of resilience for long-term resilience in cities. Ecol Econ 86:224–234. http://dx.doi.org/10.1016/j.ecolecon.2012.06.018

Bicknell J, Dodman D, Satterthwaite S (eds) (2009) Adapting cities to climate change; understanding and addressing the development challenges. Earthscan, London

Bunker R, Houston P (2003) Prospects for the rural-urban fringe in Australia: observations from a brief history of the landscapes around Sydney and Adelaide. Aust Geogr Stud 41:303–323

Busck AG, Kristensen SP, Praestholm S, Reenberg A, Primdahl S (2006) Land system changes in the context of urbanisation: examples from the peri-urban area of Greater Copenhagen. Geogr Tidsskr (Dan J Geogr) 106(2):21–34

Cabannes Y, Raposo I (2013) Peri-urban agriculture, social inclusion of migrant population and right to the city. City 17(2):235–250

Connah G (2000) African city walls: a neglected source? In: Anderson DM, Rathbone R (eds) Africa's urban past. James Currey, Oxford

Dodman D, Mitlin D, Rayos Co J (2010) Victims to victors, disasters to opportunities; community-driven responses to climate change in the Philippines. Int Dev Plan Rev 32(1):1–26

Douglas I (2013) Cities: an environmental history. IB Tauris, London

Elmqvist T, Redman C, Barthel S, Costanza R (2013a) History of urbanization and the missing ecology. In: Elmqvist T, Fragkias M, Goodness J, Güneralp B, Marcotullio PJ, McDonald RI, Parnell S, Haase D, Senstad M, Seto KC, Wilkinson C (eds) Urbanization, biodiversity and ecosystem services: challenges and opportunities: a global assessment. Springer Open, Dordrecht, pp 13–30

Elmqvist T, Fragkias M, Goodness J, Güneralp B, Marcotullio PJ, McDonald RI, Parnell S, Haase D, Senstad M, Seto KC, Wilkinson C (eds) (2013b) Urbanization, biodiversity and ecosystem services: challenges and opportunities: a global assessment. Springer Open, Dordrecht

Evans D, Pottier C, Fletcher R, Hensley S, Tapley I, Milne A, Barbetti M (2007) A comprehensive archaeological map of the world's largest preindustrial settlement complex at Angkor, Cambodia. Proc Natl Acad Sci U S A 104(36):14277–14282

Fall AS, Guèye C, Tall SM (2005) Changements climatiques, mutations urbaines et strategies citadines à Dakar (Sénégal). In: Fall AS, Guèye C (eds) Urbain-Rural: l'hybridation en marche. ENDA Tiers Monde, Dakar, pp 191–231

Fletcher R (2012) Low-density, agrarian-based urbanism: scale, power and ecology. In: Smith ME (ed) The comparative archaeology of complex societies. Cambridge University Press, Cambridge, pp 285–319

Friedmann J (1985) Political and technical moments in development: agropolitan development revisited. Environ Plan D: Soc Space 3(2):155–167

Friedmann J (2002) The prospect of cities. University of Minnesota Press, Minneapolis

Friedmann J, Weaver C (1979) Territory and function: the evolution of regional planning. Edward Arnold, London
Gallent N, Andersson J, Bianconi M (2006) Planning on the Edge: the context for planning at the rural-urban fringe. Routledge, London
Goldammer J (2005) Wildland fire – rising threats and vulnerabilities at the interface with society. In: Jeggle T (ed) Know risk. United Nations International Strategy for Disaster Reduction, Geneva, pp 322–323
Gotz G, Schäffler A (2015) Conundrums in implementing a green economy in the Gauteng City-Region. Curr Opin Environ Sustain 13:79–87
Gregersen HM, Ffolliott PF, Brooks KN (2007) Integrated watershed management: connecting people to their land and water. CABI Publishing, Wallingford
Heckenberger MJ, Russell JC, Fausto C, Toney JR, Schmidt MJ, Pereira E, Franchetto B, Kuikuro A (2008) Pre-Columbian urbanism, anthropogenic landscapes, and the future of the Amazon. Science 321(5893):1214–1217
Hoggart K (2005) City Hinterlands in European space. In: Hoggart K (ed) The City's Hinterland: dynamism and divergence in Europe's peri-urban territories. Ashgate, Aldershot, pp 1–18
Isendahl C (2012) Agro-urban landscapes: the example of Maya lowland cities. Antiquity 86:1112–1125
Isendahl C, Smith ME (2013) Sustainable agrarian urbanism: the low-density cities of the Mayas and Aztecs. Cities 31:132–143
Jones PS (2000) Why is it alright to do development 'over there' but not 'here'? Changing vocabularies and common strategies of inclusion across the 'First' and 'Third' worlds. Area 32(2):237–241
Kihato CW, Royston L, Raimundo JA, Raimundo IM (2012) Multiple land regimes: rethinking land governance in Maputo's peri-urban spaces. Urban Forum 24(1):65–83
Klaufus C (2010) Watching the city grow: remittances and sprawl in intermediate Central American cities. Environ Urban 22(1):125–137
Leichenko RM, Solecki WS (2006) Global cities and local vulnerabilities. IHDP Update 2.2006
Leck H, Roberts D (2015) What lies beneath: understanding the invisible aspects of municipal climate change governance. Curr Opin Environ Sustain 13:61–67
Lwasa S, Mugagga F, Wahab B, Simon D, Connors J, Griffith C (2014) Urban and peri-urban agriculture and forestry: transcending poverty alleviation to climate change mitigation and adaptation. Urban Clim 7:92–106
Lwasa S, Mugagga F, Wahab B, Simon D, Connors J, Griffith C (2015) A meta-analysis of urban and peri-urban agriculture and forestry in mediating climate change. Curr Opin Environ Sustain 13:68–73
Maneepong C, Webster M (2008) Governance responses to emerging peri-urbanisation issues at the global-local nexus. Int Dev Plan Rev 30(2):133–154
Mann CC (2008) Ancient earthmovers of the Amazon. Science 321:1148–1152
Mbiba B, Huchzermeyer M (2002) Contentious development: peri-urban studies in sub-Saharan Africa. Prog Dev Stud 2(2):113–131
McFarlane C (2006) Crossing borders: development, learning and the North-South divide. Third World Q 27(8):1413–1437
McGregor D, Simon D, Thompson D (eds) (2006) The peri-urban interface: approaches to sustainable natural and human resource use. Earthscan, London
Momen MS (2009) Synergistic rural-urban development: the experience of the Rural-Urban Partnership Programme (RUPP) in Nepal. Int Dev Plan Rev 31(3):281–300
Myers G (2010) Social construction of peri-urban places and alternative planning in Zanzibar. Afr Aff 109(437):575–595
Odewumi SG, Awoyemi OK, Iwara AI, Ogundele FO (2013) Farmers' perception on the effect of climate change variation on urban agriculture in Ibadan Metropolis, South-Western Nigeria. J GeogrReg Plan 6(6):209–217

Olwig M, Gough K (2013) Basket weaving and social weaving: young Ghanaian artisans' mobilization of resources through mobility in times of climate change. Geoforum 45:168–177
Parnell S, Simon D, Vogel C (2007) Global environmental change: conceptualizing the growing challenge for cities in poor countries. Area 39(3):357–369
Pelling M, Wisner B (eds) (2009) Disaster risk reduction: cases from urban Africa. Earthscan, London
Qviström M (2010) Shadows of planning: on landscape/planning history and inherited landscape ambiguities at the urban fringe. Geogr Ann B 89:269–282
Qviström M (2013) Searching for an open future: planning history as a means of peri-urban landscape analysis. J Environ Plan Manag 56(10):1546–1569
Ravetz J, Fertner C, Sick Nielsen TA (2013) The dynamics of peri-urbanization. In: Nilsson K, Pauleit S, Bell S, Aalbers C, Sick Nielsen TA (eds) Peri-urban futures: scenarios and models for land use change in Europe. Springer-Verlag, Berlin, pp 13–44
REGLAP, FAO, UNOCHA (2011) Priorities for dryland recovery and development: community control, empowerment, education and pro-poor infrastructure. In: de Jode H, Tilstone V (eds) Disaster risk reduction in the drylands of the Horn of Africa – edition 2. Regional Learning & Advocacy Programme (REGLAP) for Vulnerable Dryland Communities, pp 46–47
Rosenzweig C, Solecki WD, Hammer SA, Mehrotra S (eds) (2011) Climate change and cities; first assessment report of the urban climate change research network. Cambridge University Press, Cambridge
Rosol M, Schweizer P (2012) Ortoloco Zurich: urban agriculture as an economy of solidarity. City 16(6):713–724
Saini NS (1989) Rural development at metropolitan fringe: resource conservation approach. Anmol Publications, New Delhi
Sánchez-Rodríguez R, Seto K, Simon D, Solecki W, Kraas F, Laumann G (2005) Science plan: urbanization and global environmental change. IHDP report 15. International Human Dimensions Programme on Global Environmental Change, Bonn
Sieverts T (2003) Cities without cities: an interpretation of the Zwischenstadt. Spon, London
Simon D (2007) Cities and global environmental change: exploring the links. In: Simon D (ed) Urbanization and global environmental change: 21st century challenges. Geogr J 173(1):75–92
Simon D (2008) Urban environments: issues on the peri-urban fringe. Annu Rev Environ Resour 33:167–185
Simon D (2010) The challenges of global environmental change for urban Africa. Urban Forum 21(3):235–248
Simon D (2014) Viewpoint: new evidence and thinking on urban environmental change challenges. Int Dev Plan Rev 36(2):v–xi
Simon D, Leck H (2015a) Editorial overview: sustainability challenges: assessing climate change adaptation in Africa. Curr Opin Environ Sustain 13:iv–viii
Simon D, Leck H (2015b) Understanding climate adaptation and transformation challenges in African cities. Curr Opin Environ Sustain 13:109–116
Simon D, McGregor D, Nsiah-Gyabaah K (2004) The changing urban-rural interface of African cities: definitional issues and an application to Kumasi, Ghana. Environ Urban 16(2):235–247
Smith ME (2010) Sprawl, squatters and sustainable cities: can archaeological data shed light on modern urban issues? Camb Archaeol J 20(2):229–253
Smith ME (2012) The role of ancient cities in research on contemporary urbanization. UGEC Viewpoints 8:15–19
Sutton G, Cheese E (2011) Stabilisation agriculture: developing an agenda: workshop Report Monday 20th June 2011. Coventry University Centre for Agroecology and Food Security (CAFS) and Centre for Peace and Reconciliation Studies (CPRS), Coventry
Tacconi L, Moore PF, Kaimowitz D (2007) Fires in tropical forests – what is really the problem? Lessons from Indonesia. Mitig Adapt Strategy Glob Chang 12:55–66

Taylor PJ (2012) Extraordinary cities: early ‘city-ness’ and the origins of agriculture and states. Int J Urban Reg Res 36(3):415–417
Teaford JC (2006) The metropolitan revolution; the rise of post-urban America. Columbia University Press, New York
Ten Brink P (ed) (2011) The economics of ecosystems and biodiversity in national and international policy making. Earthscan, London
Tilstone V (2011) Integrating disaster risk reduction and climate change adaptation in the drylands of the Greater Horn of Africa. In de Jode H, Tilstone V (eds) Disaster risk reduction in the drylands of the Horn of Africa edition 1. Regional Learning & Advocacy Programme (REGLAP) for Vulnerable Dryland Communities, pp 2–3
Twig J (2004) Disaster risk reduction: mitigation and preparedness in development and emergency programming. Good practice review, No. 9. Humanitarian Policy Network, Overseas Development Institute, London
UN-HABITAT (2009) Global report on human settlements 2009: planning sustainable cities. Earthscan, London/Sterling
Wisner B, Blaikie P, Cannon T, Davis I (2004) At risk: natural hazards, people’s vulnerability and disasters, 2nd edn. Routledge, London
Wright J (2009) Sustainable agriculture and food security in an era of oil scarcity. Earthscan, London
Ye Q (2005) Living in between. In: Jeggle T (ed) Know risk. United Nations International Strategy for Disaster Reduction, Geneva, pp 318–321
Yokohari M, Bolthouse J (2011) Planning for the slow lane: the need to restore working greenspaces in maturing contexts. Landsc Urban Plan 100(4):421–424
Zhao P (2012) Urban–rural transition in China’s metropolises: new trends in peri-urbanisation in Beijing. Int Dev Plan Rev 34(3):269–294

Chapter 6
Decontamination of Urban Run-Off: Importance and Methods

Leo Crasti

Abstract The removal of contaminants from urban run-off waters is vital to preserving the health of urban communities that live in contact with and around the receiving waters. The apparatus developed is a Stormwater Screening and Filtration Unit (SSFU), which embodies a series of processes for the removal and retention of trash and litter, sediment, suspended solids, emulsified hydrocarbons, dissolved nutrients (both Total Nitrogen and Total Phosphorus), heavy metals and other chemicals as required by the run-off water composition and the receiving water quality of a specific catchment.

In addition to a small foot print and negligible installation time, the implementation of an SSFU as the sole method of contaminant removal from runoff, can reduce capital expenditure often by more than 60 % and reduce on-going service cost by over 80 %, when compared to the implementation of conventional multiple treatment measures in a treatment train as a means of meeting pollution reduce targets.

The SSFU is available to integrate with various applications, ranging from in-line drainage lines, as a pre-process within on-site detention (OSD), discharge outlets to wetlands or receiving waters and with the addition of passive secondary media can remove even fine silts and chemicals prior to harvesting and aquifer re-charge.

Keywords On-site detention • Stormwater screening • Filtration • Runoff • Wetlands • Contaminants

6.1 Introduction

Contaminants in stormwater runoff are a key contributor to the collapse of freshwater ecosystems and at source measures need to be implemented to address water quality issues (Allison et al. 2008). The findings cite reluctance by authorities to

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mandate Water Sensitive Urban Design (WSUD) treatment measures as the additional capital and maintenance costs may inhibit acceptance and implementation.

Our investigation amongst engineers, property developers and builders shows the reluctance to implementation is primarily driven by costs associated with loss of land use, installation and maintenance. Our research and development aims were to provide a low impact, low cost easy to maintain solution for the removal of all contaminants that are undesirable to receiving waters. The benefit generated by achieving this outcome in addition to preserving the environment and human health, is allowing the water to be safely used for recreation, agriculture and harvested for re-use.

To further bring the importance of preserving freshwater quality into focus the fundamental importance of fresh water as a limited resource needs to be stated. Water (H_20) on our planet earth is finite, with astronomers agreeing that water was imported to the planet by ice meteors. Abramovitz (1996) estimates that the human use of fresh water has increased 40-fold in 300 years with 50 % of that increase since 1950. Lefort (1996) calculate that only 0.01 % of the world's water is available for regular human use.

6.1.1 History of Stormwater Management in Australia

Australia and the cities of Sydney, Melbourne and Brisbane are amongst the most recently developed urban environments in the western world. Urban design was greatly influenced by the original British colonists and further impacted by European migrant designers. Because of this recent history, there are substantial lessons that can be learnt by reviewing this history.

There have been a number of articles published that draw from archaeological records that clearly show a relationship between urbanisation and pollution of creeks, rivers and harbours (Everingham 2007). The migration in the mid-nineteenth century brought debris, garbage and deterioration of harbours. Roadways became drains and the source of sediment erosion, whilst also transporting animal manure, industrial discharge and sewage that flowed into natural waterways (Fraser 1989). Yielding to public pressure caused municipal and other public authorities to adopt urban drainage systems (O'Loughlin and Joliffe 1987). Prior to the 1890s, urban drainage included both sewer and stormwater systems. Stormwater in time was seen as a problem, causing flooding and disruption to the drainage system and surrounding infrastructure.

Separate stormwater and sewer systems became an Australian standard practice by the 1920s (O'Loughlin and Robinson 1999) as a response to public concern of waterborne diseases. From this point on, sewer systems were well designed and implemented, whilst stormwater drains became a mechanism to transport street and surrounding waste to receiving waters. This followed a similar trend in Europe and the US. Unseen below ground and unnoticed because of dilution, the practice has continued unabated until recent times.

Though the removal of visible gross pollutants has been a focus through the implementation of trash racks and GPT's, a large amount of anthropogenic contaminants continue to enter the waterways. Allison et al. (2002) note the Australian Federal Government Senate enquiry into Australia's Urban water management, which noted that many of Australia's waterways are in critical condition due to pollution. Studies and experience by (Pratten 2009) and (Allison et al. 1998) showed that 90 % of gross pollutants entering both Sydney Harbour and Melbourne's Port Phillip Bay sink to the bottom and give the deceptive appearance of clean water.

More recently, the Sydney Institute of Marine Science (SIMS) have been engaged to conduct detailed studies of the sediment beds in Sydney Harbour. Their success has spread to a global linkage titled "World Harbour Project" aimed at addressing the challenges of urbanisation and the impact on marine environments. Recent achievements by SIMS includes the confirmation that micro plastics have entered the food chain and are compromising the population and health of benthic organisms in the sediment beds. Further studies are in progress to quantify the impact of heavy metals and numerous other chemicals transported by stormwater, on the marine eco system. These studies are also parallel by the CSIRO in Australia and linked groups worldwide.

There are numerous references that express concerns with the accumulation of a diverse range of contaminants in aquatic sediment beds. The author proposes that all urban designers should adopt a proactive approach and limit if not eliminate all anthropogenic derived content from runoff water and thereby not be party to increasing the current environmental degradation and threats to bio diversity.

6.2 Urban Drainage Design

As cities developed over the centuries, drainage systems were installed underground. Though this served to create an improved built environment, the result was a hidden disposal system which transports matter into waterways and in turn seas and oceans. A dramatic example is the Pacific Gyre and the impact of micro plastics spreading across all coastlines.

In recent times the principles of WSUD have been promoted to urban designers. The Australian Runoff Quality (ARQ) 2006 was used as a core document and source of design parameters. Installing and operating the SSFU in both existing drainage networks as well as an integrated element of WSUD was a primary design goal. Variants were developed for application in locations such as:

- In-line as an integral part of the drainage line, either a new or existing pipeline or culvert.
- Off line in circumstances where an in-line application is not practical. However the method of diversion or flow splitting requires specific design knowledge to avoid hydraulic jumps and premature by-pass
- End of line at headwalls which favours existing drainage outlets

Table 6.1 Contaminant type with specified percentage and design reduction targets

Contaminant/pollutant	% Reduction target	% Reduction possible
Trash and litter (gross pollutant)	90 %	95 %
Total Suspended Solids (TSS)	85 %	90 %
Total Phosphorus (TP)	65 %	80 %
Total Nitrogen (TN)	45 %	70 %
Hydrocarbons, including emulsified and free	90 %	90 %
Heavy metals		90 %
Turbidity		50 %

- Prior to detention systems, ensuring water entering a detention basin or tank is free of contaminants allowing the OSD to perform it's function without maintenance.

6.2.1 Contaminant Type and Load

The following are a list of contaminants that are considered to occur in drainage systems. The highlighted contaminants are typically noted in environmental policy documents with percentage reduction targets (Refer Table 6.1)

Gross Pollutants These include trash, packaging, organic matter such as a leaf litter and grass clippings, clog drains and choke waterways. Though trash, particularly plastics are obvious pollutants, some question whether leaf litter and grass clippings are pollutants or contaminants. The simplest way to determine if a substance is a pollutant (or contaminant) is to relate the substance and it's influent volume to the pre-urban condition of that catchment. For example, litter fell from trees and provided a compost bed below the tree canopy providing a microenvironment, for a diversity of organisms. The compost bed was reasonably well anchored and acted as an energy dissipater even during intense rainfall events, allowing water to filter into the soil or migrate at low velocity to the nearest water course. However in an urban landscape, litter falls and is either not encouraged for aesthetic reasons and removed or accumulates on an impervious surface and is washed away at high velocity during the next (often mild) rainfall event. This large volume of raw litter overloads the downstream water way and can have significant detrimental impacts, including turbidity increase, coverage that excludes light, delivery of nutrient overdose and subsequent oxygen depletion. Additionally that raw litter may be foreign to the environment and not able to be digested by the indigenous organisms.

Sediments Sediments washed from impervious surfaces (roof surfaces, pavements etc) or as erosion can change the light penetration into water, clog the gills of fish and negatively impact their breeding and feeding habits. Particles (dust and dirt) generated from road surfaces (Dempsey et al. 1993) carry a range of contaminants

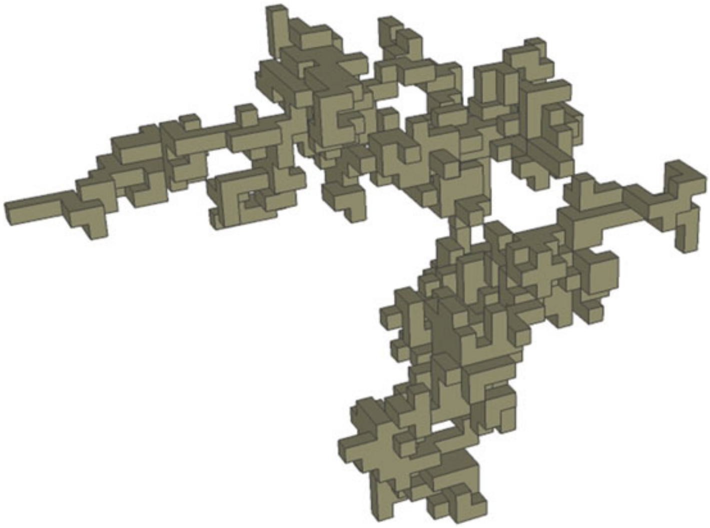


Fig. 6.1 40 μm particle illustration shows large surface area and high chemical entrapment capability

and heavy metals. The author has worked with Sydney and the University of Western Sydney to understand the role of particles as a transport mechanism. Figure 6.1 shows a an illustration of a 40 μm particle which was created from actual video recordings then translated into a 3D animation medium. This clearly shows that the particle comprises a flocculation of sub particles, creating a combined capacity to attract chemicals, both by way of surface attraction over the large surface area, as well as mechanical entrapment between the sub particles. There is further evidence emerging (which is the subject from the current studies) that these particles conglomerate to form sediment and retain the chemicals for extended periods of time. Of further interest is that nutrients such as Nitrogen have an affinity for particles. Analysis of pond systems showed that only 10 % of the total Nitrogen was available in solution whilst the remainder (90 %) was attached to particles. This view is further supported by the addition of clay to water in order to extract nutrients and improve water quality (Bakel 2006; Guo et al. 2011). There is further evidence in support from student studies and field experiments that correlate nutrient release time to catchment materials, which show that the capture of particles is an effective method of reducing nutrient load in run-off as the wetted exposure time to effect release is longer than the duration of run-off from a local catchment, prior to entry into infrastructure drainage systems. This is the subject of current research.

Organics These are mostly chemical compounds used in the manufacturing of consumer products, which, at even low concentrations have serious health implications. Analysis of stormwater (Pitt et al. 1995) showed that a significant portion of stormwater run-off contained extreme to moderate toxic organic compounds and that filtering of particles to 40 μm reduced toxicants by 70 %.

Nutrients When added to an aquatic environment can quickly cause excessive algae growth consuming available (dissolved) oxygen previously available for other aquatic flora and fauna. Then as algae die, decomposition further reduces available oxygen, which can only be replenished by a significant change to the water body, such as aeration or a complete water change. Isolated water bodies can suffer long-term loss of bio-diversity if the condition is allowed to continue. This is known as eutrophication and is harmful to fish and other aquatic organisms. Certain strains of algae are sufficiently toxic to be harmful to livestock and humans.

Oil and Grease These in stormwater introduce toxicants and coat plants and the gills of fish with a film preventing the exchange of oxygen and nutrients. Some of these compounds are dangerous even at low concentrations, include Chlorobenzenes and Surfactants, which as a generic group, impact on the health and population of benthic organisms.

Heavy Metals These are transported by urban run-off mostly bonded to particles as noted earlier. These are of concern due to their potential toxicity and ability to bio-accumulate. There is also growing evidence that these heavy metals are finding their way into the food chain, with many harbour based fisheries being closed. The Food and Agriculture Organisation of the United Nations have noted in part that many harbours world wide are adversely impacted by the heavy metals (Sciorintino and Ravikumar 1999).

Chlorine, Acid Wash and Erosion from the maintenance of pools, spas, and fountains can pose a major risk to stormwater through erosion, increase in sediments and the addition of pollutants such as chlorine and acid wash.

Bacteria and viruses are pathogens present in faecal matter which can be present in stormwater runoff as pet and wildlife waste, leaky septic systems, runoff from agriculture, broken sanitary sewers, and cross connections.

Thermal stress occurs when warmer stormwater runoff enters a coldwater system negatively impacting on cold-water dependant species.

Improperly designed and/or maintained stormwater infrastructure offers habitat for rodents, small animals and other disease carriers.

6.2.2 Treated Flow

Experience and simple observation shows that after a period of rainfall, a catchment "cleans-up". Motor vehicle drivers are well aware of the slippery road phenomena for the initial period of rainfall on roadways.

Therefore, it stands to reason that only a portion of the rainfall event needs to be treated. This is defined as the treated or design flow and is a fundamentally critical design assessment, which needs to be made prior to selecting a treatment measure.

6.2.3 Definition

The gross flow is the total flow, which may potentially be conveyed by the drainage system and is typically determined by local area needs and is expressed as a flood event, determined from statistical records. The treated flow and gross flow are not necessarily interrelated. For example a drainage system sized to accommodate a 1 in 100 year flood event will be larger than if designed to accommodate a 1 in 25 year event. The defined gross flow alters the size of a pipe or channel without necessarily altering the treated flow, which is required to pass through a process to substantially remove the target contaminants.

There is a misunderstanding that a 3 month rainfall event (being estimated as approximately 50 % of a 1 year event) is sufficient as the treated flow. The Australian Runoff Quality Guidelines (Engineers Australia 2006) notes that a 3 month event should mobilise up to 90 % of the contaminants in a catchment. This level of treated flow is simplistic and could lead to under design and inadequate performance. The following additional factors need to be included in defining the treated flow.

Firstly, the nature of the catchment and the extent of impervious areas creating high or low velocity flows needs to be considered. This will have a bearing on the flushing effect. For example, smooth hard surfaces at higher gradients will mobilise contaminants at a lesser water volume than rough low gradient surfaces.

Secondly, is the flow and time delay within the catchment area. Many drainage systems exceed 200 m in run length, with pipe flow velocities of 0.5–2.0 m/s. When overland flow times are added, the catchment time lag between entry points close to a treatment measure versus the furthest catchment areas could exceed 10 min.

If a 3 month event equivalent flow were treated, then only a small portion of the catchment load will be included in the treated flow and potentially a majority of the load would by-pass the treatment measure. Off-line systems predominantly suffer from this misunderstanding.

Therefore, the treated flow definition in sizing a Stormwater Treatment Measure (STM) is to firstly use the 3 month event as a minimum, then add the catchment area time delay factor to determine the actual treated flow and link this with the rainfall event hydrograph.

In general terms, a one (1) year event typically represents the minimum treated flow with increased treated flow up to a five (5) year event in catchments with extended flow paths.

The application of “First Flush” principles based on a one (1) factor design parameter of for example a 3 month ARI is flawed. The aim of this section is to propose a treated (design) flow calculation, which is consistent with all the research results over a 20 year period and recommends that designers take into account the nature of catchments and the sensitivity of receiving waters on a case by case basis.

6.2.4 The First Flush

Jean et al. (1997)) analysed 197 rainfall events in 12 separate catchments in France and Germany. Their analysis included the creation of non dimensional models and charts know as M(*V*) curves (Refer Fig. 6.2) which related flow rates and concentrations versus cumulative flows and mass transported, for a variety of contaminant types. This is a comprehensive and thorough attempt to establish a “first flush rule” which could be used to establish a treated flow ratio and hence size a treatment measure. Comment and analysis was also provided for several earlier attempts by various authorities and experts to create a first flush definition and 29 references were also included. Typically these attempts were proposing a rainfall volume % versus pollutant transport volume %. The authors chose to use 30/80 ie 30 % of the rainfall volume would transport 80 % of the pollutant load from a catchment as the definition of the “first flush”.

The conclusion reached was unexpected. In the conclusion to the paper the authors wrote, “*The analysis of the data available in France and abroad shows that this 30/80 first flush is very rare*.” This was stated in the context that the ratio was too low and that a much higher rainfall volume had to be treated in order to capture a high proportion of pollutants. The conclusion in the paper then went on to state, “*Nevertheless*, *it appears that* ***the concept of the first flush can not be used alone*** *to establish a reliable design methodology for treatment facilities*, *as it does not take into account the complexity and variability of the phenomena involved. It is consequently proposed to renounce the first flush concept itself*”.

6.2.5 Sediment and Pollutant Load Modelling

Rodriguez et al. (2010)) recognised that modelling methods, which reliably predict the relationship between flow and pollutant transport from a catchment area, are becoming a necessary requirement in urban drainage design. Of note is the constant reference to complexity and time lag. The issue of complexity acknowledges that input data and parameters in the simulation need to be varied across catchments, drawing the conclusion that there are no simple underlying constants. The time lag factor is a common denominator in all studies reviewed, which clearly shows that sediments will continue to be transported and appear in the flow path well after the rainfall peak has passed.

The conclusion drawn from these and several other papers is that a simple across the board rule cannot be applied and that intra-catchment time lag must be a primary function within the calculation.

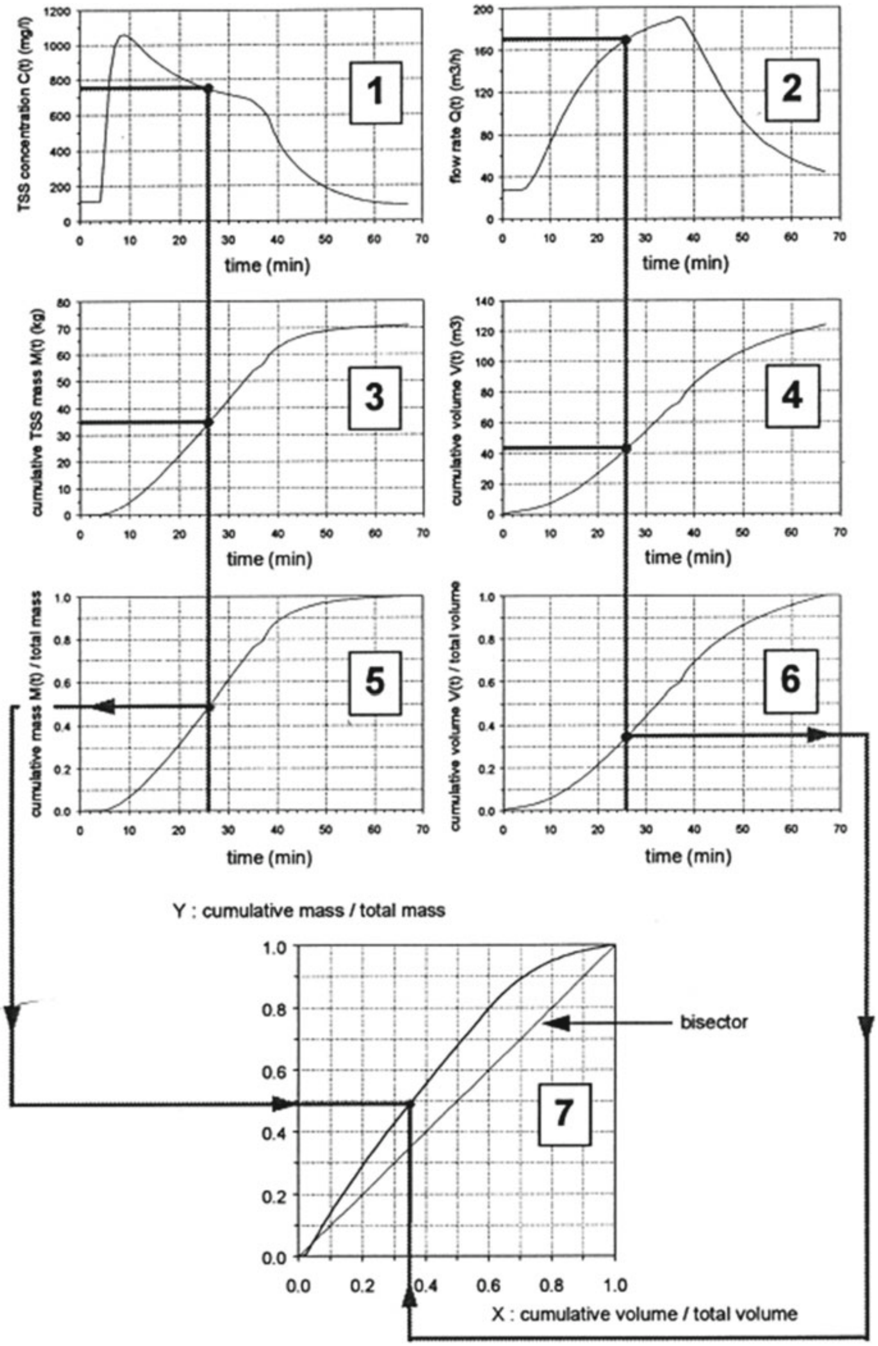


Fig. 6.2 Example of M(V) *curve* for TSS

6.2.6 The Australian Runoff Quality Guideline 2006 (ARQ)

The ARQ is a comprehensive document, which intends to provide a design guide toward the application of WSUD. Of note the ARQ makes the following comments. Section 2.4.2, notes that 70–90 % of pollutants are exported by storm events of 1 year ARI or smaller. Particle sizes down to 20 μm size range are the prime carriers of toxic contaminants and nutrients (Refer Fig. 2.1 in Engineers Australia 2006).

Chapter 8 in Engineers Australia (2006), Melbourne Water is referenced as expecting a 70 % reduction in litter load to 20 mm in size, by treating flows equivalent to a 3 month average recurring interval (ARI). A further acknowledgement follows that treating a one (I) year ARI would be necessary for the removal of particles to 90 %.

6.2.7 The Catchment Hydrology

The hydrology of a catchment created by man-made development will exhibit similar characteristics to any watershed (catchment). Principally, that rainfall impacts on the surface and transfers energy to mobilise particles, then as water depth increases, water starts to flow at a velocity determined by gradient, then enters a drainage system, which conveys that water to a discharge point. Water becomes the carrier of contaminants.

The Fig. 6.3 shows charts of the relationship between various factors that impact on water flow in a typical watershed. The same factors also apply to a man made catchment where natural flow paths are replaced by a drainage system.

The factors, which influence treated flow are:

1. **Flow gradient** in the catchment being the gradient of areas water must flow over before entering a drainage conduit. Flat areas will hold more contaminants and require higher flow rates than larger gradients to mobilise materials.
2. **Impervious areas** are often simplistically the only area considered as the catchment, however run-off from other areas both pervious and semi pervious also hold contaminants and may take greater flows to mobilise these materials. A typical example is soil and organic matter, which is the source of nutrients and other chemicals, held in landscaping surrounded by paved areas. Soil types and the moisture levels will also generate different flow conditions and materials export characteristics.
3. The **texture of catchment** areas will also influence the flow rate required to mobilise contaminants. Smooth concrete surfaces will have a lower flow versus contaminant transport rate than course surfaces such as bitumised pavements, which inherently hold sediment.
4. The **flow gradient of drainage** conduits will induce large differences in flow velocity, which is the fundamental source of energy that transports material. Gradients generally range from 0.5 to 3 % and induce flow velocities of 1–5 m/s

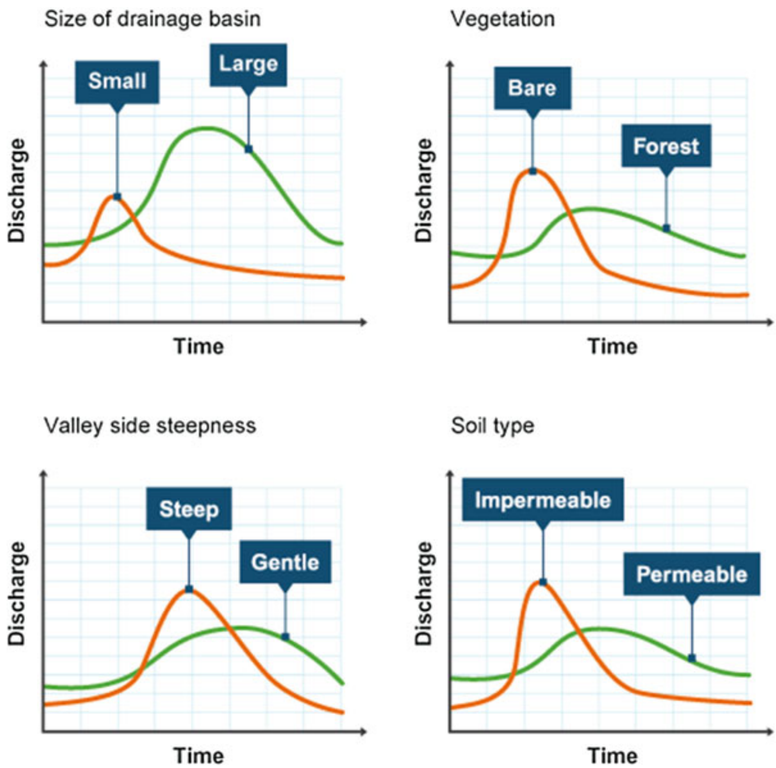


Fig. 6.3 Shows charts of the relationship between catchment factors and discharge/time relationship

when fully charged. However as Figs. 6.4, 6.5, and 6.6 show there is a non-linear relationship between flow depth, rate and velocity. At low flows, drainage lines and pits accumulate a range of contaminants. This is exacerbated by the need to often design drainage systems for extended events such as 1 in 50 and 100 year flood events as overland flow paths may not be available without asset damage. Large sized pipe systems cause shallow flow depths and low mobilisation flows, which further add to the accumulation of materials within the drainage system. The relationship between pipe size, gradient and the likelihood of materials ingress into the drainage system are all factors, which need to be considered in the level of treated flow and operation of an STM.

5. Materials within the catchment are transported relative to their **physical properties**, such as buoyancy, density, shape and size. There are further more complex factors such as wetting and clumping which complicate attempts to synthesise and model contaminant behaviour. Practical observations of many urban drainage systems reveal that accumulated materials are left behind by low rainfall events as these materials are dry and are retained by rough surfaces, then as follow on rainfall occurs, these clumps of material are carried into drainage inlets.

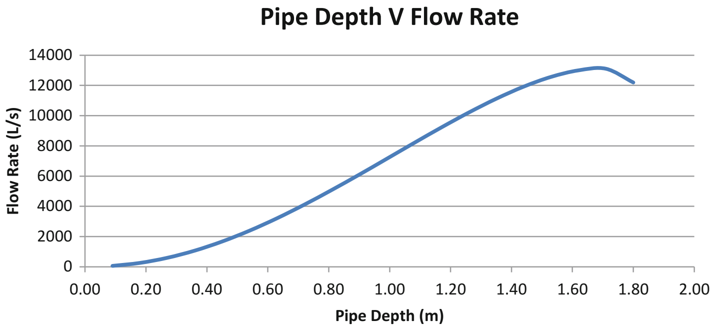


Fig. 6.4 Flow rate increases 300 % from 3 month to 1 year ARI flows

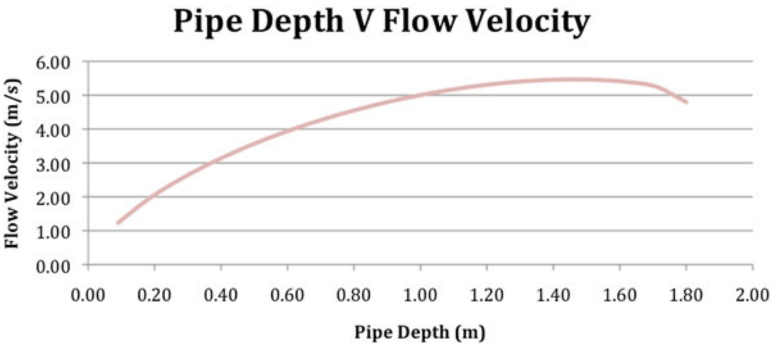


Fig. 6.5 Flow velocity increase of 200 % from 3 month to 1 year ARI flows

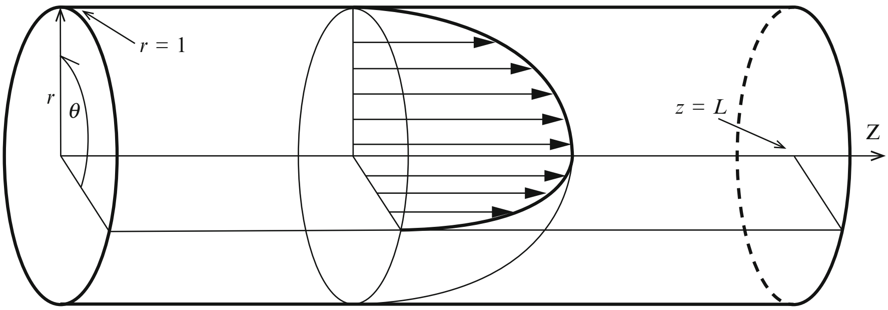


Fig. 6.6 Differential velocity profile

6.3 Proposed Design Flow Calculation

There is sufficient literature to indicate that a one (1) year ARI is the minimum rainfall event that will most likely mobilise a high percentage of the contaminants within a catchment. Therefore this should be assumed as the base design flow, or minimum treated flow.

In addition, consideration is required for the time lag factor across the catchment. This will vary depending on the catchment characteristics and influencing factors listed earlier, which influence the behaviour of water as a transport medium. There are a number of modelling tools, which allow designers to calculate the time lag of flow across surfaces and in drains. Tools that relate pollutants and the interaction with water are still in development and are unlikely to be widely used until catchment specific data is accumulated and categorised/classified.

The aim of the design is to ensure that the **entire** catchment surface, (which may collect contaminants) is exposed to a rainfall equivalent to a 1 year ARI with sufficient time for that flow to arrive at the STM, before by-pass occurs. By definition therefore, the level of flow to be treated in many instances will be higher than the minimum 1 year event, and will vary in accordance the rain fall hydrograph for that area.

6.4 Location of a Treatment Measure

Urbanisation and man-made catchments typically involve an increase in impervious areas and a change of gradient. Unfortunately, the net result is a significant increase in discharge volume over the same time interval. The location of an SSFU will vary with each catchment area topography and access to discharge or receiving waters.

It does not necessarily follow that the least number of SSFU's installed will be the lowest cost alternative. Aggregating pipe flows to convey water to one discharge location and hence one SSFU will invariably increase the cost of the drainage system. Whilst potentially reducing the cost of the SSFU the net result may a total capital increase, which could have been avoided by reducing pipe work and increasing the number of SSFU's. Other factors are long term service and maintenance, which may be, favour one centralised SSFU due to easy of access.

A common practice is to location of an STM after an OSD as the flow is low and the STM is down sized, resulting in an apparent lower capital cost. This includes the OSD as the primary treatment measure with significant consequences. Firstly any limited screening ahead of the discharge orifice will be blocked causing the OSD to over flow, releasing the buoyant materials. In some cases the overflow relief weir may also become blocked, back up the drainage system and cause inundation with asset loss. A final consequence is that the OSD become part of regular maintenance requiring intensive labour activities often in a confined space and subject to occupational health and safety provisions. Ultimately, this inadequacy will need to be solved driven by both environmental non-compliance and on going costs (Figs. 6.7, 6.8 and 6.9) shows an example of an SSFU, designed by the author.

Figures 6.10, 6.11, and 6.12 show some examples of on-site detention pits and tanks, which were not fitted with pre-treatment measures. Typically screens are blocked and high water level untreated discharge occurred in even moderate rainfall events as a result of blocked orifice plates.

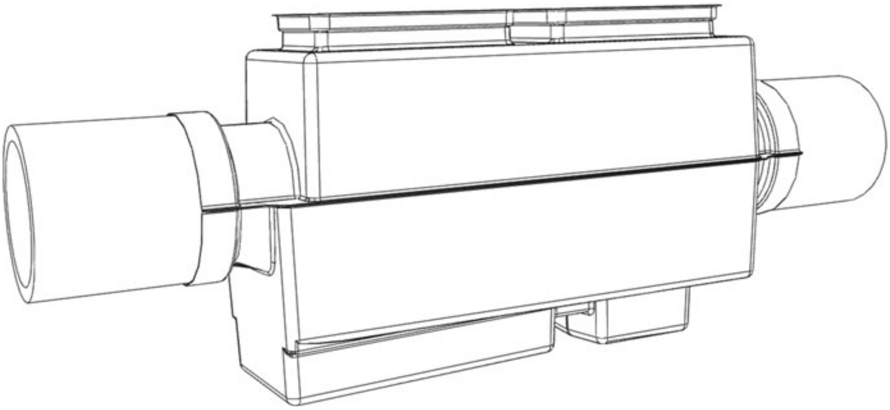


Fig. 6.7 Chamber including transition and processing cartridge housing

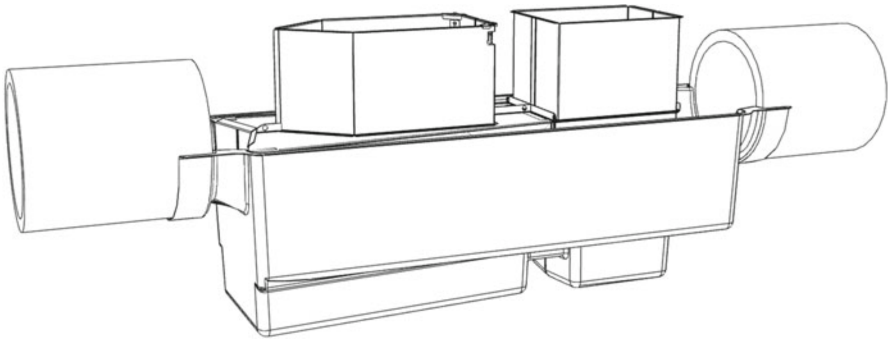


Fig. 6.8 Chamber *upper* removed exposing processing cartridge

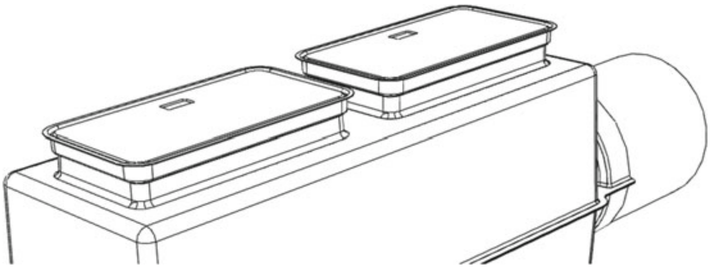


Fig. 6.9 Access available through lockable covers

There are two distinct OSD pre-treatment solutions. One is to install an SSFU in the pipe work prior to the OSD. The alternate is to integrate the SSFU processing cartridge into the OSD construction. The latter in most cases is the lower cost solution. If an open wetland is to be used as an OSD then pre-treatment is recommended (as discussed in the following section) with the addition of an overflow riser to prevent buoyant materials from being discharge during extreme rainfall events.

Fig. 6.10 This picture shows mesh screen in an open *top* detention pit, preventing flow through the orifice plate

Fig. 6.11 This picture shows mesh screen in an underground detention tank fully blocked, preventing design discharge

Fig. 6.12 This picture shows a mesh screen, which is unsecured to the walls of an underground detention tank with some of the trash collected whilst smaller materials were allowed to be released

Open detention basins can then become part of the site amenity as a permanent water feature, with a flow metering weir and allowance for a top water level increase during flood events. Restricted to flood mitigation and not a treatment measure, the open basin (pond) can be used to restore bio-diversity as an integral point of the development and avoid costly remediation required by a build-up of sediments, trash and litter.

6.5 Wetlands, Natural and Constructed

Both natural and constructed wetlands either fresh or saline are a transition between land and water and may hold surface water on a permanent or periodical basis. Some wetlands are basins that are designed to hold water whilst others may be designed to allow full or partial infiltration and may not be permanent water bodies. All forms of wetlands have a role in water quality improvement as well as being of environmental and social benefit.

In all configurations wetlands can deteriorate and are subject to collapse due to influents generated by urbanisation. Though litter traps may provide a partial solution for visible pollutants, the main cause of collapse is from the adverse impact of nutrients, silt and toxic substances many of which also include heavy metals.

The conclusion that can be drawn is that wetlands should not be used as a dumping ground for urban run-off with an expectation of self remediation. Wetlands should be regarded as a sensitive environment, which needs to be protected from the discharge of contaminants derived from urbanisation.

Avian botulism in pond birds is commonly reported in circumstances where there is a low oxygen content in the water. The botulism bacteria are common in many soils and thrive as oxygen levels deplete. Maggots also concentrate the toxins.

The cause of an anoxic condition or eutrophication (depletion of dissolved oxygen) is well documented. This often occurs when the rate of oxidation of organic matter by bacteria is greater than the supply of dissolved oxygen. Eutrophication is often caused by the inflow of phosphates present in detergents, fertilizers or sewage. These conditions are manifested by "algal blooms" visible as green slim in or on the water surface.

In conclusion, water entering wetlands should be of a similar quality to that which would have occurred before urbanisation. This therefore requires influent flows to be removed of harmful contaminants.

6.6 Broad Spectrum Treatment

The SSFU is designed and tested to remove a broad range of contaminants from the catchment run-off. Table 6.1 shows pollutant reductions expressed as a percentage for a range of contaminant groups. The table shows the generally required reduction targets as required by many authorities, alongside the potential reduction achievable if the SSFU is installed and serviced in accordance with best practice and preferably by a trained technician.

To achieve the full potential reduction performance, the design (treated) flow must be well defined so that contaminated run-off is treated and that the SSFU is located to take full advantage of the processes included within the SSFU.

In addition to the SSFU design performance, a managed inspection and service routine is required to ensure that captured materials are removed before these compromise the performance of the processes with the unit.

For critical applications where receiving waters are deemed sensitive, additional telemetry measures are available on request. These measures include water quality monitoring, performance logging and remote data transmission. These measures are custom designed to suite the specific needs of the local environment.

In summary a correctly specified, installed and serviced SSFU nominally returns run-off water quality to pre-urbanisation standards.

6.7 Design Performance

The development of the processes started with defining the contaminants, required to be removed by local environmental policy. It is noted that the current method of defining compliance is to publish a table of contaminants and then specify the reduction target as a percentage reduction (Refer Table 6.1). It is our view that absolute water quality targets consistent with the nature of receiving waters should be adopted. Basing discharge water quality on percentage reductions has the potential for under and over performance by STM's. Of greater potential, is that the performance of treatment devices is subject to misinterpretation. As an example the definition of suspended solids is not consistent and is also overshadowed by the term totally suspended solid (TSS), which can include particle sizes from 2.0 mm down to 8 μm for very fine silt. GPT's generally claim removal of suspended solids, however theses solids also have specific gravity greater than 2, which by definition is will not be suspended, unless in high flow turbid conditions. It also follows that materials of this density are sands and not associated with the attraction and transfer of chemicals.

Dempsey et al. (1993) found that the concentrations of heavy metals and total phosphorous (TP) were highest in particles between 250 and 74 μm in size. Walker and Wong (1999) compiled particle size grading from numerous catchments and charted that 20 % of particles by mass could be below 100 μm in size. The conclusion reached in determining the sediment removal aims was that particles as small as 20 μm need to be removed. This conclusion is supported by (ARQ) who observed that suspended solids in urban run-off typically occurs in the 1–50 μm size range.

Physical and chemical properties of contaminant groups were analysed to establish the removal process and retention mechanisms.

Table 6.1 shows a summary of the reduction targets currently adopted by Environmental and Local Government Authorities and the potential SSFU reduction levels which were established during performance testing and field sampling.

6.8 Process Design

The design and development of the processes included in the SSFU followed a series of disciplined steps that are briefly described in this section. The disclosure of further details are available to interested parties, but may be the subject to confidentiality as some of the process details are the subject of patent applications and on going research.

The first critical element in the design was an understanding of the relationship between catchment, contaminants, rainfall and water flow. This was described earlier as the treated (design) flow and establishes influent characteristics that must be dealt with in the design and operation of the SSFU.

In conjunction with treated flow the mobilisation of materials and the relationship between pipe depth, flow and velocity (Fig. 6.6) was studied and simulated. Contaminants of varying sizes and densities were tested to understand the mobilisation forces and reaction to flow patterns. After analysis, flow modelling and testing an in-line diversion was adopted as the most reliable orientation of the SSFU relative to the flow. Off-line diversion efficiency was sensitive to pipe gradient, flow velocities, weir shape and attack angles, therefore should only be used as a last resort.

During hydraulic modelling differential velocities across a pipe section (Fig. 6.6) generated unwanted turbulence within a receiving chamber. A transition was developed (Fig. 6.7), which reduced the differential velocity across the pipe section and eliminated turbulence, creating near laminar flow within the chamber. In-chamber velocities and flow patterns were also analysed and modelled to establish a self cleaning action at near zero differential cross screen pressure, eliminating the tendency for materials to adhere to screen surfaces. This modelling also included relating the in-chamber water flow factors to screen materials, orientation and types.

Trash and Litter design reduction was set at 100 %, on the basis that this group is generally buoyant and the blend of litter and packaging could not be separated. A buoyant materials chamber is provided which is one-way entry, which together with the modified flow patterns eliminates the possibility of draw back and re-mobilisation in circumstances where discharge maybe temporarily below water as in a tidal or detention application (Fig. 6.8).

Total Suspended Solids (TSS) design reduction was set at 90 % to reflect the understanding that particles are the prime carriers of nutrients, heavy metals and some hydrocarbons. Figure 6.1 is an illustration of a particle, which is approximately 40 μm in size. The particle appears as a flocculation of micro-particles, which creates a large surface area and extensive opportunity for chemical entrapment (as described earlier).

Background levels of Nitrogen are essential for ecosystem biota at certain concentrations. As a general rule, it is the level of nitrogen in the environment that limits plant growth in fresh water (Engineers Australia 2006), and therefore if concentrations are too low there may not be enough biological material to sustain the ecosystem. This nitrogen can enter waterways as nitrate, nitrite and ammonia, which are taken up within the aquatic community to maintain life. Nitrogen is a major component of proteins, hormones, chlorophyll, vitamins and enzymes essential for plant life, predominately in the production of plant and animal tissue.

This means that when decontaminating stormwater there must be some level of nitrogen that remains post treatment. The Australian Runoff Quality Guidelines (Engineers Australia 2006) cites a concentration of approximately 0.8 mg/L for land use classified as 'Forest', which would most likely represent pre-anthropogenic conditions, whereas research of untreated urban stormwater is recorded as 3.09 mg/L and therefore a reduction of up to 70 % may be required to return water to background concentrations.

Total Nitrogen (TN) design reduction was set at 70 % on the above basis and further supported by numerous papers that together with our own research, alerts that TN in urban run-off has been recorded up to several times greater than the N necessary for biological sustenance in receiving aquatic environments. In peri-urban areas most of the N, which impacts on receiving waters is bonded to particles from fertilizers, wastewater and many other products.

To accomplish the reduction particle sizes to below 20 μm are removed by the combined action of screening and if necessary tertiary media. Nutrients promote growth of aquatic plant life including floating macrophytes and in large concentrations produce algal blooms on the surface. With an increase in nutrients, algal growth becomes excessive often resulting in the production of toxins (refer comments earlier).

Total Phosphorus (TP) design reduction was set at 80 % on the basis that P in water is a trigger for alga in freshwater. P compounds are slow to dissolve and therefore many accumulate in sediment. Furthermore, the availability of P in the pre-urban environment is low and released from mineral bonded conditions. Removal of TSS also removes the soil bonded P allowing low levels of dissolved background P to remain.

Hydrocarbons in run-off water have many adverse impacts on receiving waters due to the extent and complex nature of additives. Reduction was set at 90 %. They appear as a scum, are emulsified and also bonded to particles. The method developed is to coalesce micro-globules that attract into larger globules, and then apply a range of capture methods to suit the nature of the catchment area. In low hydrocarbon concentration catchments, such as residential developments a hydrophobic media is utilised. Whereas for potentially high hydrocarbon concentrations such as infrastructure applications a non-return separation process has been developed which can be monitored and purged at a higher frequency than the main service interval. If hydrocarbon spills are a potential, then a dry sump to act as a bund can also be introduced.

Heavy metals are included in the target contaminants and are removed by virtue of their attachment to TSS. Reduction was set at 50 % and testing indications higher removal rates are achievable.

Turbidity is also reduced by a large reduction of TSS. In sensitive receiving water conditions an additional tertiary media is added to boost reduction by a further 50 %.

All of these processes are housed in a processing cartridge (Fig. 6.8).

6.9 The Final Device

The apparatus developed is termed a Stormwater Screening and Filtration Unit (SSFU).

The following design features are included in the SSFU in addition to the contaminant removal design targets noted earlier. The SSFU construction is compact and light weight. Installation is by on-site equipment and can be installed as part of a new drainage installation or retrofitted. Pipe adaptors are provided for varying pipes sizes. Variable risers are provided to match inverts. Inspection and service covers (Fig. 6.9) are light weight and lockable. Servicing intervals are calculated on the basis of catchment area load with nominal service intervals of at least 12 months.

Catchment loads vary with catchment nature and type. Process and containment recommendations are provided to designers to optimise water quality, installation and service costs.

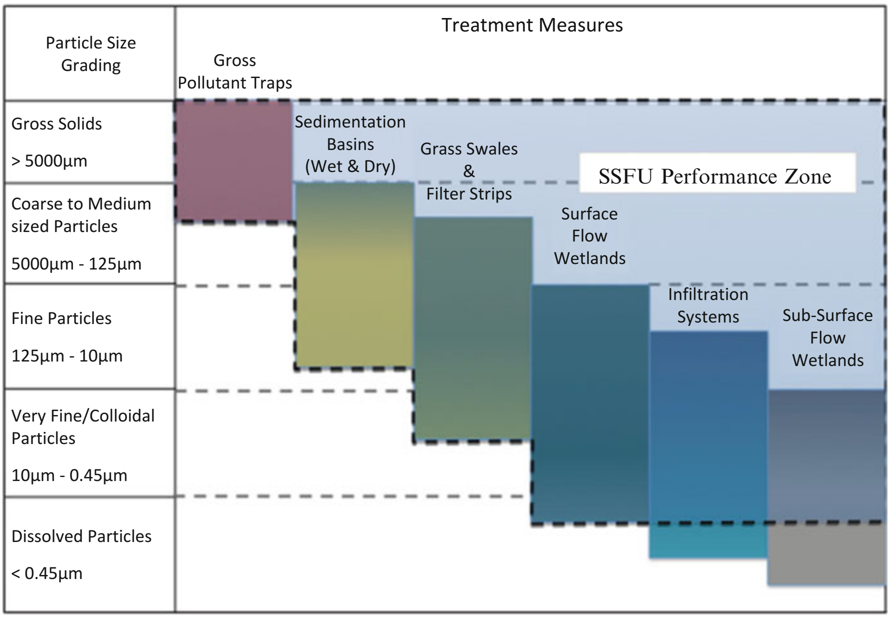
SSFU's are available in different sizes, that are selected based on treated flow, gross flow, catchment size, catchment characteristics (that define potential load) and the sensitivity of receiving waters.

6.10 Cost Effectiveness

Table 6.2 shows the performance zone of the SSFU as an overlay to the recommended treatment measures recommended in the Engineers Australia (2006). This table overlay graphically shows how one SSFU replaces the need for a treatment train, which may include a number of measures in sequence in order to remove urban generated contaminants. In some cases when used as a pre-treatment to wetlands, the capital cost may be slightly reduced with the main benefit arising from the amenity being self sustaining and not requiring remediation on regular intervals.

Life cycle analysis shows that compliance with contaminant reduction targets can be achieved in many cases at 80 % lower cost than current treatment train measures. Installation costs are typically less than 2 % of the development capital works, with service costs consistent with monthly landscaping maintenance.

Table 6.2 Figure 1.3 in Engineers Australia (2006) overlain with SSFU performance zone



6.11 Conclusion

The installation of SSFU's distributed within a watershed in both Peri Urban and Urban areas could prevent an increase of contaminant load into the receiving water and associated ecosystem, allowing time for nature or assisted remediation to take place and restore the water health to a long term sustainable level.

References

Abramovitz J (1996) Imperiled waters, impoverished future: the decline of freshwater ecosystems, Worldwatch paper no. 128. Worldwatch Institute, Washington, DC

Allison RA, Walker TA, Chiew FHS, O'Neill IC, McMahon TA (1998) From roads to rivers: gross p[ollutant removal from urban waterways. CRC for Catchment Hydrology, Clayton. http://www.catchment.crc.org.au/pdfs/technical199806pt1.pdf; http://www.catchment.crc.org.au/pdfs/technical199806pt2.pdf; http://www.catchment.crc.org.au/pdfs/technical199806pt3.pdf; http://www.catchment.crc.org.au/pdfs/technical199806pt4.pdf. Accessed 14 Jan 2010

Allison L, Tierney J, Lundy K, Mackay S, Tchen T, Wong P (2002) The value of water: inquiry into Australia's managemnt of urban water. The Parliamant of the Commonwealth of Australia, Canberra. Retrieved 16 March 2010, from http://www.aph.gov.au/senate/committee/ecita_ctte/completed_inquiries/2002-04/water/report/report.pdf

Allison RH, Wenger SJ, Fletcher TD, Walsh CJ, Ladson AR, Shuster WD, Thurston HW, Brown RR (2008) Impediments and solutions to sustainable, watershed-scale urban stormwater management: lessons from Australia and the United States. Environ Manag 42:344–359

Bakel J (2006) Impact of WFD on agriculture in Netherlands and possible effects-specific hydrological measures: the Dutch approach'. J Water Land Dev 10:45–53

Bertrand-Krajewski J-L, Chebbo G, Saget A (1997) Distribution of pollutant mass vs volume in stormwater discharges and the first flush phenomenon. Water Res J Int Water Assoc (IWA) 32(8):2249–2562

Dempsey BA, Tai YL, Harrison SG (1993) Mobilisation and removal of contaminants associated with urban dust and dirt. Water Sci Technol 28(3-5):225–230

Engineers Australia (2006) In: Wong TH (ed) Australian runoff quality: a guide to water sensitive urban design. Engineers Australia, Canberra. ISBN ISBN 0 85825 852 8

Everingham S (2007) Wild ride: the rise and fall of Cobb & Co. In: chapter 1. Penguin Books (Australia), Camberwell

Fraser DJ (1989) Sydney, from settlement to city: an engineering history of Sydney. Engineers Australia, Sydney

Guo F, Chen KK, Jiang GH (2011) Characteristic of ammonia nitrogen absorption on karst underground river sediments'. NCBI 32(5):1285–1291

Lefort R (1996) Down to the last drop. UNESCO Sources 84:7
O'Loughlin GG, Joliffe IB (1987) Historical overview of urban stormwater drainage hydraulics, Conference on hydraulics in civil engineering preprints of papers NCP no 87/14. Victoria Institution of Engineers, Melbourne, pp 82–87
O'Loughlin GG, Robinson DK (1999) The coming quality, the recognitionof urban stormwater pollution in Australia. In: Joliffe BI, Ball EJ (eds) Proceedings of the 8th international conference on urban storm drainage. Sydney Hilton Hotel, Sydney, pp 1132–1141
Pitt R, Field R, Lalor M, Brown M (1995) Urban stormwater toxic pollutants; assessment, sources and treatability. Source: Water Environ Res 67(3):260–275
Pratten A (2009) The State of Sydneys' waterways, telephone interview with the managing director of Stormwater Systems on 25 February 2009. J. Madhani, Sydney
Rodriguez JP, Achleitner S, Moderl M, Rauch W, Maksimovic C, McIntyre N, Diaz-Granados MA, Rodriguez MS (2010) Sediment and pollutant load modeling using an integrated urban drainage modeling toolbox: an application of city drain. Water Sci Technol-WST, IWA 61(9):2273–2282
Sciorintino JA, Ravikumar R (1999) Fishery Harbour manual on the prevention of pollution – Bay of Bengal
Walker T, Wong THF (1999) Effectiveness of street sweeping for stormwater pollution control. Technical report 99/8, Cooperative Research Centre for Catchment Hydrology

Part III
Peri-Urban Culture and Socio-economy

Chapter 7
Socio-Economy of Peri-Urban Areas: The Case of Lisbon Metropolitan Area

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Abstract The chapter presents typologies of peri-urban areas of Lisbon Metropolitan Area (LMA) regarding social and economic dimensions. These typologies are the outcome of a trans-disciplinary research developed by the project PERI-URBAN involving different Portuguese universities, crossing academic fields and integrating the knowledge of stakeholders from diverse institutional and territorial (local and regional) backgrounds. By bridging science and society, trans-disciplinarity allows the translation of knowledge acquired in research into useful and relevant information for planners and decision-makers. The analysis reveals diverse socioeconomic realities demanding different and specific political approaches envisaging sustainable peri-urban territories in a changing world. The socioeconomy of peri-urban areas considers identities and lifestyle issues (e.g., age, family patterns, living and working conditions) and economic characteristics (e.g., main economic activities, economic organisation and structuring, attractiveness). The influence of a metropolitan area is expressed by continuing investments in peripheral areas that offer sources of labour and natural resources such as land. The presence of industries, services, logistics and distribution platforms, enterprises, housing, big store chains, etc., constitutes manifestations of this realm. Plus, and in parallel, the coexistence of a rural-agriculture matrix establishes a hybrid territory where distinct activities co-exist defining distinct degrees of specialisation/diversity of the economic tissue.

Keywords Socio-economy • Peri-urban areas • Lisbon metropolitan area • Trans-disciplinarity • Stakeholders

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7.1 Introduction

The characterisation of peri-urban areas of LMA within Peri-Urban project considered the following dimensions: economy, society, environment, mobility, and land cover. The chapter presents the results obtained in the design of typologies for social and economic dimensions. The conception of peri-urban as an interface of social and territorial metamorphosis, imminently fragmented, and composed of changing communities with distinct identities, is translated in a geographic image of attributes and trends, that is, typologies of LMA peri-urban areas for social and economic realities. The chapter is structured as follows: presentation of a peri-urban project, its main goals and methodological options; characterisation of LMA; identification of the indicators used in the design of typologies; presentation of the typologies of LMA for social and economic dimensions; concluding remarks.

7.2 Peri-Urban Project: Goals and Methodology

Peri-urban areas encompass both characteristics of the urban and rural world and they are located somewhere in-between the urban core and the rural landscape. They have been traditionally approached from an urban planning perspective as ground for urban sprawl and location of regional and trans-regional infrastructures. Several European key policy documents (e.g., Lisbon Strategy, European Spatial Development Perspective, Territorial Agenda, Leipzig Charter, and European Landscape Convention) have been fostering the understanding of sustainable urban development as an increased integration of economic prosperity, social equity and cohesion, and environmental protection, as well as the strengthening of rural-urban relationships. The strategic role of peri-urban areas must be understood within the current societal challenges like, for instance, climatic changes and food security concerns.

Unlike urban areas, which were the object of in-depth research for a long time and from multiple disciplinary perspectives, peri-urban areas have not deserved much attention until more recently. Nevertheless, research and policy initiatives, as FP6 PLUREL Project or the PURPLE network, have put forward the case that peri-urban areas in Europe might occupy nowadays the same amount of land as consolidated urban areas, concluding that these have become a "new" kind of space that needs more targeted policies and it should be treated as a "spatial system in its own right". PURPLE (Peri-urban Regions Platform Europe) presented *The Peri-Urban Charter*. According to the Charter, peri-urban means: "a mix of urban and rural characteristics which co-exist and interact in the same territory; a wide spectrum of opportunities and urban/rural lifestyle choices for inhabitants economic diversity and intellectual capital; food production close to large populations with a range of well-established land-based services – agriculture, horticulture, forestry; infrastructure and communication – transport links, energy and other essential resources and services including fresh water for urban and peri-urban inhabitants; valued landscapes and open space for recreation and health, enjoyment of countryside, leisure and sport". Portugal was not integrated in the mentioned initiatives focused on peri-urban territories. It was precisely this absence that justifies the Portuguese Peri-urban project, which has as a main goal the assessment of the potential of peri-urban areas of LMA to meet future challenges for sustainable development in a changing world. To achieve this goal the project integrates several steps including the definition of peri-urban areas through the construction of LMA multi-dimensional typologies. These allow the delimitations of areas with similar characteristics and, therefore, the contribution to the design of public policies dedicated to these territorial contexts. The concern with the translation of knowledge acquired in research developed in the project into useful and relevant information for planners and decision-makers justifies the adoption of a methodological approach that bridges science and society (Ramos et al. 2013) through a transdisciplinary perspective.

The integration of stakeholders knowledge and proposals, allows a more holistic and systemic view and contextualises knowledge production: the challenges related with sustainability need to be envisaged through the integration of societal stakeholders such as the private sector and the broader public as well as diverse scientific disciplines into the process of generating knowledge" (Clark et al. 2005 in Luks et al. 2007: 420, *apud* Ramos et al. 2013). The crossing views of diverse and territory based stakeholders and wider public interests provide a more complete and comprehensive understanding natures of peri-urban areas. The integration of the expert (team) scientific knowledge with non-scientific (stakeholders) knowledge into the project regarding the (i) definition of peri-urban areas and (ii) construction of typologies, was made through participatory methodologies in different moments (Ramos et al. 2013). The group of stakeholders was constructed gathering people from different areas with influence on the management of the landscape in the study. These actors had the opportunity to contribute to the definition of peri-urban areas; to identify the relevant indicators to the description of typologies and to their validation. These indicators where subsequently used in statistical analysis that made possible the design of a range of territorial typologies for LMA.

7.3 Lisbon Metropolitan Area

LMA integrates the capital city of Portugal (Lisbon) and corresponds to an association of 18 municipalities (Alcochete, Almada, Amadora, Barreiro, Cascais, Lisboa, Loures, Mafra, Moita, Montijo, Odivelas, Oeiras, Palmela, Sesimbra, Setúbal, Seixal, Sintra, and Vila Franca de Xira) (Fig. 7.1). With a population of 2,8 million inhabitants (26 % of the total national), there was a demographic decrease of its center during the last years related with a displacement of population to boarder municipalities and a consequent daily movement for working reasons. LMA has a positive demographic trend with a multicultural expression, which is also associated with immigration flows. In fact, and after the 'industrial' urbanisation process until

Fig. 7.1 Lisbon Metropolitan Area (LMA)

the 1960', with flows comings essentially from rural areas, the immigration dynamic of the 1970s and the 1980s is mainly related to the population of the ex-Portuguese colonies, which occupied the first peripheral crown of Lisbon. According to a recent characterisation of LMA with planning purposes (Regional Coordination Commission of Lisbon and Tagus Valley [CCDR]), this is a polarised territorial entity with an influence that exceeds its administrative borders, explained by, and among other factors, the improvement of transport infrastructures (CCDR 2009: 33). LMA is the location of multinational enterprises and several industrial activities, especially in the South bank of Tagus River. It is the most competitive economic center of the country (38.6 % of National GDP) (CML 2012) with global integration and a strong presence in international markets. This is also a territory with problems like the lack of land use planning, urban and landscape disqualification, mobility, environmental risks, social exclusion and inequality (Figs. 7.2 and 7.3).

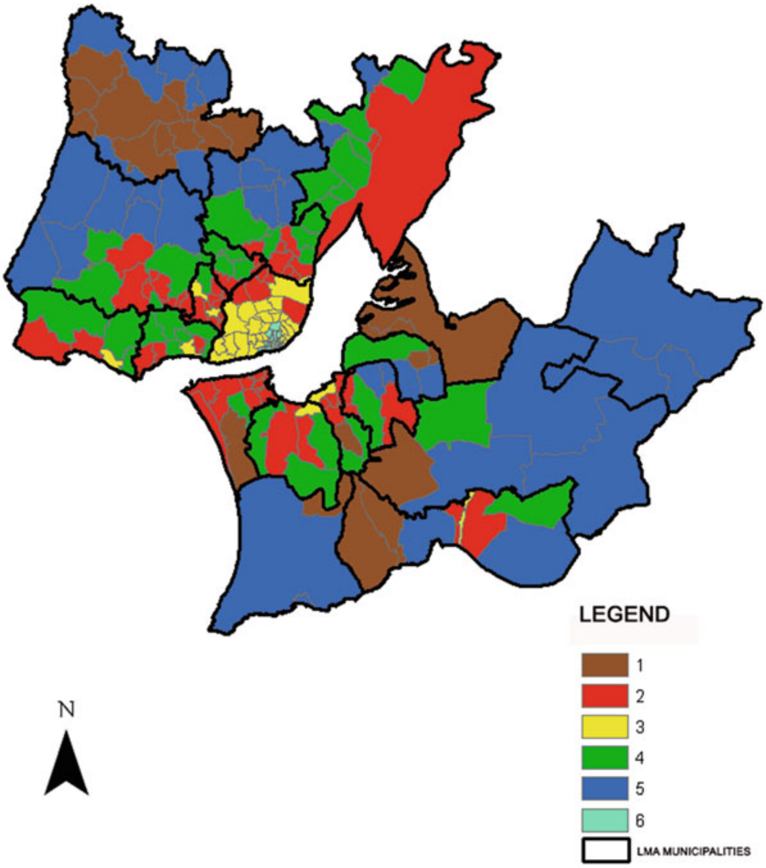

Fig. 7.2 LMA – social typologies

Social problems were aggravated with the current economic crisis and increase of the unemployment rate. Positively, LMA presents environmental and ecological amenities related to the presence of coastal areas (Atlantic Ocean and two rivers – Tagus and Sado), and other places of important ecological value (e.g. Natura 2000 places, natural parks like Sintra-Cascais and Arrabida, Natural Reserves of Tagus and Sado Estuaries, the presence of rural areas with high productive land resources). LMA has also important subterranean water resources: the aquifers of Tagus and Sado basins represent 53 % of the water reserves of Portuguese Continent and are crucial to the development of agro-forestry sector which occupy 57 % of LMA area. The main planning instrument of LMA is the PROTAML (Regional Plan of Territory Planning), a Regional Plan that develops the goals and guidelines of National Program of Territory Planning Policy. The Municipal Plans of Territorial Planning constitute the local instrument of territory planning in Portugal.

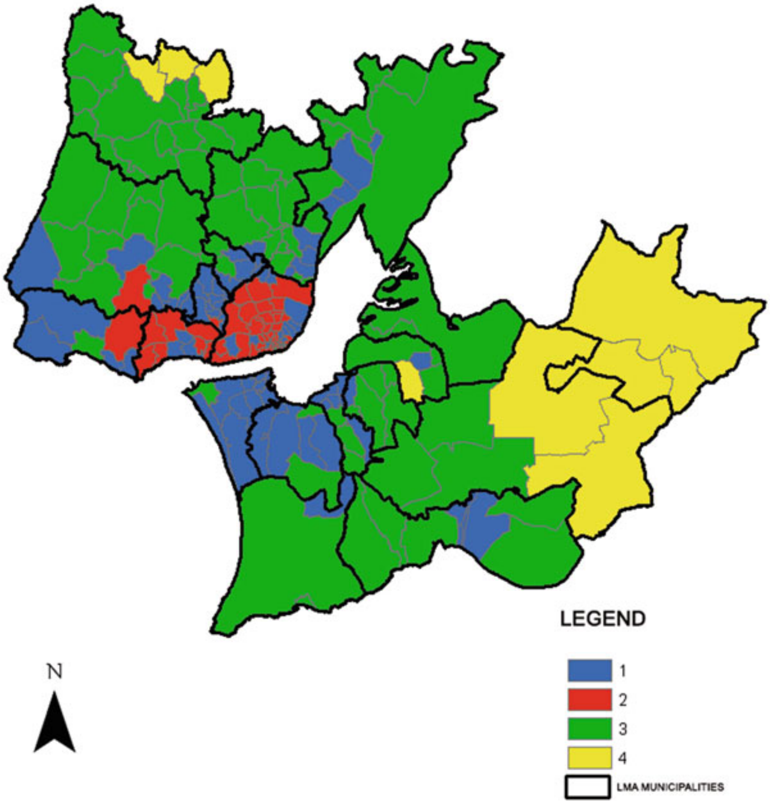

Fig. 7.3 LMA – economic typologies

7.4 Dimensions and Indicators for the Design of Peri-Urban Typologies

Instead of defining in advance a set of criteria to identify peri-urban landscapes, the project formulated a conceptual framework broad enough to accommodate distinct, and sometimes opposite, perspectives and characteristics about what can be considered as peri-urban spaces. This involved an intensive selection of the appropriate dimensions and indicators of peri-urban areas. This effort was done using a transdisciplinary approach bridging scientific and non-scientific knowledge through deeply participated working sessions. One of the major innovations of the project was the bond between spatial based and socio-economic indicators allowing a more inter-connected comprehension of facts and dynamics. Using 83 indicators aggregated in 5 distinct dimensions (economic, social, environment, mobility and land cover) it was possible to identify a set of typologies that represent the variety and dynamic of peri-urban areas.

Table 7.1 Indicators used in social characterisation of LMA peri-urban territories

Variation rate of resident population (2001–2011)
Variation in ageing index (2001–2011)
Variation in rejuvenation index (2001–2011)
New residents (diverse indicators) (in relation to 2005)
Population born in the parish of residence
Location coefficient regarding different family types
Variation of single-family houses (2001–2011)
Secondary housing rate (2011)
Variation in secondary housing rate (2001–2011)
Land-use changes (2000–2006)
% of 'Social Inclusive Income' (RSI) beneficiaries
Variation of population with higher education (2011–2001)
Average municipal voters (2005–2009)

7.4.1 Social Characterisation: In Between Identity, Territorial Recomposition and Community Relations

Considering peri-urban spaces as 'in transition' and strongly marked by social and territorial recomposition, there was an option for a 'flows-based' approach in order to address the 'processes of rapid economic, sociological, institutional, and environmental change' that occur in these territories (Marshall et al. 2009). Understanding inherent social dynamics in LAM, leaded us to the identification of trends/characteristics through the use of static and dynamic indicators. This approach made possible the distinction between urban centre and peri-urban territory, but also the identification of types of peri-urban spaces with diverse social character. Considering peri-urban as an interface of social/territorial metamorphosis, imminently 'fragmented', and composed of changing communities with distinct identities, it was necessary to translate the fragmented territorial and social mosaic (as it's inner 'movement') in a geographic image of attributes and trends. Portuguese Census (2001 and 2011) information enabled the characterisation in social terms (Table 7.1) considering the following dimensions: population growth and composition; residential mobility and social diversity; family types; types of housing; territorial reconfiguration; spatial inequalities; community relations.

7.4.2 Economic Characterisation: In Between Local, Regional and Global Relations

Peri-urban areas are characterised by complementary relations between urban and rural systems. This complementarity results from the flow of products, information and people as from the connections between sectors related to agriculture, manufacturing, and services (Pradoto 2012). Peri-urban areas are also strongly influenced by

Table 7.2 Indicators used in economic characterisation of LMA peri-urban territories

Specialisation of employment (2011)
Specialisation of companies
Diversification of employment
Diversification of employment
Diversification of companies
Location coefficient of logistic and distribution
Significance of agro industrial sector
Average size of agricultural farm (ha)
Proportion of farmers under 65 years
Proportion of pluriactivity in agriculture
Average size of agricultural farms
Importance of 'caixa agrícola' (bank specialised in agricultural sector) dependencies in relation to total (other) bank branches
Average value of housing supply (€/m^2)
Index of corporate rent – warehouse (industry) – (€/m^2) (confidential values)

the interaction of local/regional/global dynamics, and local anchoring processes of global dynamics. The influence of a metropolitan area is expressed by continued investments in peripheral areas as they correspond to sources of labour and land. The presence of industries, services, logistics, distribution platforms, services, real estate, big chain stores etc. constitutes the physical manifestation of this realm. This complex set of conditions defines distinct degrees of specialisation and diversity of the economic tissue and different relations with the territory. The economic characterisation of LMA peri-urban areas considered the following analytical dimensions: specialisation and diversity of economic activities; presence of agriculture, agrobusiness, and other specific sectors (e.g., logistics and distribution); types of agroindustrial explorations, and real estate attractiveness. Table 7.2 presents the indicators selected envisaging the design of economic typologies.

7.4.3 Typologies of LMA Peri-Urban Areas

The previous indicators were analysed through cluster analysis. It was used a 'principal component' analysis by dimension. Then four of the most significant indicators were chosen by dimension, and, finally, a cluster analysis was applied. The original group of 83 indicators was reduced to 24, which allowed the identification of 7 clusters. The result was the design of typologies of peri-urban areas of LMA in social and economic terms. Each cluster represents one specific typology. In social terms six clusters (clusters 3 and 6 were not considered because they correspond to urban centres) were identified which clearly demonstrates a high fragmented territory and important processes of social recomposition. Demographic change, resident population balance, as well as age structure composition can function as explanatory elements of these spaces where it is normally verified by the growth of population, explained either by demand of rural population (proximity to urban centre) or by demand of urban population. In fact, processes related to attractiveness (e.g., lower prices of houses) also induce a tendency of population growth and regeneration in these territories.

As determinant factors for the differences achieved, cluster 1 is mainly characterised by a tendency of population growth and dynamism matching high values of land use change, the highest values of secondary houses and the highest values of couples with children and negative values in ageing variation index. This is the most dynamic cluster providing its capability to attract new residents using the great improvement of accessibilities and the existence of new residential models, namely single-family dwellings. The new inhabitants of peri-urban areas, namely from the medium social class, are driven by the proximity of urban centre and quality of life; cluster 2 presents a stagnation with low capacity to attract new residents and a high level of ageing. Demonstrating simultaneously a large presence of single-parent families. In fact, this cluster shows the decline of territories in geographical continuity of the metropolis centre and who have participated in the first phase of the metropolisation process; cluster 4 is characterised by a loss of importance on secondary housing simultaneous with a relative population growth (2001–2011). It presents high values for families with children and single-family nuclei and a low participation in municipal elections.

Extensive bibliography draws attention on the importance of single-family houses in peri-urban areas, which derives not only from an existent 'rural model matrix' but also from the new demand of space, comfort, and quality driven by 'new comers' (Berger 2004). According to Charmes (2011), peri-urban inhabitants seek to 'consume and enjoy a certain quality of life' rather than developing a political attachment to the community in which they live. Generally, the analysis of social and demographic dynamics of these three clusters shows a trend of population displacement towards more peripheral areas of LMA; cluster 5 corresponds to the most rural municipalities, with a lower proportion of new residents and high percentage of resident population born in these municipalities. It presents low values for variation of population with higher education (2001–2011) and high values for couples without children and an important presence of secondary houses and single-family houses. This is the cluster that shows fewer processes of social and territorial recomposition, but probably one that may suffer a strong economic and social pressure for changing in the future.

Four clusters were identified concerning economic aspects of LMA peri-urban areas, with variations in the mix of economic activities and, thus, distinct degrees of diversity and character. In fact, measuring the specialisation of economic activities allows the recognition of the 'fragmented economic mosaic' of peri-urban areas of LMA. Furthermore, exploiting certain indicators we can identify the specific activities that are present in each specific space. Cluster 1 is determined by the diversification of the economic base in relation to employment and enterprises, exhibits low presence of companies and jobs related to agricultural activity. The price of housing has a positive valuation. However, requests for construction are low; cluster 2 presents some level of specialisation of the economic base in relation to employment. It is characterised by a small presence of economic sectors such as logistics and distribution, agricultural or agro-industrial and presents a positive tendency in house valuations, lower industrial rents and few requests for construction. Cluster 3 expresses a relative degree of specialisation (employment and enterprises) probably induced by the importance of logistics/distribution sector, but also by a relative dynamic of agro-industrial and agricultural sector. It also presents low values of housing prices and high rental values of industrial facilities. Cluster 4 is characterised by high levels of economic specialisation in agriculture (employment and enterprises) based on the higher values for several indicators. This cluster also presents the lowest average price of real estate supply and a high number of requests for construction. The presence and the role of agriculture in peri-urban areas should be stressed. Agriculture still represents the main land use of peri-urban areas, despite its decline in economic terms. The process of industrialisation, the improvement of transport infrastructures and technology involved in storage of agricultural products, concur to this decline. However, agricultural activities in peri-urban areas reveal also a changing nature related, for instance, with pluriactivity, the increase of subsistence farming and the presence of agro-food industry. Therefore, peri-urban areas are fundamental in the reflection about food security and sustainability of metropolitan territories.

7.5 Conclusions

The presentation of peri-urban typologies related with the social and economic reality of LMA results from the research within the peri-urban project. The absence of Mediterranean territories from the European research about peri-urban areas was one of the driving forces of the project. LMA occupies a particular geographic situation: the Tagus River, two river estuaries, a political, administrative and economic centre, the presence of important natural resources and ecological values, the cultural diversity, important social and demographic dynamics. These aspects contribute to the existence of a peri-urban socioeconomic specific situation, characterised by a diversification of activities and social practices, but also by a diversity of territorial dynamics, which appeals to different forms of intervention regarding present and future challenges of metropolitan areas including peri-urban areas. The design of typologies with stakeholders participation allows the perception of this diversity and may be an important instrument to support more coherent and realistic decision-making regarding the enhancement of the sustainability of a territory whose evolutionary pathways are strongly conditioned by planning, governance mechanisms, and territorially management policies, as well as by general driving forces of change in-between local and global processes.

References

Berger M (2004) Les Périurbains de Paris. De la ville dense à la métropole éclatée, CNRS Éditions, Espaces et Milieux, Paris

CCDR (2009) Alterações ao PROTAML. Documento de Trabalho, Lisboa

Charmes E (2011) La Ville Émitiée. Essai sur la clubbisation de la vie urbaine. La Ville en Débat, PUF, Collection, Lyon

Clark WC et al (2005) Science for global sustainability: toward a new paradigm. CID Working Paper, vol 120. Harvard University, Cambridge, MA

CML (2012) Biodiversidade na Cidade de Lisboa: uma estratégia para 2020. CML, Lisboa

Luks F et al (2007) Transdisciplinarity for social learning? The contribution of the German socio-ecological research initiative to sustainability governance. Ecol Econ 63:418–426

Marshall F, Waldman L, Macgregor H, Mehta L, Randhawa P (2009) On the edge of sustainability: perspectives on peri-urban dynamics, STEPS working paper 35, Brighton, 4–6pp

Peri-Urban: peri-urban areas facing sustainability challenges: scenario development in the Metropolitan Area of Lisbon [PTDC/AUR-AQI/117305/2010]

Pradoto W (2012) Development patterns and social economic transformation in peri-urban area. Univerlagtuberlin, Berlin, pp 24–26

PURPLE (peri-urban regions platform Europe) The peri-urban charter

Ramos I, Ferreiro MF, Colaço C, Santos S (2013) Peri-urban landscapes in metropolitan areas: using transdisciplinary research to move towards an improved conceptual and geographical understanding. AESOP-ACSP Joint Congress, Dublin

Chapter 8
Changing Economic Scenario of the Peri-Urban Area of Udaipur City, India

P.S. Rao, Hari Singh, and R.C. Purohit

Abstract The demographic data of the last few decades revealed an increasing tendency of urbanisation in many states in India, including Rajasthan. The rural:urban ratio of the population which remained 80:20 in 1971 changed to 69:31 in 2011. The high growth rate of the population in urban areas increased the urban demand for agricultural commodities on one hand and widened the demand for land for the construction of houses, roads and other civil amenities on the other hand. With the expansion of urban areas, the adjoining rural areas are changed to peri-urban in terms of facilities, amenities and lifestyle. Evidently, there is a visible tremendous expansion in the value addition of land in the peri-urban area of the city of Udaipur. The present study is aimed to ascertain the changing scenario of land utilisation, change in farming system, and composition of household income in peri-urban areas.

The study revealed that urban coverage in Udaipur has increased from 17 km^2 in 1946 to 221 km^2 in 2011, while the density of population in the city area has been found to decline from 4347 persons per km^2 in 1946 to 3773 persons per km^2 in 2011. This is because more than 25 % plots in the urban limit are left idle after the conversion of land for residential purposes, which are owned by the people only for value addition and protected by boundary walls. This area is neither used for construction of houses nor for crop production. Large numbers of small land holders residing in the periphery of urban areas generally sold their land and purchased land 40–50 km away from the city areas. The study further revealed that farmers who partially sold their land in peri-urban areas of the city are mostly cultivating vegetables and dairy enterprises on their remaining holdings. These farmers are getting 446 days of employment and Rs. 3.52 lacs as income per year from both the enterprises. The farmers who did not sell their land area at all are getting 694 days

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employment and Rs. 4.72 lacs as income per year, while farmers who sold their total land area for residential purposes to the urban people have their income reduced up to Rs. 1.47 lacs and are getting negligible employment.

Keywords Peri-urban area • Value addition • Crop production • Vegetable farming • Employment days

8.1 Introduction

A demographic census of India is carried out every 10 years and the last census was held in 2011. The demographic data of the last few decades revealed an increasing tendency of urbanisation in many states, including Rajasthan. The rural:urban ratio of population which remained 80:20 in 1971 had changed to 69:31 in 2011. The high growth rate of population in urban areas has increased the urban demand for agricultural commodities on one side and widened the demand for land for the construction of houses, roads and other civil amenities in urban areas on the other side. With the expansion of urban areas on all sides of the cities the rural areas adjoining them were changed to peri-urban in terms of facilities, amenities and lifestyle. The land value in such areas has gone up very high. The large demand for highly perishable commodities like vegetables and milk in urban areas and also the expanding need for residential homes generated mixed responses to the census in peri-urban areas in most parts of the state. People residing within the periphery of city areas have been changing their source of income and making great changes in their farming systems. Udaipur city, being an educational hub as well as a tourist centre of global importance, resulted in the migration of a large number of people not only from nearby areas of Udaipur but from other parts of Rajasthan as well as from other states of the country. Evidently, there is a visible expansion in peri-urban areas in the city of Udaipur. The present study is aimed to (i) ascertain the changing scenario of land utilisation in peri-urban areas, (ii) ascertain the change in the farming system in peri-urban areas, and (iii) ascertain the level and composition of household income in peri-urban areas.

8.2 Methodology

It is stated that land beyond the 15 km periphery of the Udaipur Nagar Nigam area is identified as peri-urban (Socio- Economic Census-2012 of Udaipur). Udaipur city and its nearby areas fall under Girwa tehsil in which 48 panchayats exist. Out of the 48 panchayats, 16 panchayats are falling under the peri-urban area of Udaipur. Out of those 16 panchayats, 6 panchayats have been selected on the basis of six major entry routes to Udaipur city. These routes are: on the east side Debari Panchayat, on the south side Titardi Panchayat, on the south west side Balicha Panchayat, on the north side Badgaon and Bhuwana Panchayat, and on the west side Sisarma Panchayat. They have been selected to ascertain the land use pattern, their level of income and cropping patterns. For this purpose two categories of farmers have been studied, such as (i) farmers who have sold their total land, and (ii) farmers who have not sold their land at all. Six farmers from each village, three farmers belonging to each category, were selected randomly. In all 36 farmers from the study area were selected randomly in which 18 farmers from each group have been selected to ascertain their income and employment through their land utilisation pattern.

8.3 Results

There are ten tehsils holding the whole district of Udaipur. The district's headquarters and city of Udaipur fall in the Girwa tehsil of Udaipur district. All 48 village panchayats are located in these tehsils of the district. These panchayats are located within 100 km from Udaipur. A list of the total number of panchayats existing in the Girwa tehsil adjoining Udaipur city is given in Table 8.1. These panchayats are in the close proximity to urban areas where all facilities are accessible to the area. However, these do not come under the municipal area of the Udaipur. The Urban Improvement Trust is acquiring the area for residential purposes, where the independent identity of the panchayat still exists.

8.3.1 Land Use Patterns and Urbanisation Trends

The land use patterns in the Udaipur district at two different periods of times is shown in Table 8.2. It clearly indicates that only 16.50 % of the area was not available for cultivation in the Udaipur district of Rajasthan in 1976–1977 which increased up to 32.42 % in 2006–2007. Out of the total geographical area only 15.58 % area is shown as net sown area in 1976–1977, with an increase to 18.38 %

Table 8.1 List of Girwa Tehsil Panchayats adjoining Udaipur city

S. No.	Name of Panchayat	Tehsil	S. No.	Name of Panchayat	Tehsil
1	Dakan Kotra	Girwa	9	Bhuwana	Girwa
2	Debari	Girwa	10	Shobhagpura	Girwa
3	Gudli	Girwa	11	Loyara	Girwa
4	Kaladwas	Girwa	12	Badi	Girwa
5	Kanpur	Girwa	13	Balicha	Girwa
6	Lakadwas	Girwa	14	Kavita	Girwa
7	Savina	Girwa	15	Bedla	Girwa
8	Titardi	Girwa	16	Badgoan	Girwa

Table 8.2 Land use pattern of Udaipur district (area in 000' ha)

S. No.	Particulars	(1976–1977)	(2006–2007)
1.	Reporting area for land utilization purpose	1917.20 (100.00)	1917.20 (100.00)
2.	Forest area	471.09 (24.57)	439.20 (22.91)
3.	Area not available for cultivation	316.32 (16.50)	621.60 (32.42)
4.	Other uncultivated land (permanent pasture and misc. Uses)	92.75 (4.84)	149.48 (7.80)
5.	Land area excluding fallow land (cultivable waste land)	180.55 (9.42)	245.69 (12.82)
6.	Fallow land	96.51 (5.03)	108.87 (5.36)
	(i) Fallow land other current fallow	40.70 (2.12)	90.15 (4.70)
	(ii) Current fallow	55.81 (2.91)	18.72 (00.98)
7.	Net area sown	298.61 (15.58)	352.30 (18.38)
8.	Total cropped area	402.05 (20.57)	497.03 (25.92)
9.	Area sown more than once	103.44 (5.40)	144.73 (7.55)

Numbers in parentheses indicates percentage to geographical area

Table 8.3 Trend of urbanization in India, 1951–2001

Census year	Urban population (in Millions)	Percent urban	Decennial growth rate of urban population	Tempo of urbanization		
				Annual exponential growth rate	Annual gain in % urban	Annual rate of gain in % urban
1951	62.44	17.29	41.42	3.47	0.34	2.48
1961	78.94	17.97	26.41	2.34	0.07	0.39
1971	109.11	19.91	38.23	3.24	0.19	1.08
1981	159.46	23.34	46.14	3.79	0.34	1.72
1991	217.18	25.72	36.19	3.09	0.24	1.02
2001	286.12	27.83	31.34	2.76	0.21	0.83

in 2006–2007. Most of the area is hilly, while 28.57 % of the area was under forest and in 1976–1977 this increased to 22.91 %. Similarly, it is remarkable that cultivable waste land also increased in 2006–2007 from 4.84 % in 1976–1977 to 7.80 % in 2006–2007 (Fertilizer Statistics -2011–2012).

The trend of urbanisation in India with effect from 1951 to 2001 has been presented in Table 8.3. This table clearly indicates that in the year 1951 the total urban population was 62.44 million which increased up to 286.12 million in the year 2001. The percentage of the population that lived in urban areas in the year 1951 was 17 which increased to 28 % in the year 2001. Annual exponential growth rate was observed around 3 %. Thus, the pressure on urban areas has increased manifold over the period.

The growth in urban areas of Udaipur city over more than 65 years together with population density is given in Table 8.4. Udaipur city covered an area of 17.17 km^2 in 1946 with a density of 4347 persons per km^2. The expansion of urban areas

Table 8.4 Growth of urban limit in Udaipur city

Year	Area increased (sq.km.)	Density (persons/km^2)[a]	Per bigha value of land (Rs.)[b]
1946	17	4347	500
1951	185	5049	525
1961	36	3089	1000
1971	61	3886	3500
1991	64	5035	5,00,000
2001	1016	4458	25,00,000
2011	221	3773	1,00,00,000

Source- District Statistical manual-2012, Udaipur
[a]Socio- Economic Census-2012 of Udaipur
[b]Data are taken from property dealers of the city

doubled from 17.75 km^2 in 1951 to 35.97 km^2 in 1961, while the population density decreased from 5049 persons per km^2 to 3089 persons per km^2 during the same period of time. Similarly, the urban area further expanded from 35.97 km^2 in 1961 to 61.10 km^2 in 1971. During the 20 year period from 1971 to 1991 the expansion of the city was only marginal at 64.28 km^2 in 1991 (Bharadwaj 2014). The population density in existing areas increased from 3886 persons per km^2 in 1971 to 5035 persons per km^2 in 1991. Again, the expansion in the urban area increased from 64.28–100.66 km^2 in 2001. The urban area has increased from 100.66 km^2 in 2001 to 221.00 km^2 in 2011, while the population density has decreased tremendously to 3733 persons per km^2 (Blackwell, Oxford Loibl W, Bell S 2011). The main reason for the decreasing density population over the period is wider roads in newly developed areas and many plots of residential purposes are lying vacant (25 %) and public purchased it only for value addition purposes.

The value of land in peri-urban areas has increased manyfold for UIT converted land after independence, i.e., from Rs. 500 per bigha in 1946 to Rs. 1.0 lac per bigha in 2011 (Arha et al. 2014). The increased value of land in peri-urban areas is mainly due to increasing pressure of population as well as changes in land use from agriculture to non- agriculture uses viz. residential and industrial purposes. The second important reason of increasing land value is that more than 50 % of converted plots for residential purposes are left idle. The householders purchase the plots for investment purposes and such plots are left idle after constructing the boundary walls. On such small plots one cannot grow crops. As an individual, the owner of the plot is gaining the profit from the land by increasing its value but to society as a whole such idle land is not beneficial. The increasing scarcity of agricultural land due to population pressure and the concept of multi-storied houses in urban as well as rural areas should be considered and acted upon by the government in the near future. It is a well known fact that most of the old cities are established near to the river due to water availability and fertile land of the area has been used for residential purposes during the expansion of the urban area. Hence, there should be a clear cut policy for the change in land use by the government of any nation to protect the land for future generations.

Table 8.5 Cropping pattern of major field crops grown in the Udaipur district

S. No.	Major crops	1976–1977	2006–2007	% increase or decrease
1	Maize	172.02	244.59	+42.17
2	Rice	Negligible	5.86	–
3	Wheat	77.50	84.31	+9.09
4	Barley	47.80	14.84	–236
5	Other cereals	18.20	17.91	+5.89
6	Gram	23.60	14.53	–64.29
7	Mustard	1.30	27.44	+2600
8	Groundnut	6.50	8.90	+40.00
9	Sorghum	12.55	17.62	+41.66
10	Sesame	4.68	7.22	+5.43

The change in cropping patterns of the Udaipur district during 1976–1977 to 2006–2007 has been presented in Table 8.5. With the exception of gram and barley crops, the area under all other crops has been increased. The area under mustard has increased by 26 times followed by wheat (42.17 %), sorghum (41.66 %) and groundnut (40.00 %). The area under barley crop decreased by 236 % and has been substituted with mustard cultivation. Similarly, the decreased area under gram crop is substituted with the production of mustard (Vital Statistics of Rajasthan-2011).

8.3.2 *Income and Employment Patterns of Peri-Urban Households Who Did Not Sell Their Land*

Land use, income and employment patterns of the peri-urban farmers who did not sell their land at two different points of time (1993–1994 and 2013–2014) are shown in Table 8.6. The average size of holding was found to be 1.75 ha out of which 0.25 ha is leased out by the farmers, because the younger generation is showing less interest in agriculture. Data clearly indicate that the income and employment generated by such farmers is more than those cultivators who sold all their land. Farmers who did not sell their land were getting 283 man days employment and Rs. 70,185/- as an annual income in the year 1993–1994. Data show that employment days were reduced to 252 man days due to technological changes over the period but the annual income of farmers increased up to Rs. 2,43,575/- annually during the year 2013–2014. These peri-urban farmers have sufficient land for crop production, vegetable production and dairy farming. They have also leased out land to the farmers who sold their land area in the peri-urban region and purchased land 30–40 km away from Udaipur. In peri-urban areas there is more profit from the production of items regularly used, such as vegetables and milk. When they were in rural areas they were growing both rabi and kharif crops on an average 0.50 ha and growing maize, jowar, urd, and guar crops in kharif and wheat, barley, gram and mustard in rabi season in the year 1993–1994. They were growing fodder crops like cheri,

Table 8.6 Land use, income and employment pattern of the peri-urban, does not sold the land (Average size of holding is 1.75 ha, 0.25 ha area is leased out)

S. No.	Crops	Area (ha)	Production (qt)	Cost/ha (Rs.)	Price/ (qt)	Income (Rs)	Employment (days)
2013–2014							
1.	Kharif crops						
	Jowar, maize, urd, guar	0.50	13.50	450	1050	14,175	52
	Rabi crops						
	Wheat, barley, gram, mustard	0.50	21.00	685	1400	29,400	75
2.	Fodder crops						
	Jowar, lucerne, cheri, berseem	0.50	100.00	250	500	50,000	40
3.	Vegetable crops						
	Okra, pea, spinach, tomato, brinjal and others	0.50	150.00	200	1000	1,50,000.	85
	Total					2,43,575	252
1993–1994							
1.	Kharif crops						
	Maize, groundnut, urd, moong	1.00	9.50	250	430	4085	65
	Rabi crops						
	Wheat, barley, gram	1.00	16.00	260	525	8400	82
2.	Fodder crops						
	Lucerne, cheri	0.25	80.00	125	215	17,200	44
3.	Vegetable crops						
	Pea, tomato, brinjal and others	0.25	90.00	230	450	40,500	92
	Total					70,185	283

berseem, lucern and jowar crops. Similarly, when these farmers fell under the peri-urban region they changed their production system and are getting more income through growing vegetables like okra, pea, gourds, spinach, tomato, brinjal etc. and gaining more employment from such production.

The cropping pattern was very different in the year 1993–1994 than that of 2013–2014. In the year 2013–2014 farmers were allocating 0.50 ha under Kharif cereals, 0.50 ha under Rabi cereals, 0.50 ha under fodder crops, and 0.50 ha of area was allocated to vegetable crops. At present farmers are allocating 0.25 ha for leased out area. If this area is to be compared with 20 years ago it is found that more emphasis was given on the growing of cereal crops and farmers were allocated on an average 1.0 ha of land for cereal production during Kharif crops and again the same area was allocated under rabi cereals. There was no emphasis on dairy production due to fewer avenues for selling milk and its products in the urban areas. Likewise, the area allocated for vegetable production was also less due to the marketing problem of perishable products such as vegetables. Farmers were getting 283 man days employment and were getting Rs. 70,185.00 annually. In this way the impact was noticed on income and employment pattern of the farmers in rural and peri-urban areas. There was a lot of difference in the income and employment patterns during this period. It was noticed that cultivators were not growing jowar and guar at that time, because guar was not commercially recognised. Similarly, jowar was also not in demand among farmers for fodder purposes as animal feed. Similarly, high yielding and low water requirement variety of mustard was not introduced. Thus, areas had more gram under cultivation than mustard. In peri-urban areas vegetable production is providing more returns to the cultivators and this started after the expansion of the urban area into peri-urban areas.

The income and employment generated through milk production is shown in Table 8.7. The people of this class have on average three cows and three buffaloes in their herd. They were getting 694 days employment for their family through dairy and crop enterprise during the year 2013–2014. The cultivator who did not sell the land was getting Rs. 8.68 lacs per year from both enterprises. They are producing on average 63.05 l of milk from both cow and buffalo per day and sell it in the urban market. The productivity and returns from cow's milk are higher than buffalo because these people were generally rearing crossbred cows that provide higher milk production than desi cows and buffaloes. If the data of milk production from cows and buffaloes is to be compared with the production employment and income data of the year 1993–1994 it is very clear that the average milk production and returns were less than today. Twenty years ago these milk producers were residing in a rural environment, there were less avenues of communication, transportation, use of agricultural technologies and extension services available for farmers. The results clearly indicate that there is a drastic change in production, productivity and use of technology by the farmers.

8.3.3 Income and Employment Pattern of the Peri-Urban Population Who Totally Sold the Land

Land use, income and employment pattern of the peri-urban farmers who totally sold their land have been shown in Table 8.8. These famers sold their total area of land except their houses and purchased land nearer to the city area within the periphery of 30–40 km. Farmers were getting 283 man days employment annually when they possessed the land and this reduced to 180 man days employment (O' Neill et al. 2012) and Rs. 1,79,100/- as an income through leased land. The average annual income of the farmers when they possessed land was found to be Rs. 70,185/- annually along with 283 man days employment. The higher income during 2013–2014 is

Table 8.7 Income and employment of peri-urban population from dairy, who did not sell the land

S. No.	Milking animal	Production per day (kg)	Cost/lit. (Rs)	Price/lit.	Returns/year	Employment (days)
2013–2014						
A	Cows					
1	1. Cross breed	10.50	11.40	25	95,812	100
2	2. Cross breed	11.60	12.70	25	1,05,850	105
3	3. Cross breed	13.20	12.75	25	1,20,450	102
	Total	35.30	–	–	3,37,112	307
B	Buffalo					
1	1. Improved	8.50	13.10	30	93,075	125
2	2. Improved	9.00	1375	30	98,550	130
3	3. Improved	10.25	14.15	30	1,12,237	132
	Total	27.75	–	–	3,03,862	387
1993–1994						
A	Cows					
1	1. Indigenous	4.25	4.31	9	13,961	91
2	2. Indigenous	4.65	5.09	9	15,275	93
3	3. Indigenous	5.01	5.13	9	16,457	95
	Total	13.91	–	–	45,694	279
B	Buffalo					
1	1. Indigenous	4.50	5.25	10	16,425	117
2	2. Indigenous	5.10	5.46	10	18,615	118
3	3. Indigenous	5.20	5.78	10	18,980	119
	Total	14.80	–	10	54,020	354

Table 8.8 Land use, income and employment pattern of the peri-urban, totally sold the land

S. No.	Crops	Area (ha.)	Production (qt.)	Cost/qt. (Rs)	Price/qt.	Income (Rs.)	Employment (days)
2013–2014 (Land sold)							
1.	Kharif crops						
	Jowar, maize	0.50	10.00	587	1100	11,000	50
	Rabi crops						
	Wheat, barley, Gram, mustard	0.50	12.00	745	1425	17,100	70
2.	Fodder crops						
	Jowar, methi, lucearn, and berseem	0.25	350.00	125	200	70,000	20
3.	Vegetable crops						
	Okra, pea, spinach, tomato, brinjal and others	0.25	60.00	812	1350	81,000	40
	Total					1,79,100	180

not a significant increase over the time and is due to changes in prices over the period. After selling the total land area in the periphery of the urban area these farmers are residing in that area mainly due to their social development, such as education and employment of their children and health facilities available for their family at any time. After selling land, these households invested the money in the purchase of non production assets like two wheelers, four wheelers, televisions, freezers, and the construction of houses. These farmers have leased land 0.50 ha for cultivation of fodder and vegetables only. The main reason behind the total selling of their land by households residing in the periphery of peri-urban areas is higher land value offered by the property dealers. This business concern develops the land area by changing land use pattern from the Urban Improvement Trust (UIT). The value of such land has increased manyfold through infrastructure development like roads, light connections for residential use, drainage channels for waste water and drinking water supply facilities. The demand for land for non-agricultural purposes is higher in the peri-urban area. The additional land required in peri-urban areas is mainly for industrial and residential purposes.

The income and employment generation is much less for the people who sold all their land. They are leasing land from other farmers who did not sell their land area. Results at two points of time show that there is a lot of difference between employment opportunities between with and without avenues i.e. land for farmers.

The income and employment generated through milk production has been given in Table 8.9. The people of this class have on average one cow and two buffaloes in their herd. They are getting 350 days employment for their family through dairy and crop enterprises during the year (Siciliano 2012). The cultivators who have sold their total land get Rs. 3.79 lacs per year from both the enterprises. They are producing 20.00 l of milk from cows and buffalo per day and sell it in the urban market.

It is very remarkable (Annual Report of town planning, UIT, Udaipur city-2012) that these farmers have sold their land area to property dealers with the impression that their land has been acquired by the UIT for development purposes of the city but their land was not acquired by the UIT and they were cheated by either big colonisers or property dealers at lower land prices. These peri-urban people are

Table 8.9 Income and employment of peri-urban population from dairy, totally sold the land

S. No.	Milking animal	Production per day (kg)	Cost/animal (Rs)	Price/lit.	Returns/year	Employment (days)
2013–2014						
A	Cows					
1.	1.	4.50	11.35	25	41,062	100
	Total	4.50	11.35	25	41,062	100
B	Buffalo					
1.	1.	7.00	12.90	30	76,650	125
2.	2.	7.50	14.10	30	82,125	125
	Total	14.50	13.55	30	1,58,775	250

taking land as leased in at half share of income from other landholders. Thus, there is clear cut demarcation between land holders and landless people. These people are getting only 350 days employment for their family during the year from dairy as well as crop production. If the data of milk production from cows and buffalo during the year 1993–1994 was compared with the production employment and income data of the year 2013–2014, it is very clear that average milk production and returns from milk was less during 1993–1994 when this at present peri-urban area was a rural area. There were less avenues of communication, transportation, use of agricultural technologies, and extension services available for farmers during 1993–1994. The present data clearly indicate that there is a drastic change in production, productivity and use of technology by the farmers.

8.4 Concluding Remarks

The demographic data of the last few decades revealed an increasing tendency of urbanisation in many states in India, including Rajasthan. The high growth rate of the population in urban areas increased the urban demand for agricultural commodities on one hand and widened the demand for land for the construction of houses, roads and other civil amenities on the other hand. With the expansion of urban areas, the adjoining rural areas are changed to peri-urban in terms of facilities, amenities and lifestyle. Evidently, there is a visible remarkable expansion in the value addition of land in the peri-urban area of the city of Udaipur. The study revealed that urban coverage in Udaipur has increased from 17 km^2 in 1946 to 221 km^2 in 2011, while the density of population in the city area has reduced from 4347 persons per km^2 in 1946 to 3773 persons per km^2 in 2011. It clearly indicates that more than 25 % plots in the urban limit is left idle after conversion of land for residential purposes, which is owned by the people only for value addition and protected by boundary walls. Large numbers of small landholders residing in the periphery of urban areas generally sold their land and purchased land 40–50 km away from the city areas. The study further revealed that farmers who partially sold land in peri-urban areas of the city are mostly cultivating vegetables and have dairy enterprises on their remaining holdings.

References

Arha A, Audichya R, Pant DC (2014) Challenges in the urban and peri-urban transition zones and strategies for sustainable cities: experiences from selected cities. In: The security of water, food, energy and liveability of cities. Springer, Dordrecht. pp 71–85

Bharadwaj GS (2014) Geo-social aspects of developments in peri-urban regions. In: The security of water, food, energy and liveability of cities. Springer, Dordrecht. pp 29–40

O'Neill BC, Ren X, Jiang L, Dalton M (2012) The effect of urbanization on energy use in India and China in the iPETS model. Energy Econ 34:S339–S345

Siciliano G (2012) Urbanization strategies, rural development and land use changes in China: a multiple-level integrated assessment. Land Use Policy 29(1):165–178

Chapter 9
Community Stakeholder Viewpoints on Issues of Urbanisation Along the River Ma Oya, Sri Lanka

Bhadranie Thoradeniya and Malik Ranasinghe

Abstract Rivers situated in peri-urban landscapes are prime natural resource bases supplying the construction industry associated with urbanisation. The study analyses and presents the river Ma Oya community stakeholders views on the impacts of river resource uses. Systematic stakeholder consultations revealed that while the river is the source for water supply for many cities, sand and clay mining for construction industry and dumping waste are the major sectors causing negative impacts. Essential remedial measures proposed are fair and effective intervention of Government authorities, stakeholder (including politicians) education together with technical measures and economic instruments to internalize the externalities caused by social and environmental degradation.

Keywords Stakeholders • Peri-urban landscapes • Urbanization • Economic instruments • Water supply • Waste dumping

9.1 Introduction

Sri Lanka has a relatively low urban population compared to other countries of the world which is at 15.1 % of the total population in 2011 with a rate of urbanization at 1.36 % (CIA n.d). Nonetheless, the cities and the urban areas of Sri Lanka are growing fast in the post internal conflict era. The urban growth of Sri Lanka is primarily due to regeneration of cities. Another reason for urbanization is the designated development of new and existing cities and townships rather than the urban sprawl that can be seen in some other parts of the world, for example in Australia.

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Fig. 9.1 Location of River Ma Oya

Rapid development of construction industry including housing, roads and infrastructure facilities is a key feature in these urban development programmes of Sri Lanka. Construction being one of the principle activities in the newly urbanised areas directly impacts the natural resource bases which supply the building materials.

The river Ma Oya discussed in this chapter forms the northern boundary of the Western province of Sri Lanka in which the commercial capital city of the country, Colombo, is located. Colombo is also the most populated city of the country. The Western province also contains the two most populated districts of Sri Lanka; Colombo (2.48 millions) and Gampaha (2.15 millions) (UNFPA n.d). Gampaha district at the northern part of the Western province is bounded by the lower reach of the left bank of River Ma Oya. Ironically, Kurunegala, the third most populated district of Sri Lanka bounds more than three-fourth of the right bank of the lower reach of this river. Figure 9.1 illustrates the location of the river with respect to the district boundaries of Sri Lanka.

The river valley areas of the lower reach of Ma Oya have been the habitat for rural communities whose main livelihood is paddy and coconut cultivation. The towns and population centres along the river were small and far apart. In the recent years, in addition to the development of existing and new urban areas in the Western province, the Urban Development Authority has identified a number of areas along the Ma Oya river banks, which are presently under going development of various foams including Townships, Free Trade Zones and Education hubs. Close proximity to the cities and town areas under the on-going urban development in Colombo, Gampaha and Kurunegala districts and the existing villages on both river banks qualify the lower reach of this river to be considered under peri-urban landscape.

Ma Oya riverine area is a major supplier of three building materials; sand, bricks and clay roofing tiles for the construction industry. The objective of this chapter is to analyse and present the views of community stakeholders on the impacts of development on different natural resource uses along the lower reach of Ma Oya river valley under peri-urban landscape.

9.2 Ma Oya River Basin

River Ma Oya is one of the largest river basins within the 103 river basins of Sri Lanka with a total catchment area of 1528 km^2 (Ratnayake 2003). Its importance lies in its location – the economically vibrant western part of Sri Lanka. It is also one of the seven major river basins in the south west quarter of the island (Panikkar 2008). It originates in the central hilly terrains and flows 130 km before falling to the Indian Ocean just north of the city Negambo. The river basin is spread in four provinces: Central, Sabaragamuwa, North Western and Western, and five districts: Kandy, Kegalle, Kurunegala, Puttlam and Gampaha.

9.2.1 Catchment Characteristics and Resource Uses

Highly stressed surface water resource situations are experienced up to 12 weeks during the dry season, though an annual average rainfall of 2219 mm is received in the basin (Ratnayake 2003). The river flows are mainly used for supplying drinking water for 17 cities. The next use of the river is as the carrier of pollutant from cities, industries as well as from private dwellings located on the river banks. The other significant uses of the river resources include sand and clay mining, which have become thriving industries of the river valley areas. There is much potential for industrial development especially along the valley of the river basin due to the impact of immigration of industries from the Western Province.

This study defined the lower reach of the river as the 87.5 km stretch from the river mouth up to Polgahawela bridge, which is at 80 m altitude and with an average riverbed gradient of 0.7 m per kilo metre.

Table 9.1 Declared urban development areas in Ma Oya downstream reaches

	Development area	Type	Approx. distance (km)
1	Colombo	MC	38.0
2	Negambo	MC	7.0
3	Gampaha	MC	20.0
4	Minuwangoda	UC	12.0
5	Ja Ela	UC	22.0
6	Peliyagoda	UC	34.0
7	Wattala-Mabole	UC	32.0
8	Divulapitiya	DS	8.0
9	Katana	DS	1.5
10	Mirigama	DS	6.0
11	Warakapola	DS	4.0
12	Ja Ela	DS	22.0
13	Wattala	DS	32.0
14	Wennappuwa	DS	8.0
15	Dankotuwa	DS	1.7
16	Pannala	DS	1.0
17	Giriulla	DS	00
18	Narammala	DS	15.0
19	Alawwa	DS	00
20	Polgahawela	DS	1.5

Source: UDA (n.d)
MC Municipality Council, *UC* Urban Council, *DS* Divisional Councils (Pradeshiya Sabha)

9.2.2 Urbanization

Ma Oya River flows through Mawanella town in its upper reach, and Alawwa, Kotadeniyawa and Giriulla towns in its lower reach. Polgahawela, Pannala, Dankotuwa and Katana are the other key towns situated along the river banks. Most lands on the lower river banks are used for paddy and coconut cultivations in a rural village set up (Thoradeniya 2005).

The economic policies adopted in the last three and half decades have resulted in fast development and urbanisation of some of the river valley areas on both banks. The left bank areas are subjected to fast urbanisation, since the river forms the boundary of the Western province which is the most developed province of Sri Lanka. The major developments include industrial parks and education hubs. As a result, the existing townships on both banks have regenerated and expended in their sizes while new population centres have emerged (Table 9.1). Rapidly developing tourism sector is also evident by the large number of hotels and other leisure areas.

9.3 Conceptual Framework

This study has drawn two ideas from the literature to develop the conceptual framework to identify the resource use sectors which will be impacted by the urbanisation and hence create issues for the stakeholders of the river valley. They are (i) the Educated Trade-off Framework concept and (ii) Stakeholder identification.

9.3.1 Identification of Resource Use Sectors

For the identification of the different sectors that use the same natural resources, this research uses the first step of the five-step Educated Trade-Off (ETO) framework developed by Thoradeniya and Ranasinghe (2006) and Thoradeniya (2010). The ETO framework was developed for educating stakeholders of competing resource uses to make informed decisions with regard to the trade-offs between their uses. In this framework, the stakeholders of a natural resource are educated on technical, economical and environmental aspects of their resource use, for rational trade-off decision making in resource scares situations which can occur during the development phase or in the management phase of any project.

The first step of the framework identifies the resource uses of a given spatial area and the stakeholders in the natural resource uses/issues that need stakeholder involvement for educated or informed decision making. The next three steps of the framework estimates the amount of the natural resource uses depending on their technical requirements at their critical bounds and the economic and environments values of such bounds respectively. The final step thus allows estimating the combined (economic and environmental) value of each natural resource use at its critical bound of the technical requirement, thus allowing for educated trade-offs between the different uses of the resources.

The valuation of environmental costs of different resource uses in the ETO framework is based on the "Total Economic Value" concept. According to Munasinghe (1993), the value of the environment arises because people (either as individuals or as society) wish to consume it due to its "use value" and "non-use value." Drawing from this concept the first step of the ETO framework identifies the full range of uses of a given resource as shown in Fig. 9.2.

Sectors that contribute to the use value can be further subdivided as direct (these sectors directly use river resources such as water and sand), indirect (these sectors use river resources indirectly) and option (the use sectors that are yet to develop). Sectors contributing to existence value (preserving the river in its present state, habitats and endangered species) and bequest value (the altruistic values of individuals desiring to preserve the wildlife, their habitats, biodiversity and so forth to be enjoyed by future generations) form the two sectors contributing to non-use value.

This approach allows identifying a complete list of use sectors as possible in the current scenario and helps to identify the impacts caused by one resource use sector on all the other use sectors.

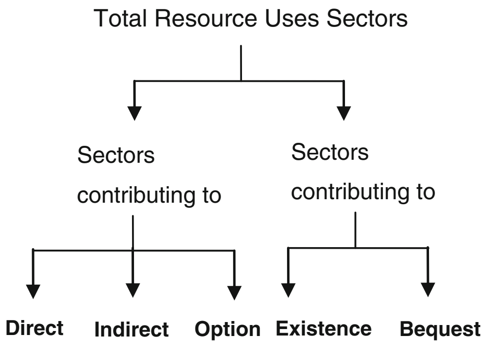

Fig. 9.2 Total resource use sectors (Adapted from Munasinghe 1993)

9.3.2 Identification of Stakeholders

Generally, stakeholders of a development project using river resource are spatially widespread; local, regional, national and international levels. Nevertheless, the scope of this study is limited to local (community) stakeholders of the river resources. Since, the interest of stakeholders could be many; the way they link themselves to the resource, use of resources and restrictions faced by them, awareness of negative impacts of their uses, concern for environment and other uses etc., there may be many different stakeholders with divergent views and expectations (ICH 2005; ODA 1995; Grimble 1998).

The approach for the involvement of stakeholders within a considered spatial entity of a river basin needs to be suitable for integrated and complex use of the resources, as against the approaches used for sector based resource uses such as hydro-power projects and irrigation development projects.

Identification of stakeholders for the study is therefore an important step which impacts upon its outcome.ICH (2005) advocates a Stakeholder classification depending on the impact (importance) and influence (power) of a stakeholder (Fig. 9.3).

Further, ODA (1995) has shown that the influence of primary stakeholders can arise due to;

- Social, economic and political status
- Degree of organisation, consensus & leadership in the group
- Degree of control of strategic resources significant for the project
- Informal influence through links with other stakeholders
- Degree of dependence on other stakeholders

Therefore, categories A, B and C types of community stakeholders have been involved in this study. Category D was not involved for the reasons that neither they are heavily impacted by any change in the resource uses nor they would represent any other stakeholders.

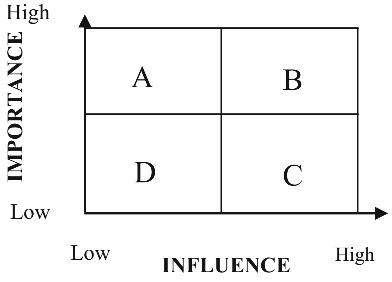

Fig. 9.3 The stakeholder classification

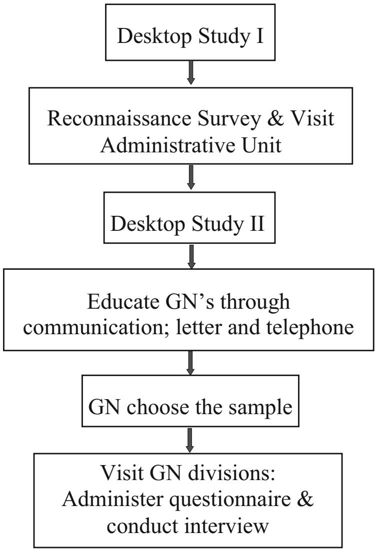

Fig. 9.4 Six-step approach for community stakeholder consultation process

9.4 Community Stakeholder Consultation Process

This study utilized a 'questionnaire survey' followed up with 'interviews' to elicit data from the stakeholders about their resource uses. The stakeholders in this study were restricted to the community stakeholders living along the river bank villages. Systematic consultation of representative stakeholders required us to develop a methodology which will neither repeat the spatial areas nor ignore any spatial locality. The methodology designed for the selection of local community stakeholders and conducting the questionnaire survey was the six-step approach given in Fig. 9.4 (Thoradeniya 2010).

The importance of this approach is the prominence given to the Government's local administrative mechanism. Establishing connections with the local community stakeholders through the 'Grama Niladhari – GN' (lowest level Government administrative official) was advantageous to develop a trustful attitude towards the research.

The Desktop study in step 1 began with the land survey maps of river basin and the urban development plans. It identified administrative units that should be visited in the reconnaissance survey. The Divisional Secretariat Division (DSD) was identified as the administrative unit to be contacted directly to initiate the field studies due to two reasons: (i) the number being small enough to handle within the scope of the study (rapid assessment of resource uses) and (ii) these are the smallest administrative divisions available in the Sri Lanka Survey Department maps.

The objectives of the reconnaissance survey and the visits in the second step were threefold;

(a) To obtain the data required for planning the main survey such as maps showing Grama Niladhari Divisions (GND), stream network etc. which are not available centrally.
(b) To create awareness about the research at the DSD level and to create an initial awareness among the concerned GNs.
(c) To obtain the necessary support of the respective Divisional Secretaries for the survey.

The third step of the approach is another desktop study where the details of the questionnaire survey was planned using the data collected at step 2. Accordingly, the numbers of GNDs on the left bank and right bank of the river in its downstream reach were 44 and 46 respectively. These belong to five DSDs on the left bank and six DSDs on the right bank. In addition to the identification of the river bank GNDs and planning the questionnaire survey, preparation of documents to educate the GNs is an important objective in this step.

Community stakeholder consultation process at the field level began with communication efforts with the GNs. A written communication articulating the purpose of the study and the expected coordination efforts to contact three to four community stakeholders who belong to categories A, B and C described earlier, was followed up by telephone. This step also allows to verify that they have received the written communication and to clarify any doubts.

Strengthened with this education, the GNs then selected community stakeholders representing different use sectors of the river resources. At the final step the researcher visits each GND and administered the questionnaire among the community stakeholders representing different use sectors of the river resources (Fig. 9.5).

Fig. 9.5 Interviews with stakeholders

The total number of stakeholders interviewed was 301 within 90 GNDs, where 12 % (36) were female. 85 % (256) of them were over 35 years and 47 % (143) were over 50 years of age.

9.5 Resource Uses and Issues

The community stakeholders first identified different uses of the river resources within their villages (GND), which finally resulted in 14 different uses of river resources in this reach of the river. These uses categorised under the different use sectors are given in Table 9.2. Few years back, the only source of potable water for some villagers had been the river. As the water quality deteriorated this number has decreased with only a very few poor peasants using river as their potable water source. Similarly, two to three decades back majority of the villagers of the river banks and people from neighbouring townships used river water for bathing and washing. It was found that the number of people making use of river for these purposes have also drastically reduced due to unsafe access with the sand mining activities and poor water quality.

One of the sectors which had increased river resource uses was 'water supply' despite the degradation of water quality. There are a number of points of extraction along the river in the downstream reach for water supply schemes. The extracted water is treated before supplying to the users. While there are proposals for new intakes the capacity of the existing intakes are also being increased.

Water extraction for industrial sector had increased with the establishment of industrial parks. This region has at least five industrial areas; Polgahawela,

Table 9.2 Resource use sectors identified by stakeholders

	Resource use sector	Direct	Indirect	Option	Existence	Bequest
1	Drinking water	√				
2	Bathing/washing	√				
3	Water supply source	√		√		
4	Industrial use	√	√	√		
5	Sand mining	√				
6	Dumping waste	√				
7	Inland fishery	√				
8	Animal rearing	√				
9	Agriculture		√			
10	Dug-well users		√			
11	Clay mining		√			
12	Tourism industry		√	√		
13	Recreation	√		√		
14	Irrigation			√		
15	Environment sector				√	

Fig. 9.6 Industrial waste discharge

Thulhiriya, Meerigama, Pannala and, Dankotuwa. Some industries located on the river banks use direct water intakes for potable and production uses while others located in the vicinity use both shallow and deep wells (boreholes) to obtain their water requirement for production. Latter is an indirect use of river (groundwater usage).

The survey established sand mining as the most popular single river resource use sector which was reported in all GN divisions of the study area. Some of the cities and townships are in the habit of dumping their garbage in the lands adjoining the river, even though this practice is illegal as garbage is washed into the river during the rainy periods. The situation is aggravated with industries both large and small discharging their untreated or partially treated industrial waste into the river (Fig. 9.6).

Two of the minor uses of the river are 'inland fishing' and fetching water for animal rearing. The survey revealed that the activities of these sectors have diminished over time not due to deteriorated quality of river water and the risk of accessing the river. Rural nature of the downstream areas is perceived by widespread rain-fed agriculture (paddy and coconut) and dug-well users. Both these sectors fall into the category of indirect users of the river resources. Clay mining which is more concentrated in the lower downstream meandering areas of the river is another indirect use of river resources. The clay deposits on the river banks are mined for the manufacture of clay roof tiles and bricks needed for the construction industry. The rapid constructions around Colombo as well as its suburbs have increased the demand on the rural clay industries and the extraction rates of clay.

Tourism industry and recreation sites are building up in the lower reaches with an enormous potential for future development, thus qualifying for uses with optional value. Irrigation is another use sector with optional value even though three lift irrigation schemes had been abandoned during the past two decades due to the increasing depths of the river.

The stakeholders input did not reveal any use sectors that would contribute to Bequest value of the river. A plausible reason would be the lack of areas designated for wildlife, biodiversity etc. in this region of the river. However, 90 % of the stakeholders expressed either their concerns about the impact of diminishing river

Fig. 9.7 Deep sand mining and excavated river banks

resources on the eco-systems or identified environment as a sector which depends on river resources for its conservation.

9.5.1 *Conflicting Issues*

Some of the identified resources uses have created conflict situations. For example, during the low flow periods the two major direct uses of the river waters (water supply and pollutant carrier) are in conflict with each other and results in critical water stressed situations due to the inadequate quantity and poor quality. Over 89 % of the respondents from all DSDs view their resource uses are threatened or are in conflict situation at present. Ninety one percent of stakeholders believe their resource uses to be threatened in the near future under the assumption that no change will take place in the river system.

The stakeholders were requested to identify the user sectors, which have created conflict situations with other uses or are already threatened by other use sectors. Three resource use sectors emerged as being principally responsible for negatively impacting the other resource users. Sand mining is identified by a large majority 60 % (180) as the single resource use sector which impacts the other users (Fig. 9.7). This was followed by clay mining on river banks and dumping waste which were identified by 17 % (51) and 13 % (40) respectively.

Interestingly, all of the above three sectors have a direct relationship to the urbanisation taking place in the surrounding areas. In the first two uses (i.e. Sand and Clay mining industries) the beneficiaries are mostly away from the river basin itself. With the rapid increase in urban construction activities both types of mining have been mechanised during the past two decades resulting in severe negative social and environmental impacts.

The unregulated sand mining has increased the depth of the river bed almost 15 m at some places. The most cited direct issues by more than 50 % of the consulted stakeholders are:

- Risk of drowning for those who use the river for bathing/washing/fetching water for drinking due to slippery and deep river bottom, poor accessibility; and
- Erosion of river banks; uprooting bamboo and other trees, and collapsing roads and railways on banks.
- Sand mining has also lowered the ground water table in the river valley. In certain areas the ground water table is lowered by 10–15 m. More than 50 % of the stakeholders stated that a considerable number of private dug wells of the community have either dried-up or have deep drawn water levels which are unable to reach easily.
- The agricultural lands located in the lower river valley which were once fertile are losing their productivity. The productivity of these lands was mainly due to the deposition of fertile suspended matter brought by the annual floods and the high ground water table. Increased depths of riverbed due to sand mining have resulted in low flood frequencies with zero floods in some years.
- Adverse impacts to the environment such as rising temperature, air pollution and low humidity were pointed out by a smaller number of stakeholders.
- Clay mining on the other hand has contributed to more social and environmental issues. These include poor health conditions of the villagers due to excessive dust when transporting clay and diseases such as malaria due to mosquito breeding in the open clay-pits which are not re-filled after mining activity. Heavy vehicles used for the transportation of clay have severely damaged the village road system consisting of gravel roads which are not designed for heavy loads. The damaged roads with large depressions filled with water make the roads impassable during the rainy seasons bringing many hardships to villagers and school children. Clay mining has also resulted in loss of habitable land due to cave-in effect when mining is carried out in adjoining lands. Social issues such as increases in the rates of theft and drug addiction due to migrant workers were other issues highlighted by the stakeholders.
- The third use of the river as a source for dumping waste is directly related to the industrial parks and townships within the river basin close to the river. The low dry weather base flow of the river combined with waste disposal from cities and industries without treating at outlets are in conflict with the intakes for water supply schemes. Poor quality water, unsuitable for drinking, bathing and washing, is the main issue, which is followed by stagnant pools of water in the river emanating foul smells and causing health hazards.
- Tourism which has emerged with urbanisation of the areas within close proximity has also adversely impacted the environment and the local populations.

9.5.2 Stakeholder Views on Remedial Measures

Stakeholders were able to identify and propose restoration and development work for the riverine environment. Majority of the stakeholders were of the view that issues created by excessive sand mining can be overcome with proper management of sand mining industry. While some wanted sand mining banned others proposedimiting mining depths. The necessity of effective and fair intervention by the Government officials was the next proposal by the majority. Lack of a common platform for all stakeholders was also cited as a reason for uncoordinated sand mining.

On the immediate issues like bank erosion, many proposed construction of rock embankments or protective walls along the river. Even though 35 % proposed the construction of longitudinal embankments, a surprisingly large number (23 %) proposed construction of bunds across the river indicating the wisdom of community stakeholders.

Even though the number of views expressed on clay mining was comparatively low, the majority were of the view that clay mining on the adjoining lands to the river should be banned. Six persons proposed stakeholder education while just one person proposed re-filling the clay pits.

The third issue of urban development which impacts the river resources is the use of river for waste disposal. While 9 % proposed a ban on dumping waste to the river 4 % proposed stakeholder education and two respondents stated that the river banks need to be cleaned of dumped garbage as a remedial measure.

9.6 Discussion

The development of cities and townships through regeneration plans and in few places with slow urban sprawl, and establishment of industrial zones have had direct impact on the river resources, such as sand and clay as building materials. Compared to the other rivers supplying sand, River Ma Oya is distinctively in a disadvantage position due to its peri-urban location.

For restoration of the mined land, the first step is to evaluate the technical feasibility. The economic benefit from sand mining, clay bricks and roof tiles, are received by the urban community purchasing them at competitive market prices without the cost of environmental degradation. The externality caused to the environment should be internalised through economic instruments. For example, Ranasinghe (1997) proposed a deposit refund system on clay mining for restoration of clay pits. That study estimated the economic value of clay mined from a sample clay pit of 20 Ac. ft. at US $ 33,440 and the environmental cost it generates at US $ 9467.

Political interference at all levels is seen as a main cause for environmental degradation while corrupt Government officials with authority were the two reasons identified stakeholders. Majority wished for a fair and effective intervention by the Government authorities. The situation was also aggravated by the different laws adopted by the local government authorities on the two river banks. Therefore, it was proposed that education has to be provided to politicians and officials on the impacts of uncoordinated and unregulated resource uses.

9.7 Conclusions

This study investigated the resource uses of Ma Oya river in the peri-urban landscape due to the urban development taking place in the three most populated districts of Sri Lanka; Colombo, Gampaha and Kurunegala. Uncoordinated and uncontrolled use by multiple stakeholders was expected to diminish the river's valuable resources within next few decades.

Sand mining, Clay mining and Dumping waste were identified as the three major sectors which have impacted the local stakeholders of the river resources. Sand and clay mining activities are directly related to the urban development through construction industry which is supplied with river sand and clay bricks and tiles as building materials. The third, waste dumping was a result of expanding cities and establishment of new industries.

Community stakeholders were able to explain the issues of the resource uses in the development and urbanisation and to provide their views on sustainable development and restoration of the riverine environment. The key challenges identified were inadequacy of Government institutions including police, unwarranted pressures by the corrupt local political leaders and lack of a common platform for all stakeholders to discuss issues on both the river banks.

River bank protection work (both along and across the river) was the major technical proposal for restoring the river while proper management, honest involvement of Government officials and stakeholder education were the key proposals on management sphere. The study also identified the use of appropriate economic instruments to internalize the externalities caused by social and environmental degradation.

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References

CIA (n.d) https://www.cia.gov/library/publications/the-world-factbook/fields/2212.html. Accessed 18 Mar 2014

Grimble R (1998) Stakeholder methodologies in natural resource management, best practice guidelines. In: Socio-economic methodologies. Natural Resources Institute, Chatham

ICH (2005) Course notes, social impact assessment progamme 2005. International Center for Hydropower development, Norway

Munasinghe M (1993) Environmental economics and sustainable development. World Bank environment paper no. 3, USA. Washington, DC: World Bank

ODA (1995) Guidance note on how to do stakeholder analysis of aid projects and programmes. Social Development Department, Overseas Development Administration, London

Panikkar AK (2008) Water profile of Sri Lanka, http://www.eoearth.org/view/article/156991/. Accessed 24 Mar 2014

Ranasinghe M (1997) Reconciling private profitability and social costs: the case of clay mining in Sri Lanka. Proj Apprais 12(1):31–42

Ratnayake R (2003) Resources and issues profile of MahaOya Basin. Colombo, Lanka Jalani (unpublished)

Thoradeniya WBM (2005) Evaluation report on the longest serving area water partnership in Sri lanka, Colombo, Lanka Jalani

Thoradeniya B (2010) Application of trade-off analysis framework in the Ma Oya River Basin. Technical report. Singapore: Economy and Environment Program for Southeast Asia

Thoradeniya B, Ranasinghe M (2006) A methodology for effective stakeholder participation through educated trade-offs, Annual transactions of IESL. The Institution of Engineers, Sri Lanka, pp 49–55

UDA (n.d) Urban development authority. http://www.uda.lk/pdf/Gazetted%20DP%20&%20Declared%20Urban%20Areas.pd

UNFPA (n.d) IPCD@15 Sri Lanka, United Nations Populations Fund Sri Lanka https://docs.google.com/viewer?url=http://srilanka.unfpa.org/drive/UNFPAICPD@15lowres.pdf. Accessed 18 Mar 2014

Part IV
Peri-Urban Landuse Planning

Chapter 10
The Role of Peri-Urban Land Use Planning in Resilient Urban Agriculture: A Case Study of Melbourne, Australia

Michael Buxton, Rachel Carey, and Kath Phelan

Abstract Peri-urban agricultural production remains important globally and its value will increase as the impacts of climate change, energy costs, rising world population and changing patterns of food consumption are felt. Maintaining the natural resource base for food production around cities will become an increasingly important part of city planning. Yet peri-urban areas continue to undergo radical change over much of the world, displacing traditional agriculture and reducing the capacity of cities to adapt to non-linear change. Urban resilience is best maintained through a regional approach which connects urban and peri-urban systems. Such system relationships are examined in a case study focused on the city of Melbourne in South-East Australia. Peri-urban Melbourne produces a significant proportion of the fruit and vegetables grown in the state of Victoria, but agricultural production on the city's outer fringe is under pressure from rapid urban development. This case study examines three scenarios which relate rural and urban land supply and demand, and explore land use planning techniques for limiting rural land development and transferring demand for rural land to regional settlements. It argues that stronger statutory planning measures are required to stem the loss of peri-urban agricultural land and that these will need to be accompanied in future by a range of other strategies to strengthen the resilience of city food systems.

Keywords Agricultural production • Peri-urban land use planning • Rural land development • Peri-urban agricultural land • Food systems

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10.1 Introduction

One of the enduring legacies of a 'pioneer' nation, such as Australia, is the belief that land will always be available for a range of uses and that technology will continue to increase production. This belief encourages the consumption of large areas of peri-urban agricultural land for urban purposes. Land use planning systems are intricately related to this process, either protecting or facilitating the conversion of agricultural land. The development of complex global food chains reduced the reliance of cities on peri-urban areas for their food supply. However attention is once again turning to peri-urban areas in the context of growing pressures on the global food system, including climate change, loss of agricultural land, water scarcity and rapid urbanisation (Morgan and Sonnino 2010; RTPI 2014; Caldwell et al. 2011; FAO 2011).

Climate change is likely to have a negative impact on global food production, due to increasing temperatures, a decrease in water availability and an increase in extreme weather events, such as drought and flooding. Its effects are expected to include rising food prices and increasing food insecurity, particularly for vulnerable and low income population groups (Porter et al. 2014). Water availability for food production is also under pressure globally from over-allocation of water resources in most major river systems (Molden 2007) and there are growing constraints on the availability of land for food production (Bot et al. 2000). These environmental pressures on food production have emerged at a time when demand for global food production is rising to meet the needs of a growing population.

In response to these emerging constraints on global food supply, as well as the pressures of rapid urbanisation (Morgan and Sonnino 2010; FAO 2011), cities are assuming a more central role in planning for the food needs of urban populations (Morgan 2010; Cockrall-King 2012). Urban and peri-urban food production is increasingly seen as an important element of urban food security. Potential benefits include an increase in the availability of healthy foods, such as fruit and vegetables, for urban consumers (WHO 2001), the provision of employment opportunities, particularly for the urban poor in cities of the global south and an increase in the resilience of urban food systems to disruptions in food supply due to climate change and natural disasters (De Zeeuw and Dubbeling 2009). Urban and peri-urban agriculture helps to strengthen the resilience of city food systems by diversifying food sources, reducing the energy requirements for transporting and cooling perishable food products and by enabling the use of urban wastewater for food production.

This chapter will examine the complex relationships between land use planning and peri-urban agriculture, concentrating on the value of peri-urban agriculture, and the role of planning systems in assisting its retention or encouraging its displacement. The chapter argues that peri-urban food production remains important despite its continuing displacement, and that it provides a vital means of increasing the capacity of urban systems to adapt to fundamental change. The chapter illustrates these system relationships by examining the importance of Australian peri-urban agriculture and through a case study of the relationships between planning systems and agriculture in the peri-urban area of Melbourne, Australia. The case study examines three scenarios which relate rural and urban land supply and demand and explore land use planning techniques for limiting rural land development and transferring demand for rural land to regional settlements. It argues that regulatory land use tools allow a precautionary approach to be taken by maintaining future options in peri-urban areas.

10.2 Production and Consumption

Peri-urban areas have been "the locus of both consumption and production activities, of both resource-seeking and growth resisting policies, and of contrasting settlement forms" (Bourne et al. 2003:257). Changes in peri-urban areas are often regarded as a progressive shift away from the traditional production based land uses associated with agriculture to places of resource consumption (Sinclair et al. 2003, Hollier et al. 2004; Barr 2003; Argent 2002, Pezzini and Wojan 2001, Pires 2004). Allen and Davila (2002) argue that such a shift involves a change from dominant forms of agriculture to a new multi-functional land use pattern in a mosaic of rural and urban uses where urban uses gradually become dominant. This new pattern is characterised by competing and increasing demands that affect the traditional cultural fabric of such areas. Aesthetic, recreational and biological resource values of this multi-functional landscape often depend on the landscape's authenticity as a food producer (Bills and Gross 2005).

This consumption is by a growing band of people who live in and outside peri-urban areas (Mattingly 1999). The conversion of land uses from production to consumption occurs at a rate far in excess of the need to accommodate the level of population growth. Much of the conversion accommodates the consumption of more intangible experiences sought by urban dwellers who seek a lifestyle experience requiring a much larger area of land than a conventional residential lot (Salt 2004). Resources consumed include agricultural products and commodities needed for nearby urban areas, such as water from catchments, stone and mineral deposits and harder to define factors, such as open space, landscape and recreational value (Willis and Whitby 1985; Johnson and Beale 2002). Some agricultural uses provide a setting to new uses, such as restaurants and convention, accommodation or recreation facilities. Bunce and Walker (1992) argue that the desire for ownership of amenity resources converts countryside into residential areas. Thus the amenity of peri-urban areas is valued and exchanged like any other commodity, driving up the value of land. They argue that exurbanisation is the process of commodification of amenity. Some researchers have used the phrase 'post productionist' to describe the new role and function of peri-urban areas (Argent 2002), implying that these areas have ceased to produce commodities.

Researchers have generally concentrated on the proximity of peri-urban areas to large urban areas, and the presence of environmental features, such as water availability, attractive landscapes, accessibility and coastal landscapes to explain demand for land in rural areas around large urban centres. The factors of amenity and proximity become the expected features of whether an area is peri-urban or not. This process results in an increased demand for land and in land value exceeding its value for agriculture.

10.3 The Value of Peri-Urban Agriculture

Despite this emphasis on the consumption of peri-urban values, and the use of a 'global hinterland' for much urban food supply (Steel 2008), urban and peri-urban areas remain significant areas of food production. One third of all US farms, for example, are in peri-urban areas (Heimilich and Barbard 1997, cited in Audirac 1999). In many Asian cities, such as Hong Kong, Shanghai, Dakkar and Accra, over 45 % of urban demand for vegetables is met from production in urban and peri-urban areas (De Zeeuw and Dubbeling 2009). Australia is a significant agricultural producer, exporting around 60 % of the food it produces (PMSEIC 2010). The nation is generally regarded as food secure (DAFF 2013), but this masks underlying vulnerabilities in food supply, reinforcing the importance of peri-urban regions. Houston (2005:210) argues that "conventional wisdom about agriculture in Australia's peri-urban regions tends to be dismissive about its economic significance". He estimates that Australia's peri-urban regions comprise less than 3 % of the land used for agriculture, but are responsible for almost 25 % of the gross value of agricultural production in the five mainland states, a figure which "consistently and substantially understates the value of agricultural production in peri-urban regions" by adopting a statistical threshold which ignores smaller and intensive industries situated close to major population centres (Houston 2005:217). Using Houston's defining peri-urban characteristics, the Victorian Department of Sustainability and Environment states that "Victoria's peri-urban region accounts for around one quarter of the State's land area but half of the agricultural production value" (Department of Sustainability and Environment 2006:16).

The South East Queensland region constitutes only 1.3 % of Queensland yet accounts for 14 % of the State's total 'farm gate' turnover (Office of Urban Management 2004). As the hub for Queensland's agricultural manufacturing and processing industries, it generates a turnover of $6.24 billion per annum (Q.DPI and SEQROC 2002). The vegetables of South East Queensland's Lockyer Valley produce a third of Queensland's vegetables (Department of Natural Resources and Mines 2005). New South Wales Agriculture has valued agriculture in the Sydney basin at about $1 billion per year representing 20 % of the total annual NSW vegetable tonnage, with the Sydney region producing 100 % of the state's Chinese cabbages and sprouts, 80 % of fresh mushrooms and 91 % of spring onions and shallots (Gillespie and Mason 2003; Sinclair et al. 2003).

Melbourne's green belt is the second highest producer of agricultural products in the State of Victoria with a gross production value of between $A1.2 and 1.5 billion (Food Alliance 2014), from about 4,000 farms on two thirds of the area, although the true value may be closer to double this figure (Parbery et al. 2008). The output per hectare of this area is the highest in Victoria, at least three times greater than any other region and four times the state average (PPWCMA 2004).). This green belt produces up to 50 % of the state's vegetables and around 17 % of the fruit, and is highly significant for the production of particular types of fruit and vegetables producing over 90 % of the state's asparagus, cauliflowers and strawberries, and over 70 % of the raspberries and lettuce (Food Alliance 2014). Some areas are significant to the national and state vegetable supply, such as Werribee South, which provides up to 70 % of south eastern Australia's leaf and kale crops, 85 % of Victoria's cauliflower crop and 53 % of the broccoli (Food Alliance 2014), Koo Wee Rup, which produces over 90 % of Australia's asparagus crop (ABS Australian Bureau of Statistics 2014) and Casey-Cardinia with produce valued at $423 million in 2006 (OSISDC 2010). The total area of agricultural land in Melbourne's green belt declined by 18 % between 1986 and 2001 (Parbery et al. 2008). Since then, over 53,000 ha have been excised from this green belt including important intensive agricultural land.

The displacement of agriculture from peri-urban land is a global phenomenon, removing agriculture from large areas in countries experiencing extensive urbanisation or population increases, such as China, India and the United States of America (US). There is a long history to claims that such displacement is not problematic (Versterby and Krupa 1993). Using the US as an example, Fischel (1985) claimed that the loss of farmland nationally in the US was small and the impacts on production minor, and that the loss of farmland could be offset elsewhere by new methods of production. However, between 1949 and 1997, the US lost 20 % of its agricultural land. Nelson (1990) estimated that one fifth of prime agricultural land in the US was located within 50 miles of the 100 largest urban areas, and showed that between 1982 and 1992 nearly 10 million acres of cropland were lost in the US and total sales of farm produce fell by over $42 billion. In peri-urban areas, sales of farm produce fell by $19 billion. Nelson (1990) claimed that most of this reduced production was due to losses of cropland, and estimated that each new household on former farmland cost the nation's agricultural economy $100,000 in lifetime sales. The 12 million new households expected to be added to peri-urban areas between 1990 and 2040 may reduce national sales of farm produce by up to $100 billion annually. Exurbanisation threatens much of the cropland located within about 100 miles of US cities. As Nelson (1999:147, 137) points out, "it is not difficult to see that if recent trends continue, much of exurbia's cropland will be taken out of inventory within the next generation…at a cost to the American economy of perhaps trillions of dollars in farm sales…[and]…much of the contiguous 48 states may no longer be distinguishable as either urban or rural, being instead characterised mostly as low density, exurban development". Goodenough (1978) argued that in many regions, the rate of farmland conversion would mean an end to most agriculture within a generation. Others have reinforced these conclusions. Halsey (1999) pointed out that the greatest conversion of prime farmland to urban use had occurred in 20 major land resource areas representing 7 % of the total US land base including some of the most productive land in the US, such as the Sacramento and San Joaquin Valleys in California.

10.4 Land Use Planning and Agriculture

Land use planning is a powerful independent factor affecting the ways peri-urban areas function and is critical to maintaining a wide range of peri-urban values. Conversion of farming areas to non-farm uses is often regarded as undesirable due to the loss of a land resource, the dilution of farming systems, and consequent urban inefficiencies created by sprawled housing (Alterman 1997). Under this approach, regulation to prevent land fragmentation is an indispensable tool to control property speculation and maintain effective rates of return on agricultural production against the allure of profits from anti-competitive land development. Effective land use planning is a necessary, though often not a sufficient, tool for the maintenance of landscapes and other environmental features, as well as productive activities, employment and agricultural land markets. Contrary perspectives suggest that as farming retreats, new urban employment opportunities emerge and local markets expand for farm produce (Bryant et al. 1982). These perspectives argue that alternative land uses are desirable, or inevitable, regardless of planning preferences (Bryant et al. 1982; Wills 1992; Bowie 1993; Barr 2003). Advocates of market oriented policy criticise the legitimacy of polices aimed at supporting non-productive activities within multi-functional landscapes, such as environmental works, as providing trade and markets distortions (Potter and Burney 2002).

The three most important land use factors which lead to the progressive loss of farm land are the large number of existing rural lots which, if developed, change the character and functioning of the entire region; the potential for future subdivision of larger properties into smaller lots; and the introduction of a wide range of urban uses, such as commercial activities. The impacts of land fragmentation can be reduced if subdivision is prevented or limited, and the right to construct a dwelling on a subdivided lot is removed. Defining the appropriate use of agricultural land is crucial (Auster and Epps 1993). Amalgamating small agricultural land holdings is another strategy but little studied in Australia. Regulatory techniques widely used are controls on subdivision, development and diverse urban related land uses. Commercial, residential and small lot rural uses introduce activities to rural areas which are often incompatible with the continuance of agriculture, add pressures to remaining agricultural uses, and more likely result in the progressive further fragmentation of land.

Despite difficulties in its application, agricultural protection zoning is a well established technique in developed countries to designate agricultural uses, retain larger lot sizes and restrict urban related and other incompatible uses of land by statute (Sinclair et al. 2003; American Farmland Trust 2002). Such zoning can also seek to achieve a range of environmental and social outcomes such as the retention of rural landscapes, biodiversity values, and limitations on high infrastructure costs to small rural lots. Larger lot sizes and use controls also maintain future options, flexibility and the potential for variation and innovation denied by close subdivision.

The effects of land speculation on the price of land have long been recognised. Archer (1973) analysed data from a subdivision developed in the late 1950s near the US city of Lexington. He found that land speculation was an important cause of land price increase and of scattered or "leapfrog" development where land parcels were developed out-of-sequence. Reciprocal relationships between land supply and demand and the rise in land prices caused by land speculation manipulate demand, so that "land speculation also accelerates the rise in land values by the initial increase in speculative demand and the subsequent reduction in the effective supply of land for building" (Archer 1973:367). The phenomenon of "out-of-sequence" development is still characteristic of much development occurring on the fringes of many US metropolitan areas today. In the 1973 Lexington study, this type of development led to the inefficient conversion of rural land to urban uses with landowners who withheld land from the market gaining an increase in value of an average $129 per acre a year but generating social costs, paid by others, of $1,360 per acre per year.

By concentrating on demand, many researchers have understated the role of increased land supply through subdivision and the exercise of development rights in creating a demand for peri-urban land types and on land prices. The liberalisation of subdivision and development controls can lead to a mutually reinforcing process of increased land supply and demand. The use of peri-urban land for development drives up land prices and makes it difficult for farmers to increase the size of their holdings. Higher land prices reduce the comparative rate of return on investment in agricultural enterprises. This reduced return, the desire for profit, and the tendency of large lot holders to regard land as a form of realised capital for retirement encourages landowners to sell in response to development pressure, and itself leads to further development pressure. These factors fuel land speculation, which raises land prices still further. Restricting the supply of smaller rural lots can reinforce the expression in price of the suitability of land for agricultural production, limit land speculation and lower land values. Figure 10.1 demonstrates that the price per hectare of peri-urban land increases as lot size falls.

These issues have been studied in detail only sporadically in Australia. Most Australian state governments have been reluctant over long time frames to protect peri-urban agriculture from a range of development pressures. Peri-urban rural subdivision controls are common but extensive urban expansion, rural residential subdivision and commercial uses continue to affect peri-urban areas and drive up the price of agricultural value. The little ex-urban regional planning which has occurred in Australia has now been generally discarded. Rural land uses usually are determined more by factors such as the structure of the economy, patterns of social change and politics and planning than regulation or the needs of agricultural production. This has produced a focus on a political struggle around rural property rights.

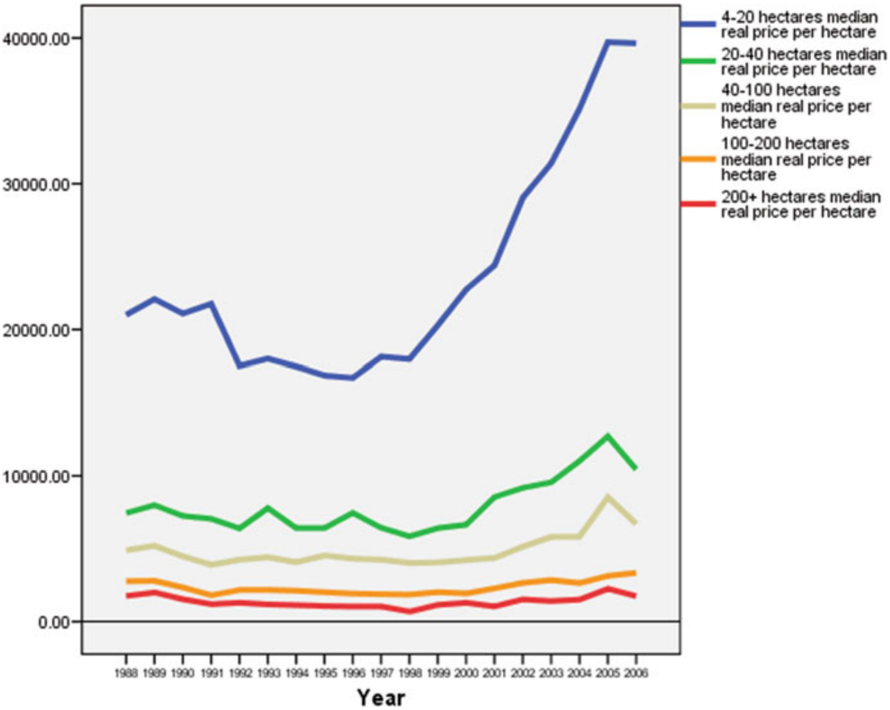

Fig. 10.1 Median price/ha by property size (Victoria $2006) (Source: Barr and McKenzie 2007)

10.5 Peri-Urban Land Use Planning in Melbourne

Despite periodic attempts to provide certainty through long term policy, land use planning for the Melbourne peri-urban area has been subjected to bewildering change. In 1971, the former Melbourne metropolitan planning authority, the Melbourne and Metropolitan Board of Works (MMBW), attempted to integrate the planning of the Melbourne metropolitan area with the city's hinterland. The green belt (incorporating green wedges between growth corridors) comprised 2400 km^2 or about half the total planning area. The MMBW used two methods to reduce both land speculation and pressures for development in the non-urban areas. The first was to reserve sufficient quantities of urban land, and the second was to protect non-urban areas from development through the use of permanent regulatory zones. These zones sought long term certainty for all affected parties through the use of high minimum sub-division sizes up to 80 ha, strong land use controls, the preservation of large metropolitan farms and the introduction of more restrictive uses in environmental zones.

In the mid 1970s, the MMBW commissioned two major studies into issues affecting the non-urban zones, the *Review of Planning Policies for the Non-Urban Zones* (MMBW 1977), and the *Metropolitan Farming Study* (Aberdeen Hogg and

Associates 1977). Both studies made strong recommendations aimed at ensuring the continuation of farming in the non-urban zones. The farming study argued that:

> when a farm is sold it tends to be subdivided to the minimum lot size allowable. This reduces the capacity of the non-urban zones to achieve the desired planning objectives of retaining agricultural production and rural landscape…There is no evidence that controls on use or development have imposed any significant constraint or caused any hardship to metropolitan farmers in the carrying out of their present farming pursuits (Aberdeen, Hogg and Associates Pty. Ltd 1977: 8–9).

The farming study concluded that "it is important to realise that any production that is lost through sub-division or urban incursion may not be capable of being produced elsewhere, or, if it is, it would involve higher prices to the consumer" (Aberdeen, Hogg and Associates Pty. Ltd 1977:1).

The government in 1971 also established regional planning authorities to develop cross-sectoral planning for the environmentally significant inner peri-urban areas of the Dandenong Ranges, Upper Yarra Valley and the Mornington Peninsula. The resultant policies, plans and statutory measures were interventionist, seeking alternative futures to path-dependent trajectories associated with trend analyses. They restrained urban development, controlled rural subdivision and prevented the introduction of urban related uses into rural areas in order to protect rural land uses, including agricultural practice, landscapes and environmental features. Land fragmentation and future development were identified as the main threats to maintain rural landscapes. The Upper Yarra Valley and Dandenong Ranges Authority, for example, severely limited future subdivision and dwelling development on the 62 % of 17,272 rural lots and the 42 % of 43,334 urban lots without dwellings (Loder and Bayly 1980). This removal of development expectations controlled land speculation, protected environmental qualities and increased the capacity of agriculture to persist by maintaining comparative rates of return and the potential to innovate. This kind of regional planning is rare.

More recently, the 2002 plan, *Melbourne 2030*, implemented new regulatory rural planning zones and a legislated urban growth boundary for the Melbourne green belt and developed a strong policy approach aimed at protecting hinterland resources. The State government had previously altered planning policy to control the proliferation of rural-residential subdivision in rural areas in 1992, and in 1996 inserted provisions for the retention of productive agricultural land in the State Planning Policy Framework (SPPF). Further amendments to Ministerial Direction No. 6 in 1997 and 2006 required an application for rural-residential development to be consistent with a range of requirements including the need to locate any such development close to existing towns and urban centres, not to encroach on productive agricultural land or adversely affect environmental resources. Ministerial Direction No. 6 was revoked in May 2012. In 2013, the State government also reduced the level of regulatory controls in most rural zones allowing further subdivision or non-farming related commercial uses to be introduced over much of the peri-urban area. These changes significantly weakened the rural zones by increasing the capacity for dwelling construction on separate lots and allowing a wide range of commercial uses to be approved on land reserved for agricultural and traditional rural uses.

The 2014 metropolitan plan, *Plan Melbourne*, proposes to investigate an agricultural food overlay to protect high value agricultural land, and to identify, protect and manage strategically significant agricultural land. However, such strategic statements about protecting the values of peri-urban land have been pre-empted by the 2013 planning system changes which make rural zones more permissive. Similarly, an undertaking to introduce a permanent metropolitan urban boundary has been made redundant by successive governments rezoning sufficient rural land on Melbourne's fringes to provide a 30 year supply of residential land at some of the world's lowest densities.

10.6 Case Study Region

This case study explores three rural scenarios for peri-urban land which test the extent to which rural land supply can meet projected rural dwelling demand, limit rural land development and transfer demand for land to urban and regional settlements. The case study focuses on seven peri-urban municipalities extending north-westerly from Melbourne. Melbourne is Australia's second largest city with a population of around 4.35 million. It is the fastest growing state capital in Australia, and its population is projected to overtake that of Sydney by 2053. Many of the areas of Melbourne experiencing the strongest growth are on the city's outer fringe (ABS 2014).

The Melbourne peri-urban region can be defined structurally by its physical structure and form, or functionally, or by a combination of spatial and functional factors (Buxton et al. 2006). Structural characteristics include lower population and building densities compared to urban regions, the heterogeneous nature of land uses and rapid rates of change; while a functional analysis of social and economic processes is both interactionist and system based. The resilience of peri-urban systems therefore is determined by the system components and how they interact, that is by multiple physical and social states. Thus, the relationships between elements determine the system's function and its capacity to respond to change.

Melbourne's peri-urban region consists of two non-urban belts of land round the city and their associated townships extending to about 160 km from the Melbourne central business district. The first, or inner belt, is the Melbourne green belt extending from the metropolitan urban growth boundary to the outer rural boundary of the 17 municipalities which form the green belt. The second, or outer belt, includes eight municipalities in a broader arc extending from the western to the eastern coast line. Beyond this belt, a number of large regional townships form the outer edge to this broad region.

The case study area (Fig. 10.2) examined includes seven peri-urban municipalities. The area is bounded to the south by Melbourne's urban-rural edge, to the west by the transport corridor to the city of Ballarat and to the north by the transport

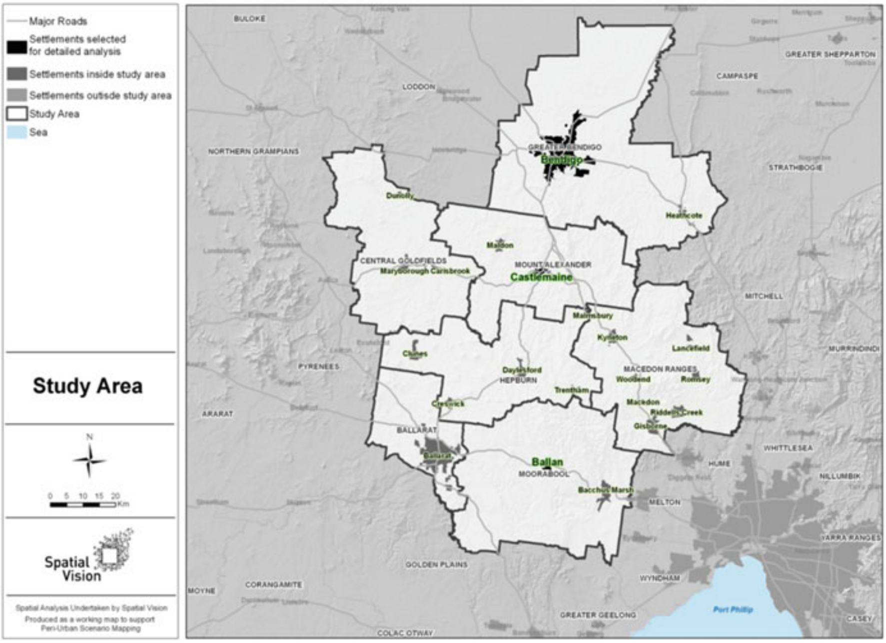

Fig. 10.2 Case study region

corridor to the city of Bendigo. The two largest regional settlements are Ballarat with a population of 95,582 and Bendigo with a population of 86,078. The seven municipalities are Moorabool, Macedon Ranges, Ballarat, Hepburn, Mount Alexander, Central Goldfields and Greater Bendigo, with a total population of 308,558. The study area also includes a number of medium sized towns, such as Bacchus Marsh, and small towns. It contains many historic features and is predominantly rural in appearance with 23 % of the land area zoned for public use, with the remaining rural land zoned for rural production, rural conservation or rural living uses. The region is notable for its landscape quality, biological diversity, rural production and tourism.

10.7 Case Study Methodology

This case study (Buxton et al. 2014) aims to help redress the lack of interest in regional planning and in the integration of metropolitan, rural and township land uses by investigating:

- methods for limiting future development in rural areas through controls on small rural lot development and on rural land subdivision, and
- means for transferring development from rural to township areas.

It is a supply-led approach, which assumes that the existence of lot types such as rural-residential lots will create a demand for dwellings on those lots, and that varying the types of land supply in townships will alter consumer preferences. This approach assumes that land supply influences demand, specifically, that the existence of small rural lots will result in their use for dwellings and that alternative housing type and lots within townships will in turn influence demand in different ways.

The study estimates current and potential land supply, and its adequacy to meet dwelling demand for both rural and urban areas through to 2040. Three rural scenarios test the extent to which rural land supply can meet projected rural dwelling demand. The first is a Business-as-usual (BAU) scenario under which supply is determined by the number of existing and potential new lots under existing planning schemes. The second, the Rural Preservation (RP) scenario, discourages rural development by requiring high minimum lot sizes of 16–40 ha in three rural zones for the construction of one dwelling. This scenario also encourages township development in three future urban zones on township fringes by reducing the minimum lot sizes for dwellings there. The third scenario, Tenement Control (TC), requires the area of multiple lots in the same ownership in rural zones to total 25 ha (TC25) or 40 ha (TC40) for the construction of one dwelling. The latter two scenarios assume an alternative future to be achieved by 2040, defined as a continuation of 2014 existing physical conditions, and are used to limit dwelling growth on rural land.

10.8 Findings

The application of the Rural Preservation and Tenement Control scenarios substantially reduces the potential for dwelling construction in the three rural zones studied by reducing rural development on existing land parcels and restricting rural land subdivision. However, the scenarios increase the development potential in the three urban edge zones by transferring forgone rural demand from rural to urban edge zones and increasing development yields in the urban edge zones. The application of the three scenarios led to the following findings.

10.8.1 Business-as-Usual Scenario

The most noticeable spatial feature of the rural areas is their extensive spatial fragmentation and the large oversupply of rural lots. Vacant rural lots total 71,990, with large numbers of these situated away from population centres in areas where demand is low. Under Business-as-usual projections, demand is unlikely to ever lead to this supply being used for housing. Yet in high amenity locations closest to Melbourne, rural development would substantially alter landscapes. Most vacant rural lots, or 47,759 on 710,686 ha, are situated in the Farming Zone (FZ), so their development would significantly affect farming. Most lots are small, with almost 75 % being 10 ha or less on 93,994 ha. However over 3500 lots over 40 ha exist on a significant land area of 286,280 ha or about 45 % of the rural land area. These large lots represent much of the study area's future, maintaining options for future agriculture and containing much of the remnant biological diversity. Only 4,455 new lots, or about 12 % of the total subdivision capacity, can be created in the three rural zones.

Yet substantial additional dwelling capacity exists on undeveloped land on the edge of townships in three future urban zones. Only 7085 lots exist in these three edge zones. However, their subdivision capacity accounts for all but 4455 of the 39,436 potential new lots from subdivision in these and the rural zones.

10.8.2 Rural Preservation Scenario

Application of the Rural Preservation scenario reduces the number of lots with rural zoning from 79,075 in the Business-as-usual scenario to 12,726 lots. Development capacity, including lots and subdivision potential, is affected even more strongly. Figure 10.3 shows that this falls in the three rural zones from 48,261 to 5,911 dwellings. The greatest quantitative reduction occurs in the Farming zone where dwelling yield falls from 34,112 in the Business-as-usual scenario to 4,841 in the Rural Preservation scenario, an 86 % reduction. This represents a fall from almost 40 % of total capacity under Business-as-usual to 4 % under the Rural Preservation scenario. Higher percentage reductions occur in the Rural Conservation zone (RCZ) by 90.3 % to only 459 dwellings and in the Rural Living zone (RLZ) by 93.4 % to 611 dwellings. Conversely, application of the Rural Preservation scenario to the three future urban zones on township edges increases their yield considerably from 38,934 to 106,082 dwellings.

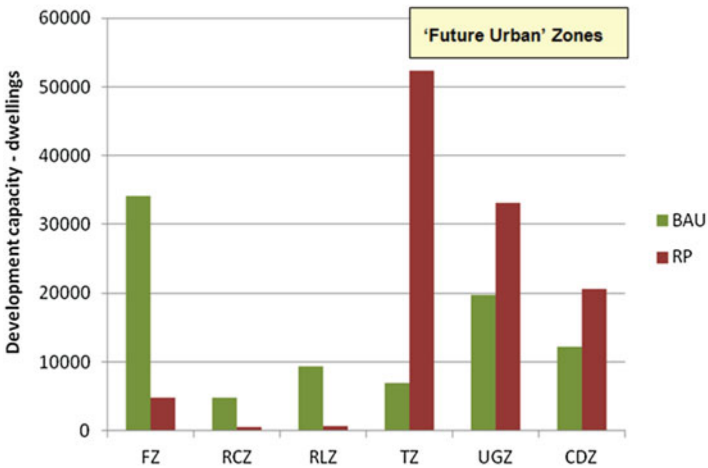

Fig. 10.3 Development capacity by planning zone under BAU and RP scenarios

Under the Rural Preservation scenario, application of a higher minimum lot size will transfer demand for 11,082 dwellings from rural to urban areas increasing urban dwelling demand from 60,651 under the Business-as-usual scenario to 71,733. Under the Rural Preservation scenario, the use of a regulatory control would shift development pressure to far fewer settlements, and significantly reduce the capacity for rural development compared to the Business-as-usual scenario. The use of pressure criteria such as services and infrastructure would tend to concentrate development in regional centres, district towns and townships on rail lines.

10.8.3 Tenement Control Scenarios

There are 32,896 singly owned lots in the six zones (three rural and three urban edge) examined in the study region qualifying for the construction of a dwelling under this scenario, of the 79,075 total lots. Tenement controls were then applied to the 46,179 multiple lots owned by a single landowner or 58 % of the total held in single ownership on the 10,196 properties comprising combinations of lots. Applying tenement controls reduces significantly the development potential of the multiple lots, under a 25 ha control to 14,597, and a 40 ha control to 7,395 dwellings (Fig. 10.4). The greatest impact would apply to the Farming zone where 70 % of lots are held in common ownership although all rural zones and the Township zone (TZ) would also be affected significantly.

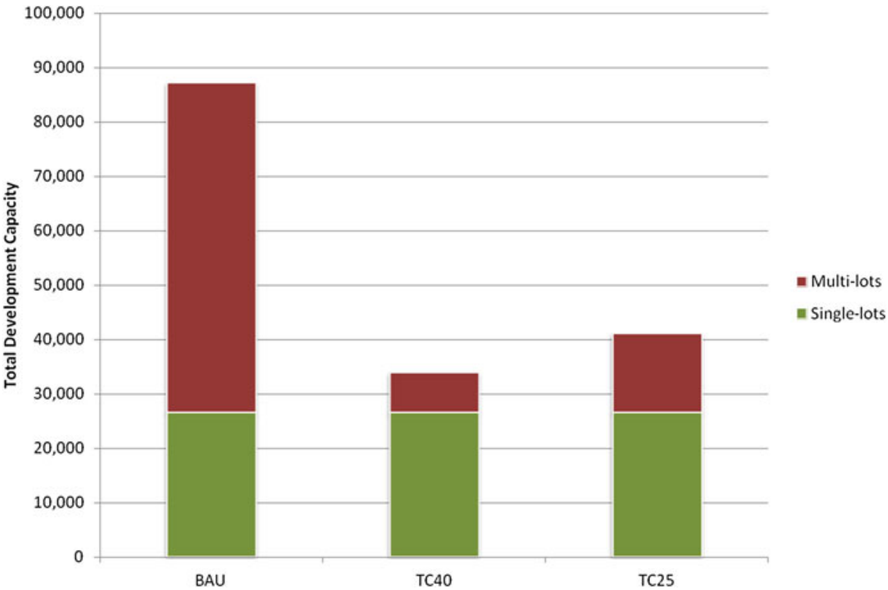

Fig. 10.4 Total development capacity – under BAU and TC scenarios

Transfer of foregone rural demand for development under the 25 ha tenement control would comprise a small component of new urban dwelling demand of 4247.

10.9 Conclusion

Cities which protect their hinterlands are likely to be the most economically prosperous this century. The maintenance of physical attractiveness and natural resources will prove to be essential to continued economic innovation, and will make significant contributions to wealth, health, personal identity and social harmony in both city and region. The retention of peri-urban agricultural areas will also contribute to the development of more resilient urban food systems. The level of successful interaction of these factors will define a liveable and functioning community. Yet governments routinely separate economic, social and environment sectors and fail to use tools within the land use planning system to achieve integration. Governments also separate rural areas from towns, and urban hinterlands from metropolitan areas. Such spatial separation leads to sectoral policies which are as fragmented as the pattern of land ownership.

Climate change, environmental degradation, regional population increases and a range of global, national and regional factors are expected to increase pressures on regional resources. Climate change is likely to reduce the resilience of human and natural systems leading to tolerance thresholds being exceeded and vulnerability increased. It is likely to particularly impact the natural systems that underpin food production. The result could be a greatly increased risk of non-linear change over a short period that is both catastrophic and irreversible. However, institutional and policy fragmentation is hampering the ability of governments at all levels to develop anticipatory policies which can assist the peri-urban region to adapt to rapid and fundamental change.

In times of rapid change with unpredictable outcomes, the resources of peri-urban areas may increase in importance. It would seem prudent to maintain the values of peri-urban areas, at least in the short term, during times of increasing change and threat. Integrated regional planning is essential if reciprocal impacts of sectors are to be considered and such planning requires a strong role for governments. A range of subdivision practices based around commercial or residential uses is increasingly being employed in Australian peri-urban areas. However, a return to regulatory practice will need to consider readoption of planning techniques formerly used, included tenement controls, rural lot restructuring and strong subdivision and use controls.

References

Aberdeen, Hogg and Associates Pty. Ltd (1977) Metropolitan farming study, Report prepared for Melbourne and Metropolitan Board of Works (MMBW), Melbourne

ABS (Australian Bureau of Statistics) (2014) Regional population growth, Australia, 2012–13. Issue 3218.0. Australian Bureau of Statistics, Canberra

Allen A, Davila J (2002) Mind the Gap! bridging the rural-urban divide. Insights 41:231–142

Alterman R (1997) The challenge of farmland preservation: lessons from a six-nation comparison. J Am Plann Assoc 63(2):220–244

American Farmland Trust (2002) Fact sheet: the farmland protection toolbox, farmland information center. Washington DC: American Farmland Trust.

Archer RW (1973) Land speculation and scattered development: failures in the urban-fringe land market. Urban Stud 10:367–372

Argent N (2002) From pillar to post: in search of the post-productivist countryside in Australia. Aust Geogr 33(1):97–114

Audirac I (1999) Unsettled views about the fringe: rural-urban or urban-rural frontiers? In: Furuseth O, Lapping M (eds) Contested countryside: the rural urban fringe in North America. Ashgate, Aldershot, pp 7–32

Auster M, Epps R (1993) Rural land use policy. In: Sorensen T, Epps R (eds) Prospects and policies for rural Australia. Longman Cheshire, Melbourne, pp 77–93

Barr N (2003) Future agricultural landscapes. Aust Plan 40(2):123–127

Barr N, McKenzie F (2007) Tree change in Victoria: Land markets, migration, population, non-resident landowners and farm business. Paper presented at managing tree change conference, La Trobe University, Beechworth, VIC

Bills N, Gross D (2005) Sustaining multifunctional agricultural landscapes: comparing stakeholder perspectives in New York (US) and England (UK). Land Use Policy 22(4):313–321

Bot A, Nachtegaiele F, Young A (2000) Land resource potential constraints at regional and country levels, World soil resources report 90. Food and Agriculture Organization of the United Nations, Rome

Bourne LS, Bunce M, Taylor L, Luka N, Maurer J (2003) Contested ground: the dynamics of peri-urban growth in the Toronto region. Can J Reg Sci 26(2 and 3):251–270

Bowie I (1993) Land lost from agriculture: a dubious basis for rural policy. Urban Policy Res 11:217–229

Bryant CR, Russwurm LH, McLellan AG (1982) The city's countryside: land and its management in the rural-urban fringe. Longman, London

Bunce M, Walker G (1992) The transformation of rural life. In: Bowler IR, Bryant C, Nellis CM (eds) Contemporary rural systems in transition volume 2, economy and society. Redwood Press, Melksham, pp 49–61

Buxton M, Tieman G, Bekessy S, Budge T, Mercer D, Coote M (2006) Change and continuity in peri-urban Australia: state of the peri-urban regions – a review of the literature. Monograph 1 – change and continuity in peri-urban Australia. RMIT University, Melbourne

Buxton M, Phelan K, Fish B, Farrell S, Groenhart L, Butt A, Kennedy M (2014) Scenarios for sustainable regional development in Melbourne's peri-urban region, summary report. RMIT University, Melbourne

Caldwell W, Collett A, Ludlow T, Sinclair I, Whitehead J (2011) Planning and food security within the commonwealth: discussion paper. Commonwealth Association of Planners, Commonwealth Foundation, London

Cockrall-King J (2012) Food and the city: urban agriculture and the new food revolution. Prometheus Books, New York

DAFF (2013) National food plan: our food future. Department of Agriculture, Fisheries and Forestry, Canberra

De Zeeuw H, Dubbeling M (2009) Cities, food and agriculture: challenges and the way forward, RUAF working paper no. 3. RUAF Foundation, Leusden

Department of Natural Resources and Mines (NRM) (2005) Lockyer valley discussion paper - declaration of the whole Lockyer Valley as a subartesian area. Government of Queensland, Brisbane

Department of Sustainability and Environment (DSE) (2006) Regional matters. An atlas of regional Victoria 2005. Victorian Government DSE, Melbourne

FAO (2011) Food for the cities. Food and agriculture organization of the United Nations. FAO, Rome

Fischel WA (1985) The economics of zoning laws: a property rights approach to American land use controls. Johns Hopkins University Press, Baltimore

Food Alliance (2014) Findings of the know your foodbowl research project. www.foodalliance.org.au/knowyourfoodbowl. Accessed 10 Dec 2014

Gillespie P, Mason D (2003) Value of agriculture in the Sydney region. NSW Agriculture, Windsor

Goodenough R (1978) An approach to land-use control: the California Land Conservation Act. Urban Stud 15:289–297

Halsey L (1999) Beyond the rural-urban edge. In: Furuseth O, Lapping M (eds) A contested countryside: the rural fringe in North America. Ashgate, Aldershot/London

Heimlich RE, Barnard CH (1997) Agricultural adaptation to urbanisation? Farm types and agricultural sustainability in US metropolitan areas. In: Audirca I (ed) Rural sustainable development in America. Wiley, New York

Hollier C, Francis J, Reid M (2004) Rural-peri-urban interface and extension, In: National Extension Policy Forum Sydney (Viewed November 6 2005). http://www.dpi.vic.gov.au/dpi/nrenfa.nsf/LinkView

Houston P (2005) Revaluing the fringe: some findings on the value of agricultural production in Australia's peri-urban regions. Geogr Res 43(2):209–223

Johnson K, Beale C (2002) Non-metro recreation counties: their identification and rapid growth. Rural Am 7(4):12–19

Loder and Bayly (1980) Inventory of subdivision and development. Upper Yarra Valley and Dandenong Ranges Authority, Lilydale

Mattingly M (1999) Institutional structures and processes for environmental planning and management of the peri-urban interface strategic environmental planning and management for the peri-urban interface research project. www.ucl.ac.uk/dpu/pui/research/previous/epm/

MMBW (Melbourne and Metropolitan Board of Works) (1977) Metropolitan farming study, report prepared by Aberdeen, Hogg and Associates Pty. Ltd., Melbourne

Molden D (ed) (2007) Water for food, water for life: a comprehensive assessment of water management in agriculture. International Water Management Institute, London

Morgan K (2010) Feeding the city: the challenge of urban food planning. Int Plan Stud 14:341–334

Morgan K, Sonnino R (2010) The urban foodscape: world cities and the new food equation. Camb J Reg Econ Soc 3:209–224

Nelson A (1990) Economic critique of prime farmland preservation policies in the United States. J Rural Stud 6:119–142

Nelson A (1999) The exurban battleground. In: Furuseth OJ, Lapping MB (eds) Contested countryside: the rural urban fringe in North America. Ashgate, Aldershot

Office of Urban Management (2004) Southeast Queensland regional plan. Local Government, Planning, Sport and Recreation (QLD), Brisbane

OSISDC (2010) Inquiry into sustainable development of agribusiness in outer suburban Melbourne, Outer suburban/interface services and development committee. Parliament of Victoria, Melbourne

Parbery P, Wilkinson R, Karunaratne K (2008) Square pegs in green wedges. Landholders and natural resource management in Melbourne's rural hinterland. Department of Primary Industries, Melbourne

Pezzini M, Wojan T (2001) Leveraging amenities for rural development: direction, dialogue, and negotiation. In: Proceedings of the exploring options for a new rural America. Kansas City Federal Reserve Bank, Kansas City, pp 121–138

Pires M (2004) Watershed protection for a world city: the case of New York. Land Use Policy 21:161–175

PMSEIC (2010) Australia and food security in a changing world. The Prime Minister's Science Engineering and Innovation Council, Canberra

Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI (2014) Food security and food production systems. In: Climate change 2014: impacts adaptation and vulnerability part A: global and sectoral aspects contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. CUP, Cambridge, pp 485–533

Potter C, Burney J (2002) Agricultural multifunctionality in the WTO—legitimate non-trade concern or disguised protectionism? J Rural Stud 18:135–147

PPWCMA (Port Phillip and Westernport Catchment Management Authority) (2004) Port Phillip and Western Port Regional Catchment Strategy 2004–2009. PPWCMA, Frankston

Q. DPI and SEQROC (Queensland Department of Primary Industries and Fisheries and South East Queensland Regional Organisation of Councils) (2002) Rural futures SEQ2021: regional strategy for rural communities and agriculture. Queensland Department of Primary Industries, Brisbane

RTPI (2014) Promoting healthy cities: why planning is critical to a healthy urban future. In: Planning horizons. 3. October 2014. Royal Town Planning Institute, London

Salt B (2004) The big shift, (second). Hardie Grant Books, South Yarra

Sinclair I, Bunker R, Holloway D (2003) From the outside looking in – planning and land management in Sydney's fringe, State of Australian cities national conference 2003, Parramatta, Sydney

Steel C (2008) Hungry city: How food shapes our lives. Vintage Books, London

Versterby M, Krupa KS (1993) Effects of urban land conversion on agriculture. In: Thunberg EM, Reynolds JE (eds) Proceedings of urbanization and development effects on the use of natural resources. Publication No. 169 Southern Rural Development Centre, Bilox

WHO (2001) Urban and peri-urban food and nutrition action plan: elements for community action to promote social cohesion and reduce inequalities through local production for local consumption. World Health Organization Regional Office for Europe, Copenhagen

Willis KG, Whitby MC (1985) The value of greenbelt land. J Rural 1:147–162

Wills A (1992) Do our prime farmlands need saving? Agric Sci 5(4):25–27

Chapter 11
Engaging Peri-Urban Landholders in Natural Resources Management

Stephanie Spry, Shayne Annett, Simon McGuinness, and Stephen Thuan

Abstract Engaging landholders in natural resource management (NRM) is a challenge in any landscape; however, it can be inherently more difficult in peri-urban landscapes. This chapter investigates why this is so and proposes practical options for addressing some of these challenges. It is proposed that current approaches to engage peri-urban landholders in NRM are in many cases based on conventional methods used to engage rural landholders. It was found that whilst the principles underpinning this approach are sound, the design and delivery of engagement must be modified in order to be effective in peri-urban landscapes. Importantly, such modifications have implications for the planning, management, cost, and delivery of peri-urban NRM projects.

Keywords Landholders • Natural resource management • Peri-urban landscapes • Biodiversity • Native vegetation

11.1 Introduction

Some of the most important and highly valued natural resource assets (biodiversity, remnant native vegetation, wetlands and waterways) occur in peri-urban landscapes across Australia. This is evidenced by a review of the literature on the State of Peri-urban Regions in Australia, completed by Buxton et al. in 2006. The review

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states that over 40 % of ecological communities listed for protection under national conservation legislation and more than 50 % of nationally listed threatened species are known to occur in peri-urban areas. Furthermore, numerous wetlands of international importance (listed under the Ramsar convention on wetlands) occur on the coastal fringe within peri-urban landscapes. Examples include the Peel-Yalgorup Ramsar site in Western Australia and the Western Port Ramsar site in Victoria. Another notable example is the Leadbeater's Possum (*Gymnobelideus leadbeateri*), an endangered species endemic to Victoria. It has a very restricted distributional range overlapping the peri-urban area east of Melbourne.

In addition, natural values that occur in peri-urban landscapes, such as waterways, and intact stands of native vegetation provide ecosystem services like the provision of clean drinking water (Buxton et al. 2006). The Maroondah Dam catchment southeast of Melbourne is a good example of this. Natural assets that are found in peri-urban areas are not dispersed uniformly across public and private lands. The area of private land across peri-urban landscapes is proportionally higher than public land (Buxton et al. 2006; Parberry et al. 2008). As a result much of the remaining natural assets in peri-urban landscapes occur on private land (e.g. river corridors, remnant patches of native vegetation, wetlands). It is also important to note that the management of natural resources on private land will influence the management and condition of natural resources on public land (Buxton et al. 2006).

Given many of the valuable natural assets in peri-urban landscapes occur on private lands, engaging these landholders in NRM projects is often critical to meet the desired environmental outcomes of relevant agencies and organisations (e.g. federal and state environment departments and local NRM organisations). However, there are many challenges associated with engaging peri-urban landholders in NRM. In part, these challenges are related to the complex set of interacting factors, which are characteristic of peri-urban landscapes, including the unclear boundaries of peri-urban areas, their dynamic and transitional nature, e.g. conversion of rural land to other uses, in-migration of new landowners, the large variety of often competing land uses and development pressure (smaller lot sizes and high rates of population growth).

This chapter describes the characteristics of peri-urban landscapes and identifies how these and the current approaches used to engage peri-urban landholders have implications for achieving meaningful NRM outcomes. It draws on the findings from reviews and evaluations of peri-urban biodiversity and NRM projects as well as relevant literature and proposes that conventional approaches to landholder engagement, largely developed by working in rural landscapes, are far less effective and not always appropriate in peri-urban landscapes.

It is concluded by using the results of analysis to highlight practical options that can be used in planning, design and implementation of landholder engagement components of NRM projects in peri-urban landscapes.

11.2 Methods

This chapter draws on the collective knowledge and experience of consultants (RM Consulting Group) with over 20 years of experience in NRM and input from the Port Phillip and Westernport Catchment Management Authority (PPWCMA) in Victoria. The experiences and observations used for this chapter have been drawn from:

- Reviews and evaluations of peri-urban biodiversity and NRM projects
- Review of the literature relevant to engagement of peri-urban landholders in NRM

Previous peri-urban NRM projects will be used to:

- Describe the complexity of peri-urban landscapes
- Illustrate the challenges of engaging peri-urban landholders in NRM in these landscapes
- Show how the assumptions underpinning conventional rural landholder engagement approaches do not apply in many cases to peri-urban landholders

11.3 Discussion

We begin by describing what we mean by the peri-urban landscape. We then outline the characteristics of these landscapes to show how they differ from others, e.g. rural or urban, and to set the context for illustrating what we propose are the main challenges for engaging peri-urban landholders in NRM. We then present what we consider to be three main challenges for engaging peri-urban landholders and describe the implications of these for effecting meaningful NRM outcomes.

11.3.1 Characteristics of Peri-Urban Landscapes

There is no single universal definition for peri-urban landscape; in fact it is the subject of much debate within the literature (Buxton and Choy 2007; Mbiba and Huchzermeyer 2007). However, it is possible to describe peri-urban landscapes conceptually as the landscape that occurs between dense continuous urban development and the rural countryside (Nelson and Deuker 1990). No clear boundaries exist to demarcate where these landscapes begin and end; instead they exist on a continuum between urban and rural settlements. The conceptual description provided here is what we consider to be a peri-urban landscape for the purposes of this chapter.

Regardless of the preferred definition for a peri-urban landscape there are numerous common elements to these landscapes that distinguish them from others (Buxton et al. 2006). Peri-urban landscapes are dynamic and transitional, they have new and diverse communities forming and land use change is occurring at a rapid rate. It is these characteristics that make it challenging to engage peri-urban landholders in NRM.

For example, in a 2010 study investigating changes in rural property ownership, Mendham and Curtis found that in the Corangamite catchment (located west of Melbourne, Victoria), areas in close proximity to larger metropolitan centres (Ballarat, Geelong, Melbourne) are being sub-divided into smaller lots and transitioning from rural to amenity land uses.

These changes in land use are resulting in changes to landholder demographics across the area (i.e. a shift away from traditional farmers to lifestyle landholders). In turn, this is creating a more diverse mix of landholders with differing values, property aspirations and economic circumstances (Mendham and Curtis 2010).

Given that these new lifestyle landholders report lower levels of knowledge and skills in land management, and are less focused on agricultural production, conventional approaches used to engage landholders, e.g. through agricultural extension officers, will be far less effective (Mendham and Curtis 2010).

Compared to rural areas, land in peri-urban areas has a larger number and greater variety of land uses, with diversity increasing closer to metropolitan centres. In Australia, this change has been observed most notably along the eastern and south western seaboards over the last 20 years, and it is continuing at an ever increasing rate (Darbas et al. 2010).

Lifestyle properties in peri-urban areas are used for a variety of purposes, e.g. horse agistment, vineyards, and smaller lots also support more traditional intensive agricultural production, such as vegetables and poultry.

With increases in smaller residential lots comes the need for infrastructure and amenities to service the increasing population moving into these areas (Buxton et al. 2006). This further increases the diversity of land uses and commonly includes a mix of industry, manufacturing, conservation areas, green and open space for recreation.

Conflict over land use in peri-urban areas is therefore common, given the diversity of uses (Buxton et al. 2006). For example, residential housing may be located next to a publically managed grassland reserve that requires burning to maintain ecological function. This can cause concern for residents who may view fire as a threat to their property. Previously the organisation or agency responsible for undertaking fire management activities may not have had to engage the community about ecological burning and similarly new landholders moving into these areas may not be familiar with or understand the importance of ecological burning to maintain the health of the grassland. In turn, this can lead to residents submitting complaints to the local council and ecological burning being stopped. As a result the grassland becomes further degraded.

Rural landholders often comment that there seems to be many similar agencies involved in land and water management, which can create confusion and uncertainty. This is an even greater issue in peri-urban landscapes with both urban and rural land management agencies and groups being involved, e.g. local NRM planning organisations, local councils, state government environment, planning and development departments, water authorities, Landcare, land developers and infrastructure agencies.

This means that often multiple organisations are attempting to engage with peri-urban landholders about many different topics at the same time. Through surveys and focus groups conducted with peri-urban landholders for various projects, we have consistently found that landholders report being contacted by multiple agencies and organisations, (e.g. water authorities, catchment management authorities, Landcare, local council, seeking their involvement in NRM activities. In many cases we found landholders have little awareness of the different environment agencies and, if they are interested, can be confused about the most appropriate contact in relation to NRM issues. For instance there were many cases where they had never heard of the local catchment management authority (CMA) and were unwilling to engage with any such organisation.

We found this was the case when running a series of focus groups and interviews with landholders in south east peri-urban Melbourne (Pearcedale, Koo Wee Rup, Yarra Glen) as part of reviewing a project that focused on protecting threatened species habitat. Some of the peri-urban landholders had not heard of CMAs or Landcare and some were confused about where the grant money to complete on-ground environmental protection works had come from. This meant that even when they were interested in participating in an NRM program they did not know where to go for help when they were having difficulty, e.g. filling out the application forms, ordering plants, getting plants in the ground. In some cases this led to landholders pulling out of the project altogether.

Peri-urban landscapes are experiencing high development pressure as a direct result of transitioning land uses (Darbas et al. 2010; Millward 2002; Murphy and Burnley 1996). Sub-division of land into smaller lots means substantially more people are moving into peri-urban areas over a short space of time. This is causing fragmentation of natural resource assets and loss of connectivity between assets (Williams et al. 2001). Native vegetation is perhaps one of the most obvious examples. Smaller lots cause fragmentation of vegetation as a result of the establishment of infrastructure, fencing, buildings and roads (Darbas et al. 2010). This leads to smaller isolated patches of vegetation across the landscape and ultimately a loss of connectivity. Smaller isolated patches of vegetation are more sensitive to edge effects and disturbances like disease and fire. The magnitude and intensity of the changes described here becomes greater as you get closer to the urban centre.

11.3.2 Challenges of Engaging Peri-Urban Landholders in NRM

We consider there to be three main challenges when engaging landholders across peri-urban landscapes.

1. Addressing competing government priorities
2. The high number and diversity of landholders
3. Using an appropriate mix of landholder engagement approaches

We acknowledge that these challenges are common no matter what audience you engage, however the intensity and magnitude of these challenges is much greater in peri-urban landscapes compared to others, such as rural. This is in a large part a result of the characteristics of these landscapes as outlined in the previous section of this chapter. These challenges have significant implications for the planning, design and delivery of engagement approaches for NRM projects in peri-urban landscapes.

11.3.3 Addressing Competing Government Priorities

Peri-urban landscapes are contested spaces. The composition of peri-urban landscapes is a product of the multiple competing government priorities driving development of these areas (Buxton et al. 2006). Planning policies, such as Melbourne 2030, have supported the conversion of rural land into residential lots on Melbourne's urban fringe in a bid to improve housing affordability and availability for Melbourne's growing population. In addition, new residential developments demand open space for recreation and increased infrastructure such as road networks (State of Victoria 2002).

In these same areas, economic policies are driving agricultural production for example, vegetable farms in Werribee South and Koo Wee Rup (Wyndham City Council 2010; DPCD 2011) and industrial land use, e.g. development of manufacturing and distribution factories in Dandenong and Laverton (DSE 2009). In conjunction, conservation policies are also driving environmental protection in these landscapes (e.g. the Victorian Volcanic Plains Grassland Reserves) (CoA 2010).

Often and particularly in peri-urban landscapes economic and social priorities conflict with environmental priorities. This means trade-offs are made and much of the time economic and social priorities come before environmental priorities (Buxton et al. 2006). In some cases it is possible to meet social, economic and environmental priorities in the landscape. However this is extremely challenging in peri-urban landscapes.

Government priorities are in part driving the diversity of landholders in peri-urban landscapes. In turn, this makes it difficult to engage the mix of landholders who have been driven to move or stay in peri-urban areas for different reasons.

The challenge of competing government priorities in peri-urban landscapes has two main implications for engaging landholders and effecting meaningful NRM outcomes:

- Development of realistic and feasible NRM outcome targets
- Development of associated landholder engagement targets

Firstly, we have found that peri-urban NRM project targets are often overly ambitious and do not take account of the landscape context (i.e. number and diversity of landholders across the landscape). Commonly, in peri-urban NRM projects limited information about how competing land uses might affect the achievement of NRM objectives is built into the project planning process, (e.g. achieving desired revegetation targets to connect habitat in a fragmented landscape that includes pockets of residential development dispersed with agricultural production).

This was observed in a peri-urban biodiversity project we reviewed focusing on protecting habitat for three threatened species southeast of Melbourne. The targets set for habitat enhancement, such as fencing to protect remnants and revegetation, were not met. We propose that this was in part a result of underestimating how the complexity of land uses across the target area might impact the extent of revegetation and remnant protection that was possible.

Secondly, we have found that landholder engagement targets are usually constructed around environmental outcomes without adequate consideration or understanding of the target audience. Therefore, this impacts the level of participation in the NRM project that can be achieved and consequently the biophysical outputs, e.g. hectares of revegetation, that can be achieved.

Inadequate understanding of the target audience is a common issue across many NRM projects and this presents problems for predicting engagement success and therefore setting appropriate landholder engagement targets. This issue is particularly amplified in peri-urban landscapes where there are more landholders in the landscape who are more diverse with different values and aspirations for their land.

In our review of the threatened species habitat projection project, we found that landholder participation targets were driven by the desired biophysical targets, and were not fully tested against an understanding of the local community. For this project, a general mail out of an invitation letter was one of the main tools used to engage landholders. A standard letter from the CMA was sent out inviting all landholders across the project area, including lifestyle and rural properties, to get involved. The mail out seemed to be based on the assumption that landholders across the project area are homogenous and would respond to this invitation in much the same way as rural landholders. This was expected to generate the desired uptake and therefore the biophysical targets would be met. This was however not the case, and uptake was well below what was expected after the first round mail out.

It is therefore important for NRM organisations and agencies to be aware of, and understand, what is driving land use and landholder behaviour in these areas. In turn, this helps projects to be realistic about participation rates and what they can achieve when setting NRM targets. Integrating biophysical and social data into project planning and target setting is important in all NRM projects, but perhaps even more critical in peri-urban areas.

Aligning NRM projects to government priorities and setting targets for these projects is further complicated by the competitive nature of funding and investment programs which drive NRM organisations, in some cases, to set unrealistic targets based on timeframes and budget available to complete the project. There are two options for addressing these issues, to secure a greater amount of funding or reduce the targets.

11.3.4 The High Number and Diversity of Landholders

The large variety of land uses and multiple factors that shape peri-urban landscapes creates more complexity for engaging landowners in these areas. This presents numerous challenges for planning and designing engagement approaches in peri-urban landscapes (Kearney and MacLeod 2006). As peri-urban landscapes are experiencing high population growth, the number of landholders to engage in NRM projects is greater compared to a rural landscape of the same size. This means the time and effort required to engage landholders in these landscapes is also likely to be greater.

Through the work we have done delivering small landholder property management workshops in Tasmania, the various focus groups we have conducted with peri-urban landholders on the outskirts of Melbourne as well as review of the literature on this topic we found that peri-urban landholders:

- Have a wide range of aspirations for their properties (i.e. what they want to mange it for)
- Have a high variation in awareness of environmental values
- Have a high variation of knowledge and skills in land management and NRM
- Tend to spend less time on their property
- Are moving into peri-urban areas from other districts and urban areas, and therefore are generally not well connected in the local community
- Derive most of their income off-farm and seem to be more willing to spend money on NRM
- Have limited knowledge of NRM and related organisations (e.g. local NRM planning organisations, Landcare)
- May fear or be suspicious of government authorities and their motives

The challenge that this diversity presents is that NRM projects need to be able to appeal across a very wide spectrum of interests. In a rural area dominated by farming, an approach that focuses on just one dimension, such as the benefits to a farm operation, might generate sufficient participation. In peri-urban landscapes the approach may need to appeal to the different interests stated above (i.e. the wide variety of; property aspirations, environmental awareness, NRM skills and knowledge, financial capacities, familiarity with and perception of government and NRM organisations and authorities) all simultaneously in order to generate sufficient participation. This presents enormous challenges in designing and delivering an appropriate set of engagement approaches. An approach that relies too heavily on a narrow view of landholders may not be successful.

11.3.5 Using an Appropriate Mix of Landholder Engagement Approaches

Given the diversity and number of landholders in peri-urban areas we propose that multiple different approaches will be needed across the one project area to achieve an effective uptake and participation in NRM. It can be a challenge to select the right mix of engagement approaches and this will be different, depending on the peri-urban landscape.

In many cases the usual NRM engagement channels/networks like Landcare or local NRM planning bodies, e.g. catchment management authorities, may completely miss the mark. This can be a factor of new landholders, such as tree changers, sea changers, moving into the area and not being aware of such organisations.

The perceived benefits of doing environmental works will depend on the land use and property aspirations of the landholders. Whilst this is the case for all landholders (peri-urban, rural) the variety of uses and aspirations will be much wider in peri-urban landscapes. Therefore how the NRM project is pitched or messaged will be important.

For example, in our review of the habitat protection project south east of Melbourne, interviews with non-participating landholders highlighted that the language used in the generic mail out letter was not appropriate for all landholders. Words such as “covenant” and the formal language used resulted in the perception amongst some landholders that their land would be taken away or “locked up” if they got involved. Even so, some landholders who did participate reported that they were comfortable with the letter and participated as a result of receiving the letter. This clearly shows that a mix of approaches is required to engage peri-urban audiences. However, selecting the right mix can be challenging and also more expensive.

11.4 Concluding Remarks

In the final section of this chapter we consider the implications of the challenges to engaging peri-urban landholders in NRM projects that we highlighted in the previous section. We then outline what we consider to be important steps in the successful engagement of peri-urban landholders to achieve meaningful NRM change across peri-urban landscapes.

11.4.1 Higher Costs Associated with Engaging Peri-Urban Landholders

As there are more landholders to engage (i.e. compared to a rural landscape of comparable size) and because landholders are more diverse, e.g. environmental awareness, knowledge, skills and interest in NRM, differing property aspirations it is likely to be more costly to undertake engagement in peri-urban landscapes. Additionally, because there are more landholders undertaking smaller projects, the capital costs are also likely to be greater, e.g. engaging numerous landholders in multiple fencing projects rather than the one or two that might cover the same area in a rural landscape.

It will be important for NRM organisations and agencies to address these factors in planning and costing NRM projects in peri-urban landscapes and not rely on assumptions made to cost rural NRM projects. This may also mean that the targets, both biophysical and landholder engagement numbers, may have to be adjusted.

11.4.2 Identify and Understand the Target Audience

Clearly identifying the target audience and having a good understanding of their motivations, drivers and values are critical to the success of any NRM project, but even more so in peri-urban areas. Getting to know the target audience should be one of the first steps in project planning. This can be done using local champions with good knowledge of the target audience, e.g. local government environment officers or councillors, baseline surveys, focus groups, and existing data (ABS Census). This can also be achieved by tapping into the appropriate communication channels used by the target audience. For example, setting up a stall at the local weekend market, pinning brochures up in the local supermarket or childcare centre, or using existing community groups to deliver the message and gather information about the target audience.

In our evaluation of the Community Skills, Knowledge and Engagement outcome of the Australian Government's Caring for Our Country program we completed a number of case studies to demonstrate the factors of success underpinning engagement of the community and landholders in NRM.

In one such project that aimed to increase native habitat and achieve landscape scale conservation across endangered native vegetation communities, we found that a key component driving the success of this project was the project team's in-depth socio-cultural understanding of the targeted landholders they wanted to participate in the project. This was done by undertaking interviews with a wide range of landholders from the project area to gather information about their physical, social and economic environment, attitudes towards land management, environmental management and participation in community networks and Landcare.

This provided a rich body of information about the landholders in this area, which was then used to design engagement approaches for this audience. Although this example is from a rural landscape the principles for engagement are the same as would be applied for peri-urban landholders, such as getting to know and understand the target audience to inform the design of fit for purpose engagement approaches. The difference in a peri-urban landscape is that there is likely to be a greater number of approaches that need to be used to get the desired uptake.

A detailed understanding of the target audience can inform the development of a tailored mix of engagement approaches that are well matched and aligned. Therefore, with the right engagement approaches, desired rates of uptake and participation are more likely to be achieved. Integrating this sort of social information with biophysical information increases the chances of effecting a meaningful change in NRM.

11.4.3 Learn from Past Experience

While working in peri-urban areas is challenging, it would be wrong to presume that there is no existing information and experience to draw on. There have been many evaluations of peri-urban NRM and biodiversity projects completed and both positive and negative experiences to build on.

11.4.4 Be Prepared to Try New and Innovative Approaches

In many cases it will be necessary to use very different approaches to achieve the required level of engagement to get meaningful NRM outcomes. This may include things like tapping into existing community groups that have little or nothing to do with NRM (e.g. local childcare centre, dog training groups, pony clubs, and CFA/Rural Fire Brigade).

The purpose of engaging through these non-conventional channels is simply to connect with people who may have an interest in the NRM work. Many new landholders are moving into peri-urban landscapes and they may have no connection to traditional environment groups such as Landcare and may not have a good knowledge of the local environment (Mendham and Curtis 2010).

Engagement may need to begin at a very basic level of simply making a connection to landholders through any channel in order to identify whether they have any interest in the local environment and NRM.

11.4.5 Adaptive Management

Given that peri-urban landscapes are dynamic and transitional, NRM projects in these areas also need to be much more responsive and dynamic. Flexibility and adequate review points should be built into the project to frequently gauge the success of engagement. Capturing the right data and information throughout the project will be an important part of monitoring success of these engagement approaches.

Building higher levels of flexibility into the project from the beginning will mean that partners and investors are not surprised when there is a need to adjust the approach to fit the changing audience.

Finally, a greater focus on adaptive management is required when engaging peri-urban landholders, because our understanding of their motivations, interests and barriers to adoption is much less than comparative rural areas (e.g. compared to an area dominated by dairy farming). As this understanding grows, it is likely to identify yet more cases where changes to approaches and techniques are required.

References

Buxton M, Choy DL (2007) Change in peri-urban Australia: implications for land use policies. Paper from the state of Australian cities conference 2007

Buxton M, Tieman G, Bekessy S, Budge T, Coote M, Morcombe J (2006) Change and continuity in peri-urban Australia, state of the peri-urban regions: a review of the literature. RMIT University, Melbourne

CoA (2010) The Melbourne strategic assessment. Department of Environment, Water, Heritage and the Arts, Canberra

Darbas T, MacLeod N, Kearney F, Smith TF, Grounds S (2010) Peri-urbanisation, social heterogeneity and ecological simplification. Socio-economic and environment in discussion CSIRO working paper series 2010–03. CSIRO Canberra, ACT

DPCD (2011) Westernport green wedge management plan discussion paper. Department of Planning and Community Development, Spring Street, Melbourne

DSE (2009) Urban development program report. Department of Sustainability and Environment, Melbourne

Kearney F, MacLeod N (2006) Bushland or parkland: vegetation management in landscapes under rapid conversion. CSIRO Sustainable Ecosystems, Brisbane, (Veg Futures Conference Paper 2006)

Mbiba B, Huchzermeyer M (2007) Contentious development: peri-urban studies in sub-Saharan Africa. Prog Dev Stud 2(2):113–131

Mendham E, Curtis A (2010) Taking over the reins: trends and impacts of changes in rural property ownership. Soc Nat Resour 23(7):653–668

Millward H (2002) Peri-urban residential development in the Halifax region 1960–2000: magnets, constraints, and planning policies. Can Geogr 64(1):33–47

Murphy P, Burnley I (1996) Exurban migration. In: Newton P, Bell M (eds) Population shift – mobility and change in Australia. Australian Government Publishing Service, Canberra, pp 242–258
Nelson A, Deuker KJ (1990) The exurbanisation of America and its planning policy implications. J Plan Educ Res 9(2):91–100
Parberry P, Wilkinson R, Karunaratne K (2008) Square pegs in green wedges? Landholders and NRM in Melbourne's rural hinterland. State of Victoria, Melbourne
State of Victoria (2002) Melbourne 2030, planning for sustainable growth. Victorian Government, Melbourne
Williams J, Read C, Norton T, Dovers S, Burgman M, Proctor W, Anderson H (eds) (2001) Australian state of the environment report 2001: biodiversity theme report. CSIRO Publishing, Canberra
Wyndham City Council (2010) Werribee south green wedge policy and management plan. Wyndham City Council, Melbourne

Chapter 12
Implementing the Urban Farming Master Plan in Horsley Park, Western Sydney: From Planning to Reality

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Abstract Maintaining rural character of peri-urban landscape is a significant challenge in Australia and it is particularly important in Australia to allow sustainable agriculture, horticulture and forestry. The Western Sydney Parklands is an urban park system located in Western Sydney with a commitment to provide urban farming in the Parklands. The Parklands is a 27 km long public open space corridor of approximately 5200 ha. The land is administered and managed by the Western Sydney Parklands Trust (Trust) under the Western Sydney Parkland Act 2006. The Trust is committed to providing 10 % (or about 500 ha) of the Western Sydney Parklands (area 5280 ha) for urban farming as per the Western Sydney Parklands Plan of Management 2020. The strategic objective for the Trust is to develop an approach for converting fallow public land to productive space by providing commercial growers a secure tenure in the Sydney basin. This chapter outlines the process of developing and implementing a master plan for a Horsley Park, Western Sydney. The case study has highlighted that implementation of the master plan has a number of challenges including: legislative and regulatory processes; environmental and social matters; and provides some insights from planning to reality of farming in the Sydney region.

Keywords Landuse • Urban agriculture • Western Sydney and landuse planning

12.1 Introduction

Urbanisation is major challenge worldwide and threatening the rural character of peri-urban landscape and it is particularly important in Australia to allow sustainable agriculture, horticulture and forestry around city fringes. The Western Sydney Parklands is an urban park system located in Western Sydney (Fig. 12.1).

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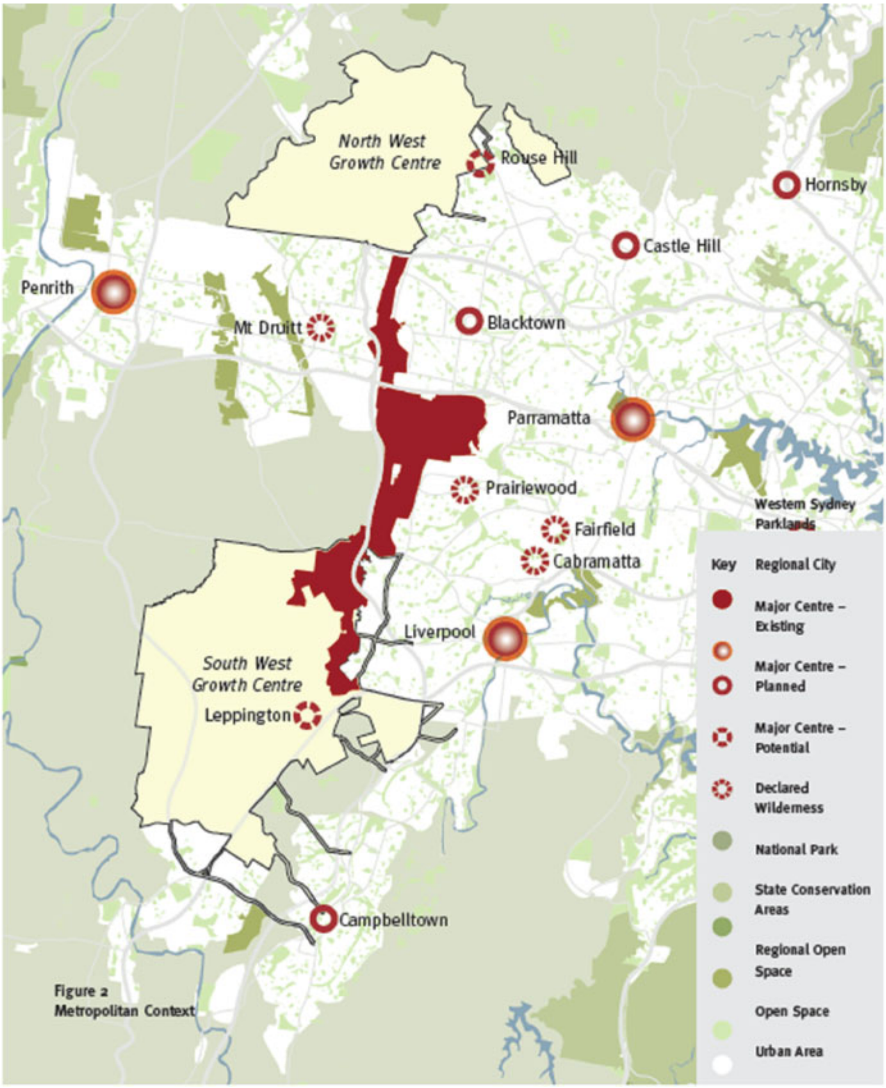

Fig. 12.1 Location of Western Sydney Parkland area (Source: Western Sydney Parklands Trust 2010)

The Parklands is a 27 km long public open space corridor of approximately 5200 ha. The land is administered and managed by the Western Sydney Parklands Trust (Trust) under the Western Sydney Parkland Act 2006. The Act identifies the Trust's principal function to develop a multi-use urban parkland and includes environmental conservation; heritage; regional recreational, entertainment and tourism; regional infrastructure for services such as water, gas and electricity; and 'to maintain the rural character of parts of the Parklands by allowing sustainable agriculture,

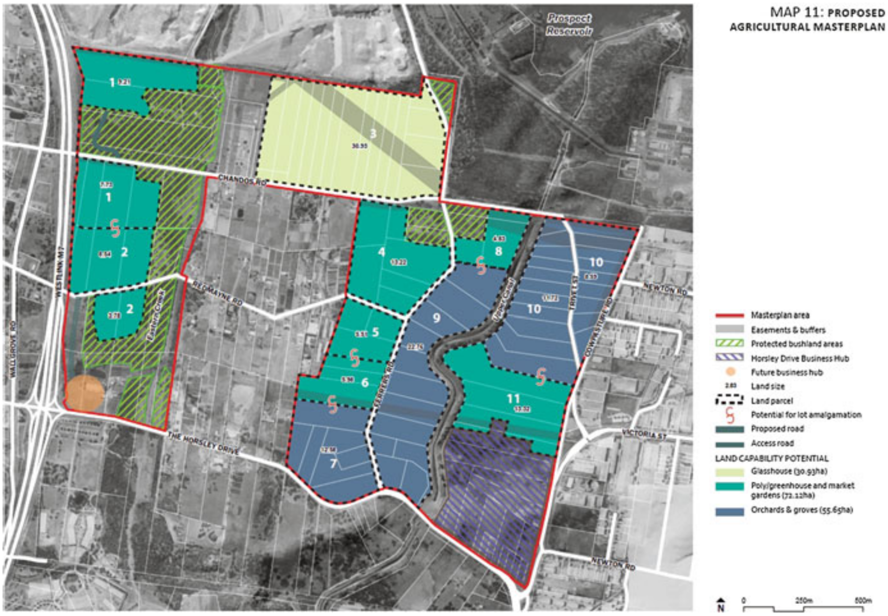

Fig. 12.2 Horsley Park precinct Master Plan in Western Sydney Parkland area (Source: Western Sydney Parklands Trust 2012)

horticulture or forestry in the Parklands'. The Trust land is unzoned and development is governed by the State Environmental Planning Policy (Western Sydney Parklands) 2009 (SEPP) (NSW Legislation 2009).

In 2012, the Trust developed a master plan to take forward the development of a 150 ha urban farming precinct in Horsley Park (Fig. 12.2). The master plan has provided a framework on the type of farming that may be suitable for the land, appropriate lot sizes, sustainability principles and general infrastructure requirements.

The Trust has been established to be a self-funded state government agency. To secure the required revenue to maintain and manage the Parklands assets and its operations, the Trust undertakes partnerships with commercial operators, primarily in the form of leases and licenses in the Parklands. This includes commercial tourism and recreational facilities such as Wet'n'Wild, Tree Top Adventure Park and the Sydney Motorsports Park; the development of business hubs; and smaller commercial operations such as horticulture and livestock agistment.

Although there is a strong commitment to urban farming in metropolitan Sydney strategic plans and directives, there are many variables such as the legislative and regulatory frameworks, variable costs of farming operations, availability of labour in the farming sector and environmental factors which hinder the growth of the urban farming sector in the Sydney Basin.

12.2 Legislative and Regulatory Framework

12.2.1 Requirements for a Development Application and Amendment to the SEPP

In the early stages of the development of the Horsley Park urban farming precinct, the Trust undertook a pilot program to test the market and understand some of the complexities in leasing public land for commercial farming. The pilot program was managed within the New South Wales (NSW) Government procurement process as an open tender application and concluded with the signing of a 3 year lease with an experienced market gardener commercially producing tomatoes, chillies and peppers. The process highlighted a number of challenges for the Trust. Some of these related to social matters in dealing with new migrants and the appropriateness of the government procurement process for these commercial activities. These issues will be discussed in later sections of this paper.

During the pilot process a requirement for a Development Application (DA) to the Local Council as the consent authority was required under the SEPP.

It was clear to the Trust that the new tenant, and indeed other applicants that submitted tenders, had not previously submitted a DA despite operating market gardens on other nearby private lots. In order to progress the pilot program, the Trust prepared and funded the DA on the tenant's behalf.

The approval to the DA detailed a number of conditions that needed to be met before the activity could occur. However, these conditions resulted in additional costs to the Trust and the new tenant. The conditions included the construction of a driveway crossing, fencing and environmental protection measures. Once again, to facilitate the pilot program the Trust undertook to implement the conditions in the consent with the cost of capital works returned to the Trust as part of rental payments.

From the experience gained through the DA the Trust determined that a simplified development approval approach was required. As noted in the introduction, the Parklands land is unzoned and development controls in the Parklands are defined by the SEPP (Western Sydney Parklands). To this end, the Trust identified the best approach would be an amendment to the SEPP to facilitate minor developments for agricultural purposes which could reduce cost and time. Critically, this amendment allows for a change in land use to agriculture without the requirement for development consent. It also enables farmers to immediately commence basic works required for initial farming setup, such as, soil movement, placement of irrigation systems and construction of a small storage shed. The important part of this amendment is that the Trust is now in a position to holistically manage the precinct access, fencing and environmental protection separately to the individual lots and commercial lease arrangements. Larger structures or farming operations still require development approval through normal processes which can be undertaken concurrently with small scale production. The process of amending the SEPP has resulted in a more streamlined and simplified process for the Trust and future operators.

12.2.2 Land Tax Exemptions for Primary Producers

Land tax is an annual tax on the total land value of all taxable land owned in NSW as at midnight 31 December of the previous year. There are a number of land tax exemptions, including an exemption for land used for primary production purposes.

Land investment in the Sydney Basin speculating on future rezoning and development opportunities has, in the short to medium term, provided an opportunity for both farmers and land speculators. The land owners are providing farming leases with little to no rent that enables the application of Land Tax exemption on the land by the land owner.

The influence of this on the Western Sydney Parklands farming program is that the realistic rent rate that the Trust can charge is much lower than the expected market rate or land value rate. This has caused the Trust to re-evaluate rental returns and review the pure financial return expected by the program. Initially the Trust planned a business case purely on the financial return from farming. The Trust is now including the non-financial benefits, such as improved land management, benefits to the local community, improved visual amenity, reduced costs from environmental and noxious weed management and illegal social activities which place an increase financial cost to the Trust such as dumping and vandalism.

12.2.3 Local Government Act and Council Rates

The Local Government Act 1993 defines land which is rateable by Local Councils. Crown Land is exempt from rates except where the land is held under lease for private purposes. Under these circumstances it is stated in the Act that the lessee is liable for the rates. As such, as soon as the Trust enters into a lease with a commercial farmer, the land becomes rateable with the cost borne by the farmer. Whilst the rates begin immediately, production on the land and a commercial return may take months and sometimes years.

On similarly leased private blocks in the Sydney Basin, the land owner will bear the cost of rates irrespective of activity on the land. The introduction of farming on the lot may allow the land owner to argue for a reduction in rates depending on the rateable category that is assessed.

The Local Council has advised that they have no discretion for any reduction, exemption or staggered application of Local Council rates. They are simply following the Local Government Act and application of rates based on Gross Rental Value as assessed by the Valuer General's Office every 4 years. They will consider a deferred payment but with the application of interest charges. The impact of rates has in effect doubled the rental charge. The net result is a marginal business model and a constraint on the financial operation of the Trust's program. The Trust is investigating the possibility of identifying any possibilities for incentives using staggered application of rates to allow the business to develop. This approach is already used by the Trust with rent waiver periods and scaled application of rents.

12.3 Environmental

12.3.1 Water Supply, Harvesting and Storage

Access to the water supply for the Horsley Park urban farming precinct is generally not an issue with Sydney Water's potable water supply lines being readily accessible. However, the cost to connect to this infrastructure, including an appropriately sized connection with backflow device and the ongoing supply costs place a heavy burden on commercial returns to the tenant.

One alternate is overland flow harvesting, tail water reticulation and storage in onsite farm dams. In a peri-urban environment, with increasing industrial and residential development within the catchment causing excessive run off from hard surfaces, the addition of dams to harvest water for agriculture makes perfect sense in the water balance equation. However, with the current embargo on Water Access Licenses, and no sub-catchment analysis of water balance completed, the difficulty in obtaining approval to construct new dams or utilise new water without purchasing an existing license is providing obstacles for the Trust and the potential tenants. This is exacerbated by a water market in Sydney that is relatively small and difficult to identify. Transfer availability and costs are uncertain.

The Trust undertook to develop a water harvesting and dam plan for the Horsley Park urban farming precinct with a view to consolidate this in a wider catchment context in discussion with NSW Office of Water.

Briefly, the dam plan process is:

- assessment of existing dam conditions and adequacy of structural elements,
- assess Maximum Harvestable Rights for current dams and Water Access License compliance,
- identify opportunities for increased water storage capacity and assess opportunities for improved water capture and circulation within each parcel to optimise water yield, and
- provide preliminary water security assessment and water quality analysis for each parcel and identify further works to optimise site water management.

Critically, the dam plan identified that storage is not the main issue for the precinct and that supply from rainfall and run off was the limiting factor. Long term this issue will need to be addressed and it is hoped the precinct will provide opportunities for development of larger stormwater harvesting from nearby industrial areas or possible sewerage treatment and reticulation. As the Horsley Park urban farming precinct develops the Trust will be looking towards innovation and investment to support water supply to the precinct.

The project is ongoing and the next stage is to work closely with the Office of Water to gain approvals and licenses for the precinct, based on the water harvesting and dam plan, and commence capital works for existing dam repairs, new dams and reticulation basin construction. The Trust is concerned about the costs of these works and acknowledges that these costs may not be fully recoverable from commercial leases.

12.3.2 Environmental and Noxious Weeds

The Horsley Park urban farming precinct is largely fallow, unmanaged lots. The spread of noxious and environmental weeds, mainly blackberry, is rife across the precinct.

Noxious weeds are plants that are controlled under the Noxious Weeds Act 1993 in NSW which is enforced by the Local Councils. Control actions will vary depending on the risk to primary production, cost to undertake the control and the ultimate benefit. They include actions such as complete removal and suppression through to restrictions on sale or propagation.

The majority of weeds in the urban farming precinct are class 4 weeds, meaning they are a serious threat and widespread. As such, the cost to control them is prohibitive so the legislated control measure for most of these species is limited to restricting propagation or sale. This highlights the reason for the spread of these weeds, that is, there is no forced control.

The impact for the Trust is that many lots are not suitable to take to the market without large capital investment in the removal of weeds. Many of these species will take many years and control attempts before they succeed. To counter this issue the Trust has embarked on a program of crash grazing. Lots are offered free of charge for short term grazing. Agistees are required to erect fencing to contain the animals and manage all access issues. There has been considerable success in the reduction of African Olive using cattle and some limited impact on the spread of Blackberry. The Trust is in the process of seeking other livestock, such as goats, that may help remove the Blackberry.

12.3.3 Critically Endangered Cumberland Plain Woodland

The Horsley Park urban farming precinct was selected within the Parklands as it was historically cleared farmland and, as such, is largely cleared of native vegetation. However, there are some small remnant patches that are important refuges and stepping stone links to larger conservation areas. These patches of bushland are of vegetation type ‘Cumberland Plain Woodland’ and are therefore protected under State and Federal Government legislation.

The Trust has implemented a Parklands Biodiversity Strategy and has included the bushland remnants within bush regeneration works that occur throughout the Parklands. Where bushland occurs on lease lots, the lease includes clauses excluding access and use of the bushland areas and allowance for the Trust's contractors to access the area for management.

12.4 Social

12.4.1 Government Procurement Process

As a government agency the Trust is required to follow Government Procurement Guidelines in offering public land to the private sector. This process is to ensure probity and equity in the market place. The reality is that it creates barriers for entry into the market for many market gardeners. The pilot project conducted prior to the master plan for the precinct provided the Trust with good insight into this issue.

The Trust released a 'Request for Proposals' to the market with an 18 page document providing details on the lot to lease, the tender process and required information to be submitted by the applicant. Information requested by the Trust included financial capacity to fund and maintain any capital works and improvements, skills and experience of key staff and a demonstration of the organisation's track record in farming, the proposed operation and in particular, to assess the impacts on public land, how the operation would respond to:

- land and soil management,
- water management,
- chemical management,
- nutrient management,
- biodiversity,
- waste management,
- air management, and
- energy management.

The applications were reviewed and assessed by an independent panel against selection criteria (weighted). The assessment included site visits by the panel to applicants existing operations. In an attempt to gain better market exposure, the Trust engaged a local real estate agent to market the opportunity through local papers and with site visits to the local produce markets to meet directly with suppliers. The agent was not part of the assessment panel so could be tasked with helping the applicants with their submissions.

Through all these efforts the Trust received six applications and most were deficient in information requested. The site visits and personal interviews proved of most benefit for the Trust in assessing operations and suitability to enter into a lease on public land. All of the applicants were from non-English speaking backgrounds and all expressed difficulty in understanding the requirements in the application process.

Following the application process, the Trust encountered further delays and negotiation with the successful applicant. The clauses within the lease, necessary to ensure the sustainable operation on public land, created anxiety for the applicant. The Trust desired an outcome whereby the operators leasing in the Horsley Park urban farming precinct would commit to achieving sustainable farming practices. Initially the lease included requirements to move toward environmental accreditation of their operation. Several meetings were required and clauses amended to a 'guideline' approach to address these concerns.

The successful applicant was a migrant from Cambodia and was fearful of Government processes. The advice received from the NSW Department of Primary Industries and other consultants in the industry was that even the best support and advice was viewed with suspicion if it came from a government source.

Following from this early experience the Trust made an attempt to simplify the early stages of the application. The aim was to obtain applications and then engage with appropriate applicants personally to garner further information. This process was to build a relationship with the applicant to foster trust. However, the few applicants who submitted during this approach became frustrated by the level of investigation by the Trust. The Trust, in safeguarding the financial risk to this public asset requested a thorough understanding of the operator's business model. This level of scrutiny was not apparent in the early stages of the simplified process and the applicants withdrew. In one case, whilst the Trust was undertaking its deliberations, the applicant was offered an alternative private block of land with no rental charge and was able to access the land immediately. Subsequently the applicant withdrew from the negotiation process with the Trust. The Trust is still working to achieve a balance in its process whereby it is simple and quick for the applicant but also transparent, risks are identified early and the arrangement is financially viable for the Trust.

12.4.2 Migrant Farmers and Generational Change

Within the Horsley Park urban farming precinct the Trust had one existing medium scale operator who had leased Trust land for many years. Their family ties to the area started when their father migrated to Australia from Malta and started farming in the area and the business continues with two brothers operating the farm. This business operates with a core staff of Vietnamese migrant workers.

The issue facing this operator is that his children are moving away from farming as a business so there is little chance for generational handover of the family operation. Also, his core staff is aging and on the occasion where the business has required additional staff it has been very difficult to source reliable workers.

This is a similar story to the applicant in the pilot project that operates his farm with the support of integrated family (his daughters and their partners). His daughter has just completed a University degree and moving to full time employment so her availability to support the farm at times of high activity continues to decline. The farmer also holds down two additional jobs to support the farm during low economic times, poor environmental conditions and to meet family financial obligations. This has led to periods where, as a contracted worker elsewhere, the farming program has been delayed or missed seasons due to lack of resources.

The Trust has experiences with similar issues through other applications to lease the land that did not proceed. Many are small scale with little to no supporting workforce that creates a risk for the Trust. Others are first time farmers looking to start in the business and the lack of experience is also a risk to the Trust. All applicants request some form of accommodation on the land to reduce costs and time constraints and enable the family unit to assist more efficiently. The Trust, under the SEPP (Western Sydney Parklands), does not permit residential dwellings and existing residential dwellings are disconnected from the farming land or require extensive maintenance to make them fit for purpose.

The information to the Trust through discussions with operators in the region is that the larger scale farmers are either secure on their land or are moving west of the Blue Mountains to larger lots with smaller overheads and are offsetting the additional transport time and costs to market.

12.5 Conclusions

This Chapter is a snapshot in the early stages of a long-term program to model urban farming opportunities on public land in the Sydney Basin. It details the challenges facing the Trust's urban farming program and the diversity of factors that it must address to be successful in achieving this outcome. The Trust will continue to pursue the implementation of the Horsley Park urban farming master plan as it is committed to the environmental, land use and social outcomes that this activity can provide to the Parklands and the Sydney Basin.

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References

NSW Legislation (2009) NSW State Environmental Planning Policy (Western Sydney Parklands). http://www.legislation.nsw.gov.au/maintop/view/inforce/epi+91+2009+cd+0+N. Accessed 10 Aug 2015

Western Sydney Parklands Trust (2010) Western Sydney Parklands Plan of Management 2020, Parramatta, NSW, 80p

Western Sydney Parklands Trust (2012) Horsley Park Precinct, Urban Farming Master Plan, Parramatta, NSW, 55p

Part V
Urban Water Security

Chapter 13
Study of Urban Water Bodies in View of Potential for Micro-climatic Cooling and Natural Purification of Waste Water

Abu Taib Mohammed Shahjahan and Khandaker Shabbir Ahmed

Abstract Urban wet lands and water bodies can reduce overheating of the urban environment as well their general function of natural water purification. Nonetheless, urban wetlands are either diminishing or contracted from their original shape and size due to pressures from the housing sector and unplanned urbanisation. This chapter presents the findings of a study investigating into the possible relationships existing between water quality of urban and peri-urban water bodies and three selected parameters; shape complexity, micro-climatic temperature and land use around water bodies. For this reason three urban and one peri-urban water bodies in Dhaka have been studied with regard to those four parameters. The study was conducted by both parametric techniques and field campaigns.

Keywords Urban water bodies • Micro-climatic cooling • Shape complexity • Housing sector • Water quality

13.1 Introduction

Anthropogenic activities causes build-up of Green House Gases (GHG) such as CO_2 and Methane, leading to increased global temperature. Spatially, cities are the highest centres of such anthropogenic activities and are major consumers of fossil fuels with over an 80 % of the global consumption. Given this, growing urban influence in consumption pattern and the need for local action as a way forward for securing global sustainable development was highlighted at the 1992 Rio Conference.

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Cities pose a significant field through which to address Climate Change (CC) as urban areas represent sites of high consumption of energy and production of waste. Dhaka being one of the most populated and polluted cities in the world, where the juxtaposition of wetlands and urban contexts have an opportunity for creating a viable and distinct character of its own. It has been reported that in the case of Dhaka during the summer months there exists a positive correlation between increased consumption of electrical energy and physiological stress and higher air temperature. Urban wet lands and water bodies have a role in balancing the over-heating environment, even though they are either diminishing or contracted from their original shape and size due to pressures from housing sector and unplanned urbanisation in Dhaka. The edge of the water bodies are modified from their natural shape by filling. Further, in this modification process all the natural reed plants, which grow inside and at the edge of the water bodies, are removed which is evident from several urban water body development projects of Dhaka.

Natural wetland always acted as nature's own purification plant in the presence of different reed plant species i.e. Sedges, Rushes and Irises help to purify the waste water in a natural way by reducing COD content of water, oxygenation, elimination of pathogens, ammonium degradation, degradation of nitrate, removal of phosphates and heavy metal. The filling up and shape modification of the water body from their original shape greatly affects the urban micro-climatic cooling capacity and natural water purification potential. It is evident from several studies that water pollution of urban water body due to human induced land use correlated with the shape complexity of the water reservoir. Water bodies with simple geometric shape are always related with human induced land use whereas natural water bodies are mostly of complex geometric shape. Water bodies with a complex geometric shape can reduce the magnitude of water pollution. Urban land use also has a direct impact on the urban microclimate which results in Urban Heat Island Effect (Ahmed 1995). Urban water bodies can play an effective role in microclimatic cooling of the urban area. So in this context, the present research aims to investigate the relationships between the geometric shapes of urban wetlands, their water quality characteristics, urban microclimates and urban land use adjacent to wetlands.

13.2 Methodology

13.2.1 General

The study was conducted by both parametric techniques and field campaigns. Four Water bodies of Dhaka city were included in the study. Among the those four water bodies three are located in the main urban area and one is located in the fringe of Dhaka. The water bodies located in the main urban area are: HatirJheel lake, Banani (adjacent to Gulshan lake) and the Dhanmondi lake. The fourth water body named Alubdi lake is located at the fringe of Dhaka in the area named Mirpur. The three water bodies located in the main urban area have gone under design intervention by professional planners and architects. The fourth water body at the fringe is not protected and the area of this water body is decreasing by continuous earth filling to extend housing area. In a study by Hwang et al. (2007) it was identified that "Urban land use within a watershed affects the water quality of the adjacent water reservoirs, and that the magnitude of this impact might depend on the shape complexity of the reservoirs". Their results also identified that human related land use is always associated with simple geometric shape of the water reservoirs, whereas the shape of the water reservoirs located in the area not effected by anthropogenic activities are mostly complex. Their study further showed that the shape complexity of a water reservoirs helps to counteract the negative impact of human induced land-use on the urban and peri-urban water bodies. It could be also observed from the study of Ahmed (1995) that urban land use has a direct impact on the urban microclimate which is resulting in Urban Heat Island Effect. From the study of environmental chemistry (Bunce 1991) it could be suggested that this hot urban environment impacts the water quality of urban wetland in a negative way. Dissolved oxygen is must for the existence of all aquatic life (Bunce 1991). Without sufficient oxygen in the water almost all the aquatic life in the water including fish will die. There are several reasons for oxygen depletion in water like thermal pollution, oxidisable substances in water from sewage, factory effluents, agricultural run-off etc., and decomposition of bio-mass like algal blooms (Bunce 1991). In high temperature oxidisation will be faster and it is impossible for replenishment of oxygen from the air to keep pace with this depletion. So descriptors (indicators of organic matter) of the oxygen status of urban wetlands which will be taken in the research are Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD). The nutrient that will be considered in the research for the water quality analysis of the urban wetland is Total nitrogen (TN). Two other parameters that will be considered for water quality tests are faecal coliforms and Total Suspended Solids (TSS).

It could be inferred from the above study of literature that urban land use, urban micro climate and water quality of the urban wetland are interrelated. So in this context, the present research aims to investigate the relationship between the geometric shape of an urban wetland, it's water quality characteristics, urban microclimate and urban land use adjacent to the wetland. The underlying rationale of this research is that urban and peri-urban wetlands can be considered as a basic unit of landscape "patch", whose shape complexity determines the characteristics of its edge. The permeability of edge controls the influx of pollutant into the wetland due to the surface water runoff. The characteristics of edge also determine the microclimatic cooling effect of the wetland. So the shape complexity of urban and peri-urban wetlands have unique effects on the relationship between the three parameters urban land-use type, urban micro climate and water quality characteristics of the urban wetland. Originality of this research is that effect of shape complexity of urban wetland on urban microclimate as a fourth parameter would be investigated besides its interrelationship to other two parameters urban land-use type and water quality characteristics of the urban wetland.

Based on the above discussion Four parameters have been identified as having an impact on the phenomenon discussed above i.e. shape of water body, water quality, land use and microclimate.

13.2.2 Shape Complexity

Shape complexity of the selected urban wetlands was measured using Fragstat software. One type of shape index based on perimeter-area relationships is the Fractal Dimension Index (FRAC). FRAC would be used to measure the shape complexity of urban wetland. As described in the Fragstat software manual "Benoit B. Mandelbrot (1977, 1982,) introduced the concept of fractal, a geometric form that exhibits structure at all spatial scales, and proposed a perimeter-area method to calculate the fractal dimension of natural planar shapes." As per the Fragstat software manual FRAC equals two times the logarithm of patch perimeter (m) divided by the logarithm of patch area (m^2); the perimeter is adjusted to correct for the raster bias in perimeter. The equation is given below:

$$\mathrm{FRAC} = \frac{2\ln\left(.25p_{ij}\right)}{a_{ij}}$$

where p_{ij} = perimeter (m) of patch ij, and a_{ij} = area (m^2) of patch ij.

A fractal dimension greater than one for a two-dimensional patch indicates a departure from a Euclidean geometry indicating an increase in shape complexity (McGarigal and Marks 1995). FRAC approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling (Mandelbrot 1982) perimeters. ESRI (Environmental Systems Research Institute) grid (Raster GIS file format) file of the shape of Urban Wetlands as an input for the Fragstat software was prepared by GIS software ARCMAP 10. Again the Autocad drawing file containing the shape information of urban wetlands was prepared with the help of google earth image. This Autocad drawing file was imported to ARCMAP 10 to prepare the ESRI grid file. In the Fragstat software FRAC value for the shape of each of the four urban wetlands was determined by running the software at patch level.

13.2.3 Water Quality

The water quality of selected water wetlands of both urban and urban fringe area in the study was measured at Environmental Microbiology Laboratory, icddr, b, Mohakhali, Dhaka. Descriptors (indicators of organic matter) of the oxygen status of urban wetland taken in the research are Chemical Oxygen Demand (COD) and

Biochemical Oxygen Demand (BOD). The nutrients that were considered in the research for the water quality analysis of the urban wetland are, Total nitrogen: TN. Total Suspended Solids: TSS test are conducted to determine the suspended solids in the water. Faecal coliforms, a subset of total coliform bacteria, are used as indicators of possible sewage contamination because they are commonly found in human and animal faeces (U.S. Environmental Protection Agency).

Faecal coliform tests were conducted to determine the faecal coliform bacteria which are the most common microbiological contaminants of natural waters. To make the sample of water collected from each water body as much representative as possible of the particular water body following procedure was followed. Firstly, a big bucket was fully soaked in the water of the lake to make the microbial condition as same as the water body. Secondly, water samples from different points both at the edge and middle of the lake were collected and mixed in that particular water bucket. Finally the water container supplied by the icddrb was filled with the water from that bucket and supplied to Environmental Microbiology Laboratory, icddrb for testing within 2 h of collection. The vegetal configurations at the edge of the water bodies in the study are also recorded.

13.2.4 Land Use

GIS land-use map of Dhaka city compiled by the RAJUK (Dhaka development Authority) was studied within the watersheds of the selected urban wetlands. The categories of land use designated in the maps are residential uses, mixed uses, commercial (offices and retails), industrial, recreational, slum, health facility, roads and water bodies. In this study a buffer zone of half a kilometre (0.5 km) was considered to study the direct impact of urban land use on water quality.

13.2.5 Urban Micro-climatic Measurement

For urban micro-climatic measurement, temperature profile within the half (0.5) km buffer zone created for urban land use around each urban wetland was created by direct spot measurement. Measurement campaign around each water body was conducted in between 12:00 and 15:00 as this is the hottest period of the day in Dhaka. Mean air temperature of those spot measurements was then calculated. Two air temperature reading one at 12:00 and the other at 15:00 by the meteorological station of the Dhaka city of the corresponding day of spot measurement campaign was collected. The average of these two reading is the mean regional air temperature in between 12:00. and 15:00. of the Dhaka city. The difference between the mean air temperature of the spot measurement around each water body and the mean regional air temperature of that particular day is then determined. This value is a good indicator of how hot the urban micro climate is.

Finally all the four parameters were correlated to find out if the overheated urban microclimate within a watershed deteriorates the urban water quality of the wetland by decreasing dissolved oxygen in the water. Urban wetlands with complex shape in its natural form can positively contribute to water quality while simultaneously moderating the negative effects of land use and increasing the cooling capacity of urban wetland (Hwang et al. 2007).

13.3 Results and Discussion

To determine the shape complexity of the urban wetland Fractal Dimension Index (FRAC) was calculated using Fragstat software (Table 13.1). From the FRAC value it is evident that Dhanmondi Lake has the most complex shape and Alubdi Lake has a comparatively simpler shape, as it is changing from its natural shape due to the earth filling.

The test results of the water quality of the selected urban wetlands are given on Table 13.2. From the water quality report it is evident that the quality of water at Dhanmondi Lake is best and Hatirjheel Lake is the worst. The quality of water at Alubdi Lake located at urban fringe are much closer to Dhanmondi Lake specially in terms of faecal coliform count although this water body is not protected like the other three. One of the reasons could be the presence of large amount of reed plants at the edge of this water body as shown in the Fig. 13.1. Reed plants are also present

Table 13.1 Fractal dimension index of the lake shape

Lake	Fractal dimension index (FRAC)
HatirJheel	1.1507
Banani	1.1599
Dhanmondi	1.2334
Alubdi	1.112

Table 13.2 Water quality report of the lake

Water quality parameters	Unit	Hatirjheel lake	Banani lake	Dhanmondi lake	Mirpur Alubdi lake
Faecal coliforms	CFU/100 mL	270,000	105,000	600	1,500
Chemical oxygen demand (COD)	mg/L	17.5	15	<3.0	12.5
Biological oxygen demand (BOD; 20° C)	mg/L	6	5	<2.0	4
Total nitrogen (TN)	mg/L	2.68	1.6	0.86	1.75
Total Suspended Solids (TSS)	mg/L	134	186	37	265

Fig. 13.1 Reed plants at the edge of the Alubdi lake

Table 13.3 Land use in percentage of total area with in half km buffer zone of the lake

Land use in percentage of the total area in the buffer zone	HatirJheel	Banani	Dhanmondi	Alubdi
Residential land use %	10.1	32.67	70.95	91.46
Mixed use land use %	2.53	0.01	7.92	0.001
Commercial land use %	1.32	0.0021	1.5	0.5
Industrial land use %	5.69	0	0	0
Health facility land use %	0.36	67.02	0	0
Road land use %	5	0.0147	18.48	2.21
Recreational land use %	0	0.002	1.13	0
Slum land use %	0	0	0.02	1.11
GraveYard land Use %	0	0.0001	0	0
Unknown land use %	74.99	0.2783	0	4.71

at Dhanmondi Lake both at the edge and under water although all types of reeds were cleared off during the time of development work of this lake. Those plants naturally grew back and helped to improve the water quality. In the other two lakes all the natural reeds were completely cleared off during the development work. Due to the better water quality there is aquatic life in Alubdi and Dhanmondi Lake. Some bird species like Kingfisher could be observed at the Alubdi Lake.

The result of the GIS land use map analysis of the Dhaka city within half km buffer zone around each lake are given below. The entire land use category is given in percentage of the total area (Table 13.3). It is clear from the result that Dhanmondi (70.95 %) and Alubdi (91.46 %) have mostly residential use around them whereas Hatirjheel (10.1 %) and Banani (32.67 %) have less residential use. Around

Table 13.4 Urban micro-climatic measurement around the lake

Lake	Temperature difference °C
HatirJheel	2.07
Banani	1.29
Dhanmondi	0.63
Alubdi	2.46

Hatirjheel Lake there is industrial land use (5.69 %) which other lakes do not have around them. A higher portion of health facilities are located around Banani Lake within the buffer zone.

All the average spot temperature measure around the lake in the study is above the air temperature reading by the meteorological station of the Dhaka city. Table 13.4 shows the temperature differences. Dhanmondi Lake has the lowest temperature difference whereas Alubdi lake has the highest temperature difference. Dhanmondi Lake has the highest level of vegetation around it and Alubdi Lake is almost devoid of shading trees. Although there is no hard pavement such as concrete around the Alubdi Lake the land fill around it is sand, which becomes much hotter in the day in comparison to natural soil and grass cover. HatirJheel Lake has the most hard pavement around it and is also devoid of shading trees.

It can be inferred from the result that shape complexity has a positive impact on the water quality as the lake with best water quality in the study is Dhanmondi Lake which has the most complex shape in terms of FRAC value (Table 13.5). Although the lake with the second best water quality, Alubdi Lake has the least complex shape among the four. This is due to constant change of the shape of Alubdi Lake due to human intervention by earth filling of the area of the lake.

The lake with the best water quality in the study, Dhanmondi Lake, has the minimum temperature difference with the regional temperature i.e. temperature from the meteorological department of Dhaka city. There could be several reasons behind the lower temperature difference such as the presence of large amount of vegetation, less hard paved areas and also the shape complexity. Again in this case Alubdi Lake has the second best water quality has having the highest temperature difference because of an absence of shade trees, sand instead of normal soil and grass cover around it due to land filling and also a change of its natural fractal shape due to earth filling.

Both the Dhanmondi and Alubdi Lakes are having mostly residential use around them which may have a positive impact on the water quality. One things to note is that human sewage flow into Dhanmondi Lake is stopped during the development process which is definitely helping to improve water quality. In case of unprotected Alubdi Lake, although human sewage together with animal excreta flows into the lake, the water quality is relatively good due to the presence of natural reed plants which are proven to have water purification capabilities. The highest reading of TSS in the Alubdi Lake is due to earth filling for residential use, which is also changing and decreasing its original shape.

Table 13.5 Co-relating the results of the analysis done for the lake

Lake	FRAC	Faecal coliforms CFU/100 mL	COD mg/L	BOD; 20° C) mg/L	TN mg/L	TSS	Temperature difference deg C	Residential land use %	Industrial land use %	Health facility land use %
Hatir Jheel	1.1507	270,000	17.5	6	2.68	134	2.07	10.1	5.69	0.36
Banani	1.1599	105,000	15	5	1.6	186	1.29	32.67	0	67.02
Dhanmondi	1.2334	600	<3.0	<2.0	0.86	37	0.63	70.95	0	0
Alubdi	1.112	1500	12.5	4	1.75	265	2.46	91.46	0	0

13.4 Limitations of the Study

There are several limitations of the study as given below:

- The number of lake in the study is relatively low; this is due to the high cost of water quality test in icddr, b, which is an internationally recognised organisation for its reliable testing quality. There should be more samples from the fringe areas of the lakes. Some lakes from the rural setting should also be included in the study.
- There was a lack of data logging instruments to log the temperature data at the same time on the same day around each lake. The author measured the spot temperature with Thermo-Hygrometer around different lakes on different days. However comparing the temperature difference with the data from the meteorological department is also a way to overcome the problem of not having enough data logging instruments, as this method has proven to be an effective way of measuring urban micro climatic temperature. This method is also used in previous research (Ahmed 1995).
- Simulation study with the help of ENVI-MET should be conducted to see urban micro climatic effect if the lake in the study has a simple and pure geometric shape.
- The natural reeds present in the Dhanmondi and Alubdi Lakes should be tested separately for the extent of their water purification capabilities with the help of REED Bed or Constructed Wetland.

13.5 Conclusions

The findings of this research would have the potential for use in urban wetland areas of Dhaka in the form of 'landscaped water parks' which besides water purification and micro-climatic cooling, will also serve purposes of leisure and have park amenities. Urban cooling in a growing energy crisis in the Dhaka city will be an effective way forward along with the supply of recycled urban waste water by natural means. A significant part of the urban wetland of Dhaka would be constructed to enhance the habitats for birds and fish, such as to establish a thriving ecosystem which would also enhance activities like bird watching. Such a wetland would also help in recharging groundwater which in turn reduces earthquake vulnerability.

References

Ahmed KS (1995) Approaches to bioclimatic urban design for the tropics with special reference to Dhaka, Bangladesh. Phd thesis, Environment and Energy studies Programme, Architectural Association School of Architecture, London

Bunce NJ (1991) Environmental chemistry. Wuerz Publishing Limited, Winnipeg

Hwang SJ, Lee SW, Ju-Youn Sona JY, Park GA, Kimb SJ (2007) Moderating effects of the geometry of reservoirs on the relation between urban land use and water quality. Landsc Urban Plan 82(2007):175–183

Mandelbrot BB (1977) Fractals, form, chance and dimension. W. H. Freeman and Co., New York

Mandelbrot BB (1982) The fractal geometry of nature. W. H. Freeman and Co., New York

McGarigal K, Marks BJ (1995) Fragstats: spatial pattern analysis program for quantifying landscape structure. General technical report PNW-GTR- 351, USDA Forest Service, Pacific Northwest Research Station, Portland, OR

Internet Sources

McGarigal K (2015) Fragstats help. Computer software documentation produced by the authors at the University of Massachusetts, Amherst. http://www.umass.edu/landeco/research/fragstats/documents/fragstats_documents.html. Accessed 12 Aug

Chapter 14
Groundwater Crisis of a Mega City: A Case Study of New Delhi, India

Vijendra K. Boken

Abstract This chapter analyses the groundwater table data derived from various wells across Delhi for the 2007–2011 period in order to examine the fluctuation in the groundwater table. Due to the inconsistency in data coverage, data for only one pre-monsoon month (May) was analysed. It was found that the depth to the groundwater table increased during 2007–2010 for all of the districts except the northeast district. Nevertheless, this trend changed in 2011 due to the groundwater recharge and heavy rains in 2010. Parameters influencing the groundwater availability (e.g., population growth and density, urbanisation etc.) indicate that Delhi may soon face a groundwater crisis if efforts to retard population influx into Delhi is not checked. This could be done by improving economy and infrastructure in the adjoining states thus making Delhi less attractive for the migrating population. In addition, the practice of apartmentisation (converting single or double story homes into multiple apartments) should be slowed down or permitted wisely by bearing in mind future groundwater sustainability.

Keywords Groundwater crisis • Sustainability • Groundwater table • Popolation influx • Migration

14.1 Introduction

Delhi is one of the mega cities in the world with the current population (including suburbs) exceeding 20 million. In the past few decades, its population has grown rapidly. People from other states migrate to Delhi for various reasons and thus contribute significantly to its peri-urban growth. Homeowners who owned a single family home 20–30 years ago now have redesigned or reconstructed their homes converting them in multi-storey apartments to earn rental income. The plot that housed a

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single family of five or six people 20–30 years ago is now occupied by 20 or more people. In addition, commercially developed multi-apartment complexes have added significantly to the population thus enhancing the water demand enormously. To ensure the water availability for the increased population is one of the main concerns Delhi faces today. Urbanisation and development works (Rohilla 2012) cause an increase in built-up area leaving less area as permeable land that is able to recharge the groundwater table.

Due to the lack of a municipal water supply for the increased population, many households, particularly rapidly developing multi-story apartments, have set up their own tube wells to extract groundwater to meet their water demands. Such a practice has caused a decline in the groundwater table over a long period of time. With uncertainties both in the development practices and in the arrival of the monsoon, the declining groundwater table can lead to a crisis. This chapter discusses fluctuations in the groundwater table in the context of the population growth and suggests incorporating the groundwater availability as an increasingly important factor in all developmental plans for the city.

14.2 Study Area

The study area includes the National Capital Territory (NCT) of Delhi, India. Delhi is currently a pseudo-state, unlike other regular states of India, and is governed by both the federal government and the state government. The total geographical area of Delhi is about 1483 Km^2 (Shekhar et al. n.d). Its geographical coordinates are centered approximately at 28.38° North latitude and 77.13° East longitude. The responsibility of providing water for various purposes (domestic, agricultural, industrial, recreational.) rests with the state government. Both the surface and the groundwater resources are used to meet the water demand of Delhites.

Delhi receives about 755 mm of annual rainfall (average for the 1981–2005 period; rainwaterharvesting.org), about 80 % of which falls during the monsoon period (June through September). Administratively, Delhi is divided into nine districts (Central, North, South, East, Northeast, Southwest, New, Northwest, and West Delhi) as shown in Fig. 14.1.

Significant variation in the depth to groundwater table exists across Delhi (Dash et al. 2010). The groundwater situation in these districts depends on the hydrogeological formations (Maria 2006), the population density, and the urban versus rural area ratio.

Delhi's population has increased rapidly in recent decades. However, the growth rate varied significantly across districts. Figure 14.2 presents how the population density has varied during 1991–2011. The East and the Northeast districts have registered much higher growth rate in population density than the remaining districts.

Fig. 14.1 Administrative districts of Delhi, India

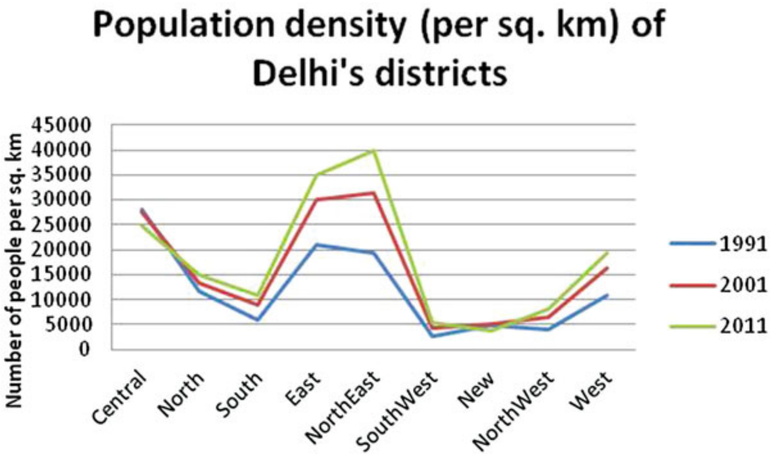

Fig. 14.2 The population density of different districts of Delhi

14.3 Methods

The objective of this study was to examine the variation in the groundwater table in different districts of Delhi. Ideally, the study required the groundwater data for a longer period, for example, since 1980, but the actual data were not available by the

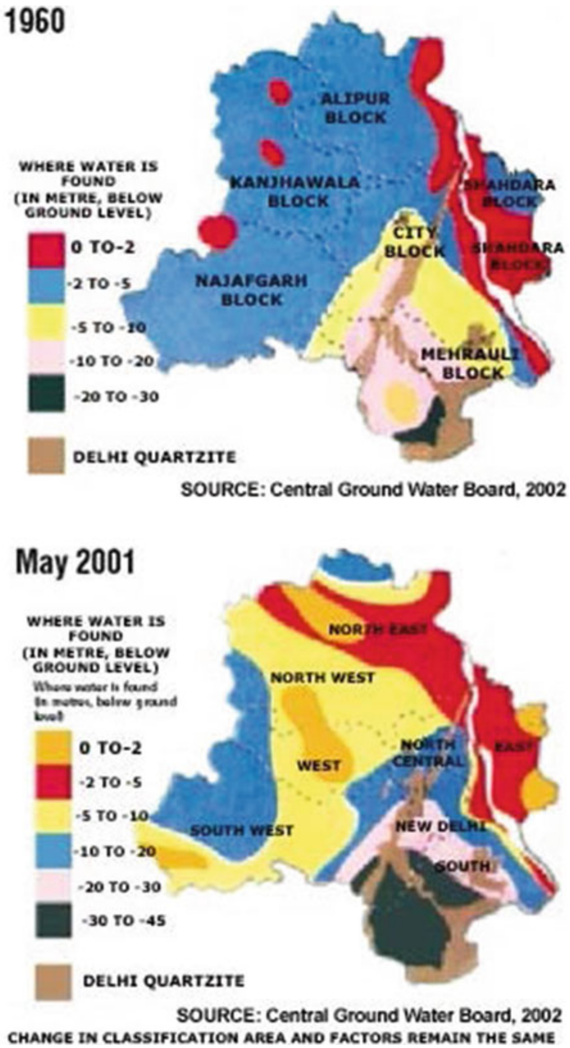

Fig. 14.3 The depth to ground water in Delhi in 1960 and 2001

time this chapter was written. The author is continuing his efforts to acquire data for a longer period. Figure 14.3 shows the depth-to-groundwater data in 1960 and 2001 showing significant fall in the water table.

14.3.1 Delhi's Water Demand

A significant number of Delhi homes are unofficially connected to the municipal water supply and therefore do not pay their water bills. For unknown reasons, Delhi's Water Department does not enforce monitoring of unofficial/unmetered

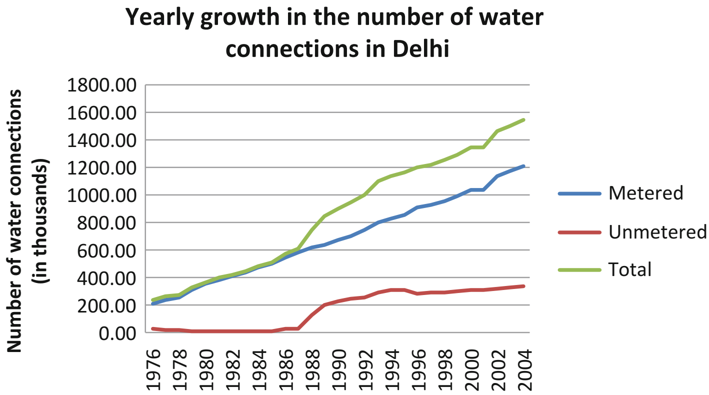

Fig. 14.4 The growth in the number of water connections in Delhi

connections. Figure 14.4 shows the growth in metered and unmetered connections. The unmetered connections are more common in rural or semi-urban areas of Delhi. Under such a situation, it is hard to estimate the actual water usage.

14.3.2 Data Collection

The depth-to-groundwater table data were collected from the Central Groundwater Board, New Delhi. The data were available only for the 2007–2011 period; no data were made available for the period prior to 2007. Significant inconsistency in the data existed. The depth to the groundwater table was measured in different months of the year in different wells across Delhi. The maximum observations were made in the month of May, prior to the beginning of the monsoon/rainy season. Therefore the May data were analysed for this study to achieve greater consistency and reliability. The wells with missing data for more than 1 year were not included in the analysis.

The number of wells for which data were consistently available was 2 for Central Delhi, 14 for East Delhi, 23 for New Delhi, 11 for North Delhi, 5 for Northeast Delhi, 39 for Northwest Delhi, 38 for South Delhi, 43 for Southwest Delhi, and 12 for West Delhi district.

14.4 Data Analysis

The depth to the groundwater table, averaged for each district during the month of May is shown in Fig. 14.5a, b for each year during the 2007–2011 period. Table 14.1 shows the statistical characteristics (min, max, average, standard deviation, and the coefficient of variation) of this fluctuation.

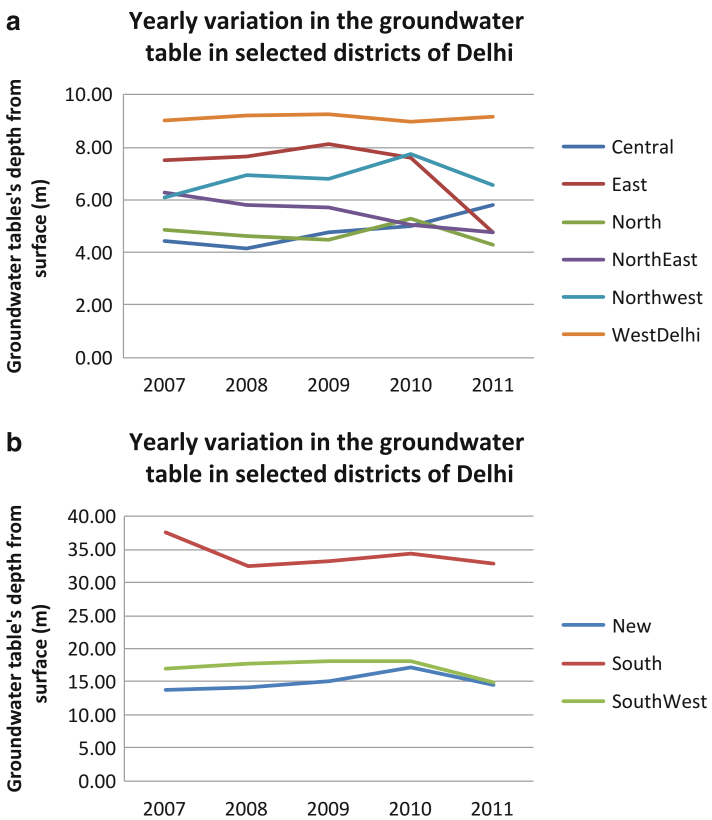

Fig. 14.5 (**a**, **b**) Fluctuation in the groundwater table in different districts of Delhi in the pre-monsoon month (May) as derived from the well-data (Central Groundwater Board n.d)

Table 14.1 Statistical characteristics of variation in groundwater table measured in pre-monsoon time during 2007–2011 period for Delhi, India

District	No. of wells	Fluctuation in ground water table				
		Minimum (m)	Maximum (m)	Average (m)	Standard deviation	Coeff. Of variation (%)
Central Delhi	2	0.90	9.26	4.83	3.71	76.8
East Delhi	14	2.40	13.07	7.39	2.86	38.7
New Delhi	23	0.96	44.1	14.90	7.21	48.4
North Delhi	11	1.88	14.77	4.71	2.21	46.9
Northeast Delhi	5	1.65	8.05	5.49	1.90	34.6
Northwest Delhi	39	0.8	27.08	6.87	4.26	62.0
South Delhi	38	1.99	66.70	34.11	20.05	58.8
Southwest Delhi	43	2.16	59.5	17.31	11.75	67.9
West Delhi	12	1.8	33.5	9.13	7.77	85.1

The data thus collected were analysed to study the fluctuation of the groundwater table over time and seek suggestions to improve the groundwater availability for Delhi dwellers.

As shown in Table 14.1, the depth to the groundwater table measured in May (a pre-monsoon month) during 2007–2011 ranged between 4.83 and 34.11 m across different districts. These depths could be classified into four categories – Low (0–10 m), Medium (10–20 m), High (20–30 m) and Very High (greater than 30 m). According to this criterion, six districts (Central, East, North, Northeast, Northwest, and West Delhi) had Low depths, two districts (New Delhi, Southwest Delhi) had Medium depths, and One district (South Delhi) had Very High depth (from the surface) of the groundwater table.

14.4.1 Groundwater Fluctuation

Figure 14.5a, b shows the fluctuation in the depth to the groundwater table during 2007–2011. Various factors contribute to fluctuations in the groundwater levels, such as the hydrogeological formation, permeability of the surface, groundwater extraction and population density.

It is apparent from Fig. 14.5a, b that the depth to groundwater table showed somewhat increasing trend for all of the districts except Northeast district during the 2007–2010 period. However the trend changed in 2011 for a few districts apparently due to enough groundwater recharge resulting from the heavy rainfall (about 1056 mm) received in 2010.

14.4.2 Impact of the Population Density

The population density of different districts has grown over time at different rates as shown in Fig. 14.2. Areas with low living costs have grown faster. Fluctuation in the groundwater table is a complex function of the population density, the groundwater recharging capacity/hydrogeological formations, proximity to the river, amount of rainfall received and the runoff produced. Apparently the districts with a high population density have favourable conditions for the groundwater recharge due to high percolation rate in the flood plains.

14.5 Future of Groundwater Resources

In order to examine the sustainability of water resources for Delhi, one has to evaluate the demand and supply of water. As the population and urbanisation continues to expand, the water sustainability will continue to decline. Delhi is more than 90 %

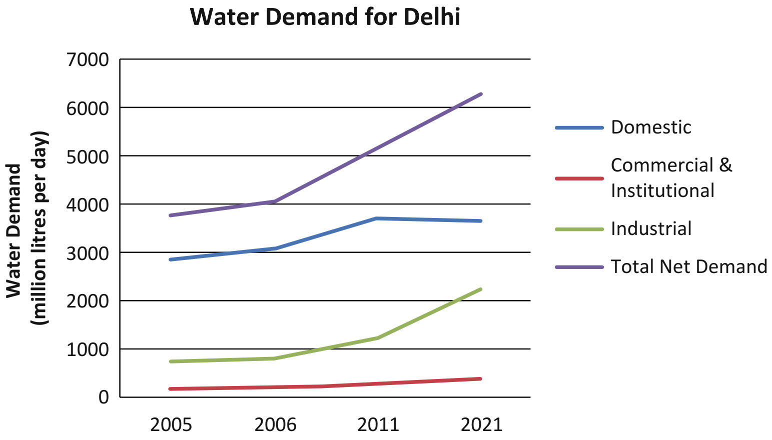

Fig. 14.6 Water demand for different sectors in Delhi (Source; Delhi Jal (water) Board, In: Statistical Handbook of Delhi)

urban and this percentage tends to continue increasing as the rural/agricultural land is being urbanised to absorb the increasing population influx.

It has been a difficult task to estimate the total water consumption in Delhi due to the substantial number of unmetered connections as well as unmetered groundwater extraction in privately owned homes/apartment buildings. The total water demand for Delhi is likely to rise significantly (Fig. 14.6; Singh 2007). In addition, the amount of the surface water flows in the Yamuna River is expected to decline in future due to global warming and the Himalayan glaciers that feed this river retreating (Rodell et al. 2009). If the urbanisation of and the population influx to Delhi is not restricted, Delhi's existing water problem will worsen. Urban development laws relating to residential expansion need to be strictly followed to retard the growth in population density that directly influences the groundwater availability.

14.6 Conclusion

This chapter has highlighted factors relating to increasing water usage in Delhi. Although the groundwater table data for a longer period was desired and sought, the same could not be made available. Based on the 2007–2011 data, it was found that the groundwater table fluctuated significantly across Delhi districts due to the change in rainfall, the hydrological formation and population density. The groundwater table exhibited a declining trend in all of Delhi's districts except the Northeast district during the 2007–2010 period. However the trend changed in 2011 in a few districts due to the groundwater recharge that resulted from the heavy rainfall received in 2010. Population growth, particularly due to the permanent migration to Delhi and also due to temporary migration of the workforce of all levels including less skilled labour is one of the main causes of fluctuation in the groundwater availability. There is an urgent need to retard both the urbanisation of and the migration to Delhi by improving economy, infrastructure, and industrialisation, job prospects in nearby states and elsewhere in rural India. Also, the apartmentisation of homes needs to be restricted in order to retard growth in population density in order to avoid a water crisis for Delhi in the future. If the global warming fears come true in form of estimated low flows in River Yamuna, Delhi will likely face groundwater crisis in near future.

References

Central Ground Water Board (n.d) http://www.cgwb.gov.in/gw_profiles/st_delhi.html. Accessed 11 Aug 2015

Dash JP, Sarangi A, Singh DK (2010) Spatial variability of groundwater depth and quality parameters in the National Capital Territory of Delhi. Environ Manage 45:640–650

Maria A. Role of ground water in Delhi's water supply, 2006. In: Urban groundwater management and sustainability series. NATO science series, 74., Springer, pp 459–470

Rodell M, Velicogna I, Famigliatti JS (2009) Satellite based estimates of groundwater depletion in India. Nature 460:999–1002

Rohilla SK (2012) Water, city, and urban planning-assessing the role of groundwater in urban development and planning in Delhi. CSH Occassional Paper N0. 31

Shekhar S, Purohit R, Kaushik YB (n.d.) Groundwater management in NCT Delhi. www.indiaenvironmentportal.org.in. Accessed 15 June 2014

Singh V (2007) Delhi master plan 2021. Rupa and Co., New Delhi

Chapter 15
Safe Water Supply Determinants in Peri-urban Communities of South-East Nigeria

E.E. Ezenwaji, H.O. Ahiadu, and V.I. Otti

Abstract In most peri-urban communities of south east Nigeria, shortages of domestic water supply relative to demand is a common feature. This is because most of these peri-urban communities usually fall outside the urban water supply projects physical boundary, thus forcing the people who live there to consume water from doubtful sources which most often contain pathogens found in human faeces. Apart from consuming water from doubtful sources, most inhabitants of this area also travel long distances to collect it or pay dearly to purchase it from water vendors. The study was therefore undertaken to determine the factors necessary for a safe water supply in such areas. Towards achieving this objective, a questionnaire was designed and 2000 were administered to households in the area between January and June, 2013. A total of 15 factors were isolated and analysed in 10 peri-urban communities of the region. The major analytical tool employed was multiple regression analysis with which we were able to determine the relative importance of each variable using SPSS version 20. Based on the result obtained, important determining factors for safe and sustainable water services were discussed in terms of their implications to the formulation of a needed policy that will ensure improvement in supply of the service to meet demand.

Keywords Peri-urban communities • Safe water supply • Human faeces • Water vendors • Sustainable water services

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15.1 Introduction

In most peri-urban communities in Nigeria, there are multiple sources of water supply with municipal, shallow wells, vendors, streams and rain water sources being the most common. One common feature of all the sources is that water collected from them is of poor quality, although in varying degrees. Water collected from the municipal source is always adjudged the best in terms of quality although the standard is far short of prevalent international standards. Conversely, both shallow wells and streams are recognised as the sources with the lowest quality (Bob-Duru 2001; Osirike 2003: Onuzuligbo 2013). The problem of an inadequate safe drinking water supply is, therefore, of national concern in Nigeria. The continued increase in the population of such areas with associated economic activities imposes enormous pressure on the fresh water supply to the extent that the WHO maximum recommendation of per-capita water consumption of 20 l per day is becoming very increasingly difficult to realise in parts of some urban and peri-urban communities (Phil-Eze and Ezenwaji 2009; Adebiyi 2013). Increasing access to safe water supply is a sure way of ensuring a healthy populace. A number of researchers have investigated the pollution level of rivers, streams and shallow wells that serve as a source of water to peri-urban communities of South Eastern Nigeria and their health implications (Anyadike and Ibeziakor 1987; Okoli and Bade 2010; Ezenwaji et al. 2013). In all developing countries including Nigeria, the principal risks to human health associated with the consumption of polluted water are microbiological in nature although there are significant concerns about chemical contamination. The risk of acquiring a waterborne infection increases with the level of contamination by pathogenic micro-organisms There are indeed a wide variety of technologies for treating water at the point of need or use and the common methods include aeration, filtration and disinfection which are employed to remove physical and microbiological contaminants, but not chemical contaminants (Kayaga and Reed 2010).

In South Eastern Nigeria, government efforts at improving sanitation and hygiene has made some inhabitants of peri-urban settlements embark on various forms of water treatment before use. Boiling is a very effective method of disinfecting water but it is energy consuming. Apart from the high cost of energy involved in boiling water, the other disadvantage is the change in taste of the water. Apart from boiling many other ways exist to ensure that water available for consumption is safe from contaminants.

Many studies in peri-urban water supplies in South-East Nigeria largely involve investigations into the degree of water scarcity and its associated water pollution and in some instances local ways of purifying them (Ezeaku 2012; Abangwe 2011; Ezenwaji et al. 2013) but the study of determinants of a safe water supply in these communities has remained scanty. The aim of this chapter, therefore, is to determine the factors that have tended to inhibit safe water supplies in the study area. The result of this study will provoke government interest in tackling the age old problem of providing safe water to the inhabitants of the area as well as attract donor agencies that wish to partner with the governments of the area to tackle the problem.

15.2 Study Area

The South East geopolitical zone of Nigeria has 10 out of 15 urban areas in Eastern Nigeria and consists of 5 States namely, Abia, Anambra, Ebonyi, Enugu and Imo States and is located between Latitudes 50.001 N and 70.001 N and Longitudes 60.421E and 80.201E, (Fig. 15.1). It is surrounded by Benue State and Kogi States

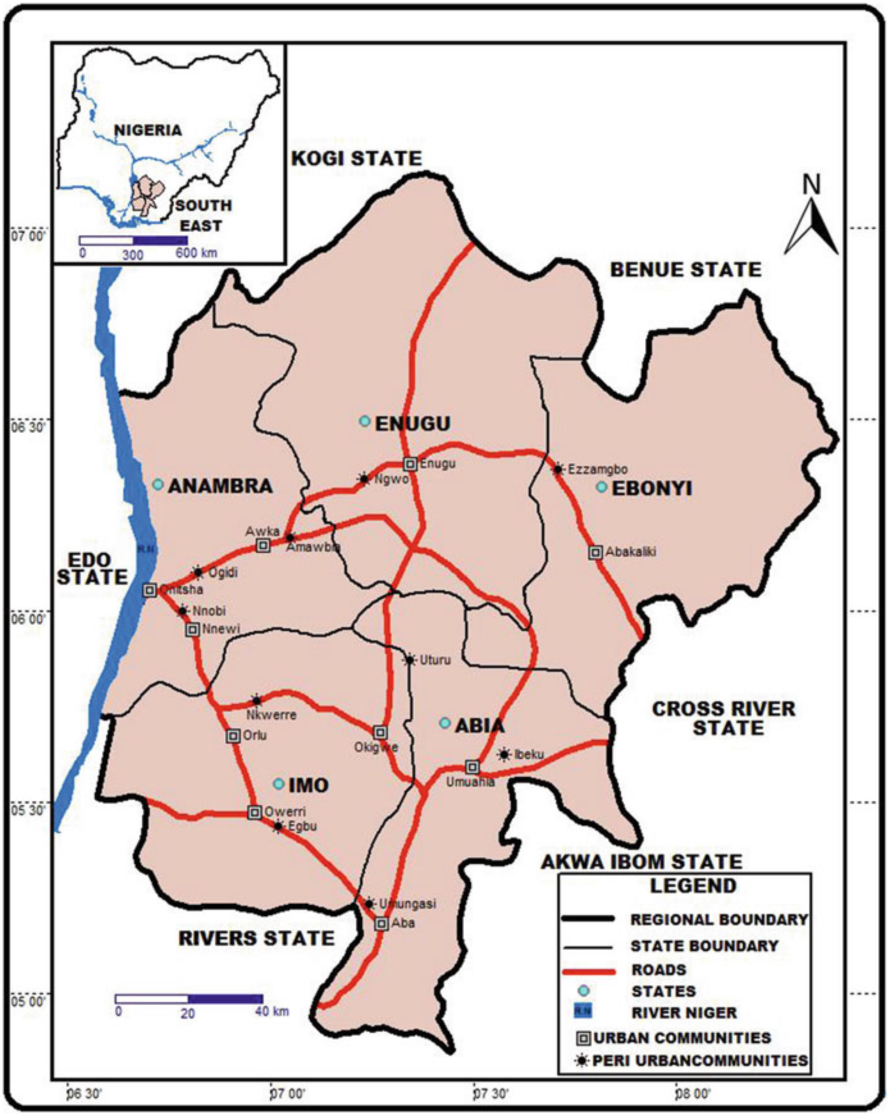

Fig. 15.1 Map of South East Geopolitical Zone

in the north, Rivers and Akwa-Ibom States in the South, Cross-River State in the east as well as Delta State in the west. It covers an approximate area of 29,000 km^2 and has a 2013 projected population of 20,003,200 from the 2006 base figure of 16, 595, 555 (National Population Commission 2006).

The climate of the area is hot-wet equatorial with an average maximum annual temperature of 280 °C and a minimum of 240 °C. Rainfall begins in March and ends in October while dry season begins from November and ends in February. The total annual rainfall amounts hover between 1500 mm in the northern parts of the region to 2000 mm in the southern area of the region. Vegetation is typically rainforest, but has been largely disturbed by human activities thus leaving derived Savanna vegetation as patches of the outliers within the area.

Geologically, the northern parts of the region in Anambra, Enugu and Ebonyi States are made up of variegated formations which include the Imo clay shales, upper coal measure and lower coal measure. In the southern area around Imo State and a substantial part of Abia State there are Awgu/Ndiabo and Afikpo formations as well as a significant presence of basement complex formation (Orajiaka 1975). Ten peri-urban communities are selected for the study from ten urban areas. Each urban area and one prominent peri-urban community close to it are Abakaliki (Ezzangbo), Awka (Amawbia), Enugu (Ngwo), Owerri (Egbu), Umuahia (Ibeku), Okigwe (Uturu), Orlu (Nkwerre), Onitsha (Ogidi), Aba (Umungasi), Nnewi (Nnobi): The 2013 population of each peri-urban community are Ezzangbo (73,010), Amawbia (112,301), Ngwo (72,111), Egbu (101,210) and Ibeku (68,392), Uturu (112,120), Nkwerre (69,286), Ogidi (102,620), Umungasi (98,266) and Nnobi (78,214).

15.3 Data Collection

Data for the study were collected from households via the questionnaire which was designed and administered to them between January and June 2013. A total of 2000 questionnaires were served on the respondents according to an arranged proportion for each peri-urban community. However at the end of the questionnaire administration only 1600 were recovered as some respondents misplaced their copies while a small percentage did not fill them out. Stratified and random samplings techniques were employed in the administration of the questionnaire with each of the ten peri-urban communities forming a stratum. The total number of households in each community is as presented in Table 15.1 as well as their sample sizes together with total number of questionnaire returned from each community. Sample proportion from each peri-urban area was determined by dividing the number of households by the total number of households.

From the questionnaire 15 determinants of safe water supply were extracted. Table 15.2 shows the variable label, code, description and their parametisation aimed at converting them to mathematical values.

Table 15.1 Sample proportion and size from the peri-urban areas

Stratum (peri-urban community)	Total no. of household	Proportion	Sample size	Total returned
Ezzangbo	12,168	0.082	165	112
Amawbia	18,168	0.123	247	158
Ngwo	12,019	0.085	163	140
Egbu	16,868	0.114	229	213
Ibeku	11,399	0.077	155	127
Uturu	18,686	0.126	254	200
Nkwerre	11,548	0.078	156	124
Ogidi	17,103	0.116	232	206
Nnobi	13,036	0.088	177	150
Umungasi	16,377	0.111	222	170
Total	147,372	1.00	2000	1600

Source: Field work

Table 15.2 Variable description and their parametization

S/N	Variable label	Variable code	Variable description	Parametization of variables
1.	CONT	X_1	Average no. of water containers not covered by the household	The average number of uncovered containers were determined and recorded
2.	SANI	X_2	Average no. of days water stored in the container before use	The number was determined from the respondents and recorded
3.	OPEN	X_3	Whether or not there is an open defecation around the water sources	If there is an open defecation (I) was recorded and if there are none (O) was recorded
4.	COST	X_4	Total cost of water supply to household per month	Total cost was supplied by the respondents and recorded
5.	LEAK	X_5	Average number of water leakages in the distribution pipe around the household	This was determined by the respondent while the average for each community was recorded
6.	TECH	X_6	Type of Technology used in the treatment of water at the point of use	Each treatment technology was assigned numbers according to its sophistication – Aeration (1) filtration (2) Disinfection (3). The number assigned to a relevant technology in each case was recorded and average found for the peri-urban community
7.	CUPS	X_7	The average hygienic condition of CUPS for drinking water	The hygienic condition was determined by examining the E-Coli content of the CUPS and recorded
8.	ACCE	X_8	The average level of water access in terms of distance	This distance was determined from respondents and recorded

(continued)

Table 15.2 (continued)

S/N	Variable label	Variable code	Variable description	Parametization of variables
9.	WELL	X_9	Sanitary condition of ropes and buckets used in drawing water from wells	This was determined by examining the E-Coli content of the ropes and buckets
10	ECON	X_{10}	Average number of human activities near the water source	The average number was determined by the total number derived by total locations
11.	TYPE	X_{11}	Dominant type of land use near the water source	Dominant land use was observed. Each land use was assigned number according to its pollution potential as follows: Residential (1) Commercial (2) Agricultural (3) and Industrial (4)
12.	PIPES	X_{12}	Whether or not water distribution pipes pass through poor sanitation environment	When it passes through poor sanitation environment (1) was recorded and when not (O) was recorded
13.	HOUS	X_{13}	Cost of water purification by households per month	This cost was supplied by respondents and recorded
14.	PLACE	X_{14}	Whether or not water safety plan is in place in the study area	If the plan is in place (1) is recorded if not (O) is recorded
15.	DIST	X_{15}	Average distance of refuse dumps to water sources	This distance was determined and average found for each peri-urban community and recorded

15.4 Data Analysis

The above data were analysed with the Multiple Linear Regression (MCR) statistical technique often employed to analyse causal relationships among dependent and independent variables. The dependent variable is the quantity of water supply in each of the communities during the period of the study extracted from various government publications while data in Table 15.3 are employed as independent variables. The technique may be viewed as a descriptive tool by which the linear dependence of a variable can be summarised and decomposed, or an inferential tool by which the relationships in the population are evaluated from the examination of sample data.

The general expression for the multiple linear regression is written as follows:

$$Y = a + b1X1 + b2X2 + b3X3 + \cdots + bnXn + e \quad (15.1)$$

Table 15.3 Field data of determinants of safe water in peri-urban communities of South East Nigeria

Community	X1	X2	X3	X4	X5	X6	X7cfu/100 m	X8 (M)	X9cfu/100 m	X10	X11	X12	X13	X14	X15
Ezzangbo	8	1	1	4	10	3	3	300	10	4	2	0	2	0	150
Amawbia	10	0	1	4	7	3	1	250	12	4	1	0	3	0	50
Ngwo	4	1	1	6	10	3	3	300	10	6	1	1	2	0	30
Egbu	6	1	1	5	13	2	2	500	14	5	1	1	1	1	100
Ibeku	6	0	1	3	8	2	5	300	10	4	4	1	3	0	60
Uturu	4	1	1	4	6	1	5	350	15	4	2	1	3	0	120
Nkwerre	0	1	1	4	0	3	2	300	10	4	1	0	2	0	50
Ogidi	5	0	1	4	5	1	3	300	10	5	1	1	2	0	30
Nnobi	0	0	1	5	0	3	5	400	14	3	1	0	2	0	20
Umungasi	10	1	1	4	8	1	2	300	12	5	4	1	2	0	20

where y is the dependent variable

X1, X2, X3, …Xn are independent variables

While b1, b2, b3 … bn are regression coefficients; a is the base constant and e is the error term or the proportion of the variance not explained. All data were analysed using SPSS programme package Version 20.

15.5 Results

The total amount of water supply was regressed against 15 variables. The combined strength of the relationship between the 15 variables was assessed by multiple correlation coefficients (R). The level of variation was computed to be 77.7 % leaving 22.3 % unexplained. This shows that 77.7 % of the variation in water supply safety is explained by our 15 variables working together. The multiple correlation coefficients (R), the coefficient of determination (R2) and the standard error of estimates (SEE) of the determinants of water safety in the per-urban areas are presented in Table 15.4.

The standard error of estimates of 182 l explains the standard error and it is a measure of the magnitude of the likely error that may occur if the regression equation is used to estimate values of dependent variable. In a simple explanation the ± 182 l is a range implying either an over estimation or under estimation of safe water supplies using the 15 independent variables. The low standard error of estimates of ± 182 l indicates that safe water supplies in the area can be predicted by the 15 variables working together.

The relative importance of each of the independent variables in the Multiple Regression Analysis can be determined in a number of ways (Anyadike 2009). However, because of the weakness of some of the methods, the method involving calculation of successive values of the multiple correlation coefficient obtained by introducing independent variables at each computation i.e. R_y. X_1, R_y. X_1, X_2, R_y. X_1, X_2, X_3 etc. is the most universally employed. The difference between the Squared Multiple Correlations (R^2) may be regarded as the contribution of each variable(s). In our own case all variables altogether contributed 85.23 % and so we used the formula to determine what individual variable contributes to the variation (Table 15.5).

Table 15.4 Result of the multiple regression analysis, the determinants of safe water supply in the peri-urban communities

Statistics	Result
Multiple correlation (R)	0.8815
Coefficient of multiple determination (R^2)	0.7770
Standard error of estimates (litres) SE	182

15.6 Discussion

From Table 15.5 it could be seen that all the 15 variables contributed to a safe water supply in the 10 peri-urban centres under study but by varying degrees. One essential feature of their contribution is that three of them contributed very highly. For example apart from the variable X_3 (whether or not there is an open defecation around the water source) with 21.1 % X_{11} (Dominant type of land use near the water source) with 16.5 % and X_{15} (Average distance to the refuse dump) which has 14.1 % all others contributed low values less than 10 % with many contributing less than 1.0 %. Based on this, we shall discuss more on the variable that contributed highly.

15.6.1 Open Defecation Near the Water Source

We had earlier noted that the inhabitants of these ten peri-urban communities rely on a range of water sources. These include rivers, shallow wells, public water sources, vendor's rainwater harvesting etc. It is important to say that the level of open defecation in these towns is high which resulted in defecation even around the water sources. This has given rise to high cases of water borne diseases reported in the area. For example over 48 % of daily hospital visits in the area are as a result of typhoid fever while dysentery and cholera constitute about 30 % of the remainder which mostly affect children (Okedi 2011; Onyegocha 2013). This is in line with the opinion of Humphries (2009a, b) that more children under the age of five die from diarrhoea than from HIV, Malaria and Tuberculosis put together in Africa. Many

Table 15.5 Relative contribution of safe water determinants

Variable label	Variable code	Multiple R	R^2	R^2 change	% R^2 change
OPEN	X_3	0.469	0.2199	0.2119	21.1
TYPE	X_{11}	0.620	0.3844	0.1645	16.5
DIST	X_{15}	0.725	0.5260	0.1412	14.1
LEAK	X_5	0.788	0.6209	0.0953	9.5
CONT	X_1	0.820	0.6720	0.0511	5.1
SANI	X_2	0.841	0.7023	0.0303	3.0
COST	X_4	0.852	0.7259	0.0236	2.4
ACCE	X_8	0.861	0.7413	0.0154	1.5
WELL	X_9	0.869	0.7551	0.0138	1.4
ECON	X_{10}	0.874	0.7639	0.0088	0.9
PIPES	X_{12}	0.879	0.7726	0.0087	0.9
PLACE	X_{14}	0.882	0.7779	0.0053	0.5
HOUS	X_{13}	0.884	0.7814	0.0035	0.4
CUP	X_7	0.885	0.7832	0.0018	0.2
TECH	X_6	0.886	0.7850	0.0017	0.2

more children, according to him, are irreversibly debilitated and stunted by water related illness during their early years. Furthermore, Bongartz et al. (2010) vividly described the menace of open defecation in the following ways:

During a "transect walk" to common areas of open defecation, the problem stares people right in the face: 'shit' is everywhere and seeing it, smelling it and stepping in it is highly unpleasant …. the effect this exercise has on the people is written largely on their faces. Combined with exercises that illustrate the paths from shit to the mouth and the way food and water gets contaminated, this generally leads to a moment of ignition.

The high rate growth of slum and squatter settlements in and around these peri-urban areas is alarming where the above observation is a daily occurrence. A visit to these settlements reveals that toilet facilities are not a part of their housing development, as only a few houses have toilets.

15.6.2 Dominant Type of Land Use Near Water Sources

Type of land use is an important determinant of a safe water supply, because some land use generates more harmful wastes to the environment than others. Although most of the peri-urban areas in the study area have residential land use as the dominant use, a few others have heavy industry located in their communities. Out of ten peri-urban areas in this study only two – Ibeku and Umunagasi have industries, two others namely Ezzangbo and Uturu have commercial activities, while residential land use dominate the rest. Residential areas generate household wastes, some of them microbiological and others chemical contaminants. The poor disposal of these wastes is one of the reasons why many water sources are the reason why water from such areas are polluted.

15.6.3 Refuse Dump

Contaminated refuse dumps are seen indiscriminately in most of these peri-urban communities. Johnson (2013) in his investigation of the effect of household wastes and refuse dumps on water sources in parts of Lagos, Nigeria concluded that household wastes that usually find their way to the water bodies contaminate them with both high microbiological and chemical substances and suggested that both the inhabitants and local governments authorities should always ensure that the areas around these sources are kept clean.

Distance of refuse dump sites to water sources is very closely related to the previous determinant which is the type of dominant land use near the source of water. The land use generates refuse which, for unknown reasons, are usually found very close to either a shallow well, at the river back, close to public water stand pipe or even dumped inside the storm drains or river channels from where the inhabitants collect the water they consume daily. Lack of appropriate refuse disposal is one of the central problems of environmental sanitation in Nigeria. Zadock (2012) was of the view that continued lack of interest by the relevant government authorities in this regard continues to be a veritable source of worry. One reason for this is that the environmental sanitation by the government on the inner city areas are often not extended to these peri-urban communities.

15.6.4 Policy Recommendations

The three most important determining factors for a safe water supply are already discussed namely; open defecation near the water source, dominant type of land use near water source and distance of refuse dump sites to water sources and should be drawn into the policy development of the sector in the affected peri-urban communities. The objective of such a policy is to limit the activities leading to these isolated determinants. The policy instruments to be employed to achieve this should include laws and regulations, economic incentives such as subsidies for those that keep a clean environment near the water source and fines for offenders. Also to be included are sensitisation and education programmes that will be designed to create safe water supply for the inhabitants.

In terms of laws and regulations, the various Houses of Assembly in the affected States should closely work with their State governments who are expected to prepare and send executive bills to the House in this regard. Such bills should be thoroughly discussed and expeditiously passed. The important areas of such bills should include (i) designating an area of about a 500 m radius of any water source as well as 500 m from a stream or river as open defecation prohibited zone (ii) imposing appropriate fines for offenders (iii) providing incentives to staff of the water corporation who will ensure compliance (iv) discouraging open defecation by making a provision mandating government to provide public latrines in squatter and slum settlements. The bill should also include the prohibition of establishment of housing estates or building of any house very close to urban rivers or streams as well as imposing appropriate fines for all economic activities including the siting of industries near these rivers. Furthermore, there should be a combined policy that should focus on water supply and sanitation. Such a policy will make it an offence for individual households to dump refuse at designated locations.

As it is not sufficient to look only at policy, but also on the conditions that need to be in place for policy to make a difference, it is recommended that all such conditions, especially the need for stakeholders to accept the provisions of the policy, should be pursued with clear commitment.

15.7 Conclusion

We have in this paper tried to determine the relevant factors that impede a safe water supply in the peri-urban communities of selected urban centres in the South Eastern parts of Nigeria. The result of our study indicates that three factors with high percentage contributions which are already discussed should be drawn into the water policy documents of the relevant peri-urban communities. Policy implications of the existence of these factors were examined and it is our recommendation that various Houses of Assembly in the zone should work together to handle all the issues relating to water supply in peri urban communities as they are located in the same geographical, cultural and environmental areas. This therefore means that the same measures will be taken by all of them to improve their water supply in peri-urban communities. Furthermore, it will be necessary that the Assemblies enact realistic laws that should check these activities. It is only when these measures are put in place than we will be sure that the citizenry of these areas would have safe water to consume. It is noted that all the five State governments in the region have now began small town water supply programmes as advised by donor agencies in the sector. This new measure will undoubtedly improve the water supply conditions of the peri-urban communities.

References

Abangwe J (2011) Computing the health implications of the consumption of polluted water in Slums of Aba, Nigeria. J Environ Pollut Nigeria 3(1):48–59

Adebiyi EO (2013) Water demand in peri-urban communities of Lagos Mainland, Nigeria. J Urban Environ 3(2):121–138

Anyadike RNC (2009) Statistical methods for the social and environmental sciences. Spectrum Books Ltd, Ibadan

Anyadike RNC, Ibeziakor MN (1987) Spatial structure of residential demand in Enugu Urban Area Nigeria. J Soc Dev 2(1):54–62

Bob-Duru RC (2001) Rural settlements in Nigeria. Survival or demise. In: Ofomata GEK, Phil-Eze PO (eds) Geographical perspectives on environmental problems and management in Nigeria. Jamoe Enterprises, Enugu, pp 96–115

Bongartz P, Musyoki SM, Milligan A, Ashley H (2010) Tales of shit: community led total sanitation in Africa – an overview In: IIED (ed) Participatory learning and action on tales of shit: community – led total sanitation in Africa, Juggly Publishers, New Delhi, India, pp 27–61

Ezeaku P (2012) Water scarcity in some sub-urban settlements of Onitsha, Nigeria. J Water Hum Ecol 4(1):22–31

Ezenwaji EE, Phil-Eze PO, Otti VI, Eduputa BM (2013) Household water demand in the peri-urban communities of Awka, Capital of Anambra State, Nigeria. J Geogr Reg Plann 6(6):237–243

Humphries J (2009a) Child under nutrition, tropical enteropathy, toilets and handwashing. Lancet 374:1032–1035

Humphries J (2009a) Tropical enteropathy and poor sanitation in Africa. International Institute for Environment and Development (IIED) Publication

Johnson N (2013) Households, refuse dumps and water supply. Kamara Press, Lagos

Kayaga S, Reed B (2010) Emergency treatment of drinking water at the point of use. WEDC Technical Notes on Drinking Water, Sanitation and Hygiene in Emergencies. vol 3

National Population Commission (2006) 2006 population figures in Nigeria. Government Press, Abuja

Okedi TN (2011) Assessment of dominant water borne diseases in hospitals located in peri-urban communities of Port-Harcourt, Nigeria. J Water Supply Urban Dev 4(2):68–79

Okoli D, Bade AO (2010) Refuse dumping in urban water ways and implications for community health in Nigeria 8(1) J Urban Built Environ 4(2):210–224

Onuzuligbo PA (2013) Water supply in some informal settlements of Enugu Urban Area, Nigeria. In: Abuja JJ (ed) Regional water supply and community development in Nigeria, Newway Publishers Ltd., Abuja, Nigeria, pp 114–124

Onyegocha MM (2013) A determination of the prevalence of typhoid diseases in peri-urban communities of Okigwe, Nigeria. J Water Supply Urban Dev 6(1):120–131

Orajiaka SO (1975) Geology. In: Ofomata GEK (ed) Nigeria in maps: Eastern States. Ethiope Publishers, Benin City

Osirike AB (2003) Water supply management in Niger Delta. In: Proceedings of the 29thWEDC international conference, Abuja, Nigeria, pp 273–276

Phil-Eze PO, Ezenwaji EE (2009) Rural water supply development strategy for environmental sustainability in old Aguata Local Government Area of Anambra State, Nigeria. Int J Archit Built Environ 1(1):77–83

Zadock JO (2012) Government and sanitation of small towns. Gale Pre Accra, Ghana.

Chapter 16
Risks of Coal Seam and Shale Gas Extraction on Groundwater and Aquifers in Eastern Australia

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Abstract In the developed world there are growing concerns about water security due to the increase in exploration and production of coal seam and shale gas in peri-urban areas using both the hydraulic fracturing (fracking) technique of gas production and the method of extraction of naturally occurring groundwater by pumping it from coal formations to release coal seam gas (CSG). In Australia there is a competing prerequisite to maintain and increase the natural resource base as well as the need to protect and sustain the supply of potable and agricultural groundwater in peri-urban areas. One identified issue for this chapter is whether the increasing popularity of fracking in peri-urban and semi-rural areas in New South Wales (NSW) and Queensland poses a risk to the quality of groundwater supply as well as its contamination. The other main issue is whether the extraction of groundwater from coal seams where fracking is not needed has a major impact on groundwater depletion; and, if so, investigating the appropriate risk assessment and risk management approaches.

One problem at hand is that fracking is a technique designed to produce gas from coal seams and shale strata. The process involves pumping water, sand and chemicals under high pressure into layers of coal or shale to create fissures or cracks that force gas to the surface where it is collected and processed. The technique impacts on water supplies in two main ways: It requires large quantities of water at the pumping stage and it is alleged to produce vast amounts of contaminated groundwater containing chemicals known collectively as BTEX, methane gas and excessive amounts of salt. Attractors to this method of gas exploration and production are twofold. The drilling technique invented and developed by George Mitchell in 1980s and 1990s made drilling previously inaccessible strata reachable and cheap.

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The other attraction is that in the United States of America (USA), since 2008 the domestic price of 'Henry Hub' gas has fallen from $12 per million BTUs in 2008 to $4 per million BTUs in 2012. The impact of this 66 % fall in price has relieved the USA's reliance on imported carbon based fuels momentously, but has had a deleterious impact on groundwater supplies.

The evidence based on the development of drilling sites using fracking in NSW and Queensland peri-urban areas so far, suggests that environmental concerns may not be given as much consideration as they ought, in particular because compliance with environmental risk assessments is not specific enough. In this chapter, we explore the above issues and report on a methodology to assess the potential risk to groundwater supplies in NSW and Queensland using an environmental risk model for CSG extraction in combination with the 'triple-bottom line' (TBL) process for community consultation informed by the Global Reporting Initiative (GRIG4) guidelines.

Keywords Fracking • Risk assessment • Groundwater • Energy security • Water security

16.1 Introduction

16.1.1 The Necessity for Risk Assessment and Risk Management Strategies of Fracking in Peri-Urban Areas

The two main risk factors to consider for this paper are whether or not the fracking process has the potential to reduce the current volume of and access to groundwater/aquifers in NSW and Queensland particularly in peri-urban areas: The major related issue is the possible impact of fracking on the accessibility and quality of water for human consumption and farming purposes. The other main issue for this paper is to examine the impact on water quantity due to the extraction of CSG by pumping groundwater out of coal seams so that robust pro-active risk assessment and risk management approaches can be examined and recommended.

Overseas experience, in particular in the USA, which has a long time-frame of large scale extraction of mainly shale gas, suggests that the impacts on water quantity and quality in peri-urban areas of Queensland and NSW may be adverse if the development and methods of extraction proceed in a similar fashion. Other issues to consider are whether currently used methods of risk assessment for the fracking process and the drawing of water from coal seams in Queensland and NSW are adequate to protect against potential adverse effects on quality and quantity of water as well as health and other environmental impacts. Currently in NSW peri-urban areas there is very little extraction of shale gas and it is highly unlikely that there will be significant development in the extraction of shale gas because it is extracted from a hard sedimentary rock with low permeability which does not permit water or gas to exude effortlessly; it has to be fracked which is an expensive and environmentally problematic process. However, there are large and accessible coal deposits in NSW in peri-urban landscapes and at the time of writing these are being considered for the extraction of CSG notwithstanding the recommendations for caution in the Final Report of the Independent Review of Coal Seam Gas Activities in NSW conducted by the Chief Scientist and Engineer, Professor Mary O'Kane and released in October 2014 (O'Kane 2014). According to the Office of Water NSW, prior to the publication of the O'Kane (2014) Final Report:

> Coal seam gas does not generally require hydraulic fracturing for its extraction. It is the exception rather than the rule. To date less than 5 % of CSG wells in Australia have been fracked, and this figure is unlikely to exceed 10 %. (NSW Office of Water 2014)

NSW has an abundance of coal seams (broad estimates by Geoscience Australia proclaim that there are about 41 years of economically accessible coal available) which may or may not require fracking and which according to the Office of Water NSW's projection is likely to double and this may impact adversely on groundwater quality and quantity (NSW Office of Water 2014). Much of NSW coal is accessible for CSG extraction in peri-urban areas which are close enough to transport to urban or export depots to keep costs down. The other driver is that at the time of writing NSW produces only 5 % of its own gas and relies on imported gas for the remainder. In November 2014 an estimated 60 % of NSW was subject to CSG exploration licences with an estimated tendering process for a quarter of that land mass which encompasses a large number of peri-urban landscapes (Alderman 2014). Therefore, in all probability, considering the accessibility of coal deposits and a new Premier of NSW in office since 23 April 2014 suggests that the Office of Water NSW underestimates the proliferation of peri-urban fracking sites in NSW. Most of Australia's identified 'black coal' deposits are located in NSW and Queensland: 24 % of total coal deposits in NSW and 62 % in Queensland (Geoscience Australia 2013).

> Most of Australia's Recoverable Economic Demonstrated Resources (EDR) is located in Qld (59 per cent) and NSW (37 per cent) within four coal bearing, sedimentary basins (Bowen, Sydney, Surat and Galilee Basins). Approximately 31 per cent of Recoverable EDR is located in the Sydney Basin (NSW), 31 per cent in the Bowen Basin (Qld), 13 per cent in the Surat Basin (Qld) and 10 per cent in the Galilee Basin (Qld). (Geoscience Australia 2013)

Nearly all of the coal is accessible for fracking or by pumping groundwater out of coal seams where these methods do not compete with the extraction of coal for mining purposes. The Sydney Basin (Fig. 16.1), or giving its full dimensions, the Sydney-Gunnedah-Bowen Basin which extends from Ulladulla on the NSW south coast to Newcastle on the mid north coast and north-westerly through to Narrabri and into Queensland has five major coalfields, the Hunter, Newcastle, Southern, Western and Gunnedah (NSW Government 2011). In the Sydney Basin in particular a sizeable portion of the coal is found in peri-urban/urban regions such as Camden

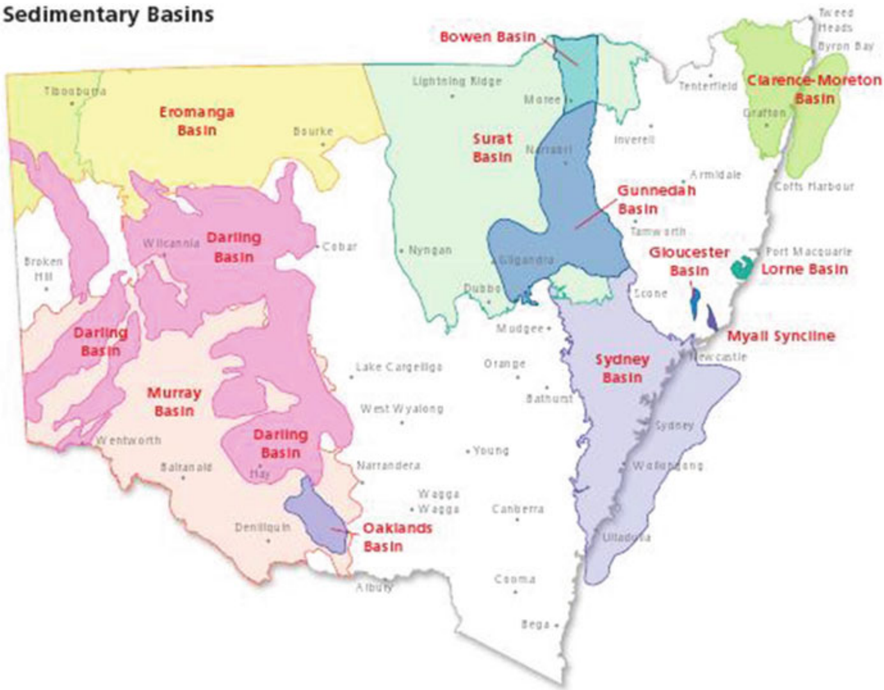

Fig. 16.1 Coal Map NSW 2009 (Source: NSW Government (2011) Atlas of NSW, Geology)

(south west of Sydney) where there are currently 120 CSG 'well heads', operated by Australian Gas Light Company (AGL) of which 10 % of the 95 tested by the NSW Environmental Protection Agency from September to December 2013 were found to be leaking methane gas, even though AGL's own previous audit found no leaks (Sydney Morning Herald 2014, p. 5),. CSG is also about to be extracted in semi-rural/peri-urban settings such as Gloucester (situated in the Mid North Coast Region of NSW) and Bentley (near Lismore, Northern NSW) where at the time of writing farmers and Green supporters have coalesced to oppose fracking (successfully challenging the development of fracking at Bentley, but not at Gloucester). Similarly, drilling for CSG at St Peters, a western inner-city suburb of Sydney, was abandoned by the energy provider Dart Energy in May 2012 subsequent to objections by residents and Marrickville Council, the relevant local government organisation (Sydney Morning Herald 2012).

Since the installation of the Baird Government in NSW on 23 April, 2014, the cautionary approach to the extraction of CSG using the fracking method seems to have dissipated. In Queensland, both CSG and shale gas are extracted at a higher rate in peri-urban areas than in NSW relying on fracking or by pumping groundwater from coal seams (Queensland Water Commission 2012). Since 2013–2014 CSG has been the dominant source of gas in Queensland and from 2011 to 2014 about 1100 CSG wells were drilled. Extrapolated from Queensland Department of Natural Resources and Mines (2014) CSG is principally accessed in the Surat and Bowen basins which encompass many peri-urban landscapes reliant on coalmining as well as agricultural activities with the capacity to affect groundwater and aquifers adversely. Accordingly, the essential issues to discuss below are whether or not the process of extracting CSG from coal seams is deleterious to the groundwater above and in the vicinity of coal strata: And, to identify the adverse outcomes and how these may best be subjected to risk assessment and management. For environmental (and safety and health and public health risk exposures) these must be conducted proactively. The undertaking of risk assessments after CSG and shale gas extraction has commenced evades accepted principles of risk assessment and invites avoidable environmental risk exposure.

16.1.2 Groundwater Impacts from the Extraction of CSG and Shale Gas and Prevailing Current Risk Assessment Approaches

According to the 2013 Initial report on the Independent Review of Coal Seam Gas Activities in NSW, conducted by the Chief Scientist and Engineer, Professor Mary O'Kane (2013, p. 2), there are a raft of issues other than those which are the subject matter of this chapter, viz.;

There has been widespread concern about CSG activities across Australia and in particular NSW. The major areas of concern are:

- contamination and depletion of groundwater resources and drinking water catchments
- impacts of the co-produced water from CSG activities on the environment
- impacts on the environment of hydraulic fracturing or 'fracking'
- impacts on human health from air quality, chemicals, noise, etc.
- rapid expansion of the industry
- land access and landholder rights
- potential impact on property values
- fugitive emissions
- uncertainty of the science, a lack of data especially baseline data and a lack of trust in the data sources
- the industry is moving ahead of scientific understanding and regulation
- cumulative impacts of multiple CSG wells and multiple land uses such as other mining and agricultural activities
- inadequate monitoring by government of industry activity and perceived unwillingness by government to enforce legislation
- complex and changing legislation.

16.2 NSW and Queensland Codes of Practice and Risk Assessment Methodologies

Those major concerns which are specific to this chapter, i.e.; (a) contamination and depletion of groundwater resources and drinking water catchments; (b) impacts on the environment of hydraulic fracturing or 'fracking', and; (c) cumulative impacts of multiple CSG wells and multiple land uses such as other mining and agricultural activities, are vigorously contested by opposing interested parties in peri-urban areas as detailed below. What is missing from these concerns and the entire O'Kane (2013) report is an apparent lack of a rigorous all-encompassing pro-active environmental risk assessment tool as well as one that in addition to environmental and economic attributes considers the incorporation of community or social impacts as a risk factor. Instead, the Report recommends compliance with Australian/New Zealand/ISO Standard *AS/NZS ISO 31000:2009 Risk management-Principles and Guidelines* (ISO 31000), a generic risk Standard which although mandatorily required by the 2012 *NSW Code of Practice for Coal Seam Gas Fracture Stimulation Activities* does not include a risk 'tool' precluding it from conducting a comprehensive risk assessment unless a risk methodology is incorporated into the already over-complicated risk process of the Standard. In addition, there is no compliance requirement to use ISO 31000 under the 2012 *NSW Code of Practice for Coal Seam Gas Well Integrity* an inexplicable divergence of risk management policy which is discussed further below. In Queensland there are two Codes of Practice (CoPs) which have application to CSG; the *Code of Practice for constructing and abandoning coal seam gas wells and associated bores in Queensland* and the *Code of Practice for coal seam gas well head emissions detection and reporting*, neither of which mandate a specific risk assessment tool. Further, the latter of the two is specific to CSG leaks only whereas the former applies to CSG wells and water bores but, unlike in NSW, there is no CoP which has application to fracking. The lack of specificity relative to fracking in all probability leads to evasion of legal requirements to make the exploration and extraction of CSG safe for groundwater, aquifers and the environment generically.

16.2.1 The Applicability of ISO 31000 vs. Triple Bottom Line Risk Assessments

Owing to the complexities and range of direct and ancillary hazards associated with CSG and shale gas extraction, a raft of dedicated risk tools may need to be imported into ISO 31000 to manage the array of risks of fracking and groundwater extraction methods. Due to these complexities the application of one dedicated risk model in conjunction with the Triple Bottom Line (TBL) approach of risk management is suggested below owing to the latter's capacity to address the environmental, social and economic aspects of CSG and shale gas extraction. However, as with the ISO

31000, the TBL approach, even though it is promoted by Federal government departments as the appropriate risk approach for community consultation, is not mandated at law. TBL was not mentioned in the O'Kane Final Report which is not surprising as it is not mandatory. Even so, there was an implicit recognition that the community should be incorporated into a risk mitigation approach; viz., under the heading 'There are no guarantees', the Report (p. 2) opined:

> All industries have risks and, like any other, it is inevitable that the CSG industry will have some unintended consequences, including as the result of accidents, human error, and natural disasters. Industry, Government and the community need to work together to plan adequately to mitigate such risks, and be prepared to respond to problems if they occur.

Nonetheless, it may be more appropriate to resort to the Quadruple Bottom Line (QBL) approach which incorporates corporate and public sector governance, as well as environmental, social and economic attributes although like TBL it is not mandatory and is not discussed here.

16.2.2 How the Nature and Location of CSG in Coal Beds Governs Extraction Processes

It is instructional in this regard to acknowledge the terms of reference of the New South Wales Legislative Council General Purpose Standing Committee Report (No. 5) Inquiry into coal seam gas, 2012 which were to inquire into and report on the environmental, economic and social impacts of CSG activities, including exploration and commercial extraction activities, allowable under the NSW Petroleum (Onshore) Act 1991 (the umbrella enabling legislation for minerals exploration). The root causes of how extraction of CSG impacts on water quality and water quantity are inherent to the location and nature of the gas and the processes required to bring it to the surface. CSG occurs naturally during the formation of coal seams in varying quantities and mainly consists of methane developing in the coal.

Methane accumulates during the geological process of coal formation (coalification) when organic plant material is converted into peat and then coal over millions of years due to the pressures of underlying and overlying strata. The methane is confined in the coal seam by the coalification process comes adsorbed to micropores (tiny openings) on the coal surface and held within the natural fracture system, called cleats. The combined pressures trap the methane in place after the coalification process has ended which means that for it to be released it must either be accessed by a vertical well by pumping groundwater from the coal seam or by fracking if it does not exit up the well. Typically coal seams are closer to the surface than 'conventional' natural gas reservoirs hence the designation 'unconventional' gas for CSG as well as for shale gas which require less drilling.

CSG extraction drilling techniques started to evolve in the 1980s in Australia to extract (bleed) methane from very 'gassy' underground coalmines to minimise explosions, initially letting it escape to the surface. However, methane began to be

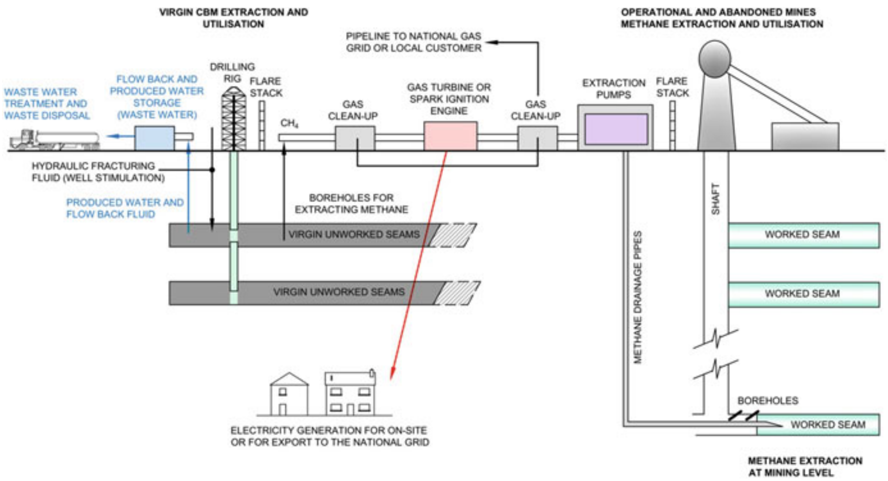

Fig. 16.2 Options for methane extraction and utilisation (Adapted from DTI 2001a) (Source: Environment Agency, UK (2014))

harnessed to pit top turbines from wellheads to produce electricity for mine usage initially, but eventually putting electricity into main grids to create cost offsets. Earlier in the USA these extraction techniques evolved when the USA government offered large tax incentives for the production of CSG to minimise the reliance on petroleum hydro-carbon fuels. Since this period CSG drilling has evolved quickly with the adaptation of traditional oil and gas techniques such as fracking to the already existent coal mining techniques of bleeding methane (Fig. 16.2).

16.2.3 The Extraction of CSG and Managing the Risks of 'Produced' Water

To extract gas without fracking the pressure of the water in the coal seam must be lowered. This is done by pumping water from the coal seam to the surface through one or more wells. This dewatering process results in significant quantities of saline water, known as incidental or produced water, to be brought to the surface which according to legislative requirements, typically by CoPs in NSW and Queensland, must be safely disposed of. Water that has been pumped from a coal seam to enhance the flow of methane can often be saline or brackish and may be polluted with other substances dissolved from the coal, such as heavy metals and radionuclides, which can be toxic to plants, animals and humans. Concentrated brines (with or without toxic chemicals) found in expelled groundwater need environmental risk management and disposal based on proactive risk assessments (Bureau of Resources and Energy Economics 2013).

Contaminated ‘produced’ water also needs risk immune storage, transport and treatment predicated on proactive risk assessments. Relevant risk assessments may ameliorate and/or prevent spills or leaks into crops, native vegetation, surrounding surface waters, aquifers and groundwater above and underneath the pumped coal seam which may be articulated portions of the same hydrological system. Even after treatment of produced water, its disposal into rivers and creeks can affect stream ecosystems if not matched to stream temperature, constituents and natural flow patterns (Bureau of Resources and Energy Economics 2013). In December 2013, AGL attempted to dispose of produced water from its Gloucester pilot CSG wells by having it transported in tankers to be disposed of at Hunter Water, the state agency managing Newcastle’s sewage network, but which Hunter Water rejected. One of the reasons cited was that, ‘it viewed the dangers as too high to rely on local waste processing sites to remove all potentially harmful chemicals before discharging the remaining water into its network.’ (Sydney Morning Herald 2015).

Ensuring structural integrity of CSG well casings, usually made from concrete, is also an essential element of managing potential impacts of CSG operations on groundwater by conducting proactive risk assessments to manage contamination of groundwater due to cracking, fracturing and shrinkage of the cement casing required under CoPs in NSW and Queensland. Well casing failure could result in ‘produced’ water leaking down the well into surrounding strata causing contamination of aquifers and groundwater (Bureau of Resources and Energy Economics 2013).

The National Harmonised Regulatory Framework for Natural Gas from Coal Seams under the Standing Council on Energy and Resources (SCER) also requires that:

> Decommissioning and well abandonment must ensure the environmentally sound and safe isolation of the well for the long term. It must ensure the protection of groundwater resources, isolation of the productive formations from other formations, and the proper removal of surface equipment

and:

> Sound well integrity can also minimise leakage of CSG into the air a direct greenhouse gas emission. Greenhouse gas data for CSG are being collected, including the primary sources of emissions and reasons for variance in leakage rates. (Bureau of Resources and Energy Economics 2013)

These and other regulations are requirements of relevant NSW and Queensland CoPs are discussed below.

In Queensland CSG was, and is, produced since 1995 from the Walloon Coal Measures of the Surat Basin and the Bandanna Formation of the Bowen Basin from many thin coal seams separated by layers of strata which exude water easily and are known as aquifers using the method which pumps groundwater to the surface. Significantly, the Walloon Coal Measures are a geologic layer of the Great Artesian Basin which comprises layers of lower permeability rocks alternating with aquifers of high economic importance which also feed springs of high ecological and cultural importance (Queensland Water Commission 2012). More water is taken out during ‘unconventional/unnatural’ CSG extraction than during ‘conventional/natural' petroleum and gas production which, according to the Queensland Water Commission Report in 2012, used 1800 ML of water per year whereas water extraction from CSG was about 18,000 ML per year. According to the Queensland Water Commission Report the combined impact of petroleum and gas extraction on groundwater extraction was deemed significant enough to declare a cumulative management area in 2011 because;

> When water is extracted from a gas well, the groundwater levels fall in the area surrounding the well. Where a petroleum well field is established, the impacts extend laterally beyond the extent of the well field. If there are multiple well fields adjacent to each other, the impacts of water extraction from the fields on water levels will overlap. (Queensland Water Commission 2012)

16.3 Fracking and the Potential for Adverse Impacts on Groundwater, Aquifers and the Environment

On the other hand, if gas extraction is slow due to the gas being 'tightly held' within the coal seam, hydraulic fracturing must be used to improve gas recovery. Fracking involves high-pressure injection of sand, water and chemical compounds, the BTEX chemicals (benzene, toluene, ethylbenzene and xylene) into the coal seam to fracture the rock and hold the fractures open to release the gas as with 'conventional' gases such as LPG and LNG that occur in deeper underground porous sedimentary rock reservoirs. The potential for deleterious effects of CSG extraction on water quality and quantity are great although not yet definitively investigated in Australia. Currently, the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia (the National CSG Chemicals Assessment Project) conducted by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Department of the Environment and Geoscience, Australia has not yet reported notwithstanding that the assessment was due in 2014 (Australian Government 2014). Even though in NSW and Queensland stricter legislation and companion CoPs have been introduced it seems that the impact of chemicals used for CSG extraction are either intentionally or inadvertently not observed.

In NSW, for example, in 2011 the Government banned the use of BTEX chemicals in CSG fracking fluids and banned the use of evaporation basins for the disposal of CSG produced water (NSW Office of Water 2014). According to the NSW Office of Water (2014), 'The NSW Aquifer Interference Policy was released in September 2012 and ensures that the impacts of CSG and other mining developments on groundwater resources are now subject to greater scrutiny and control'. Whether it is effective, or not, is uncertain. Two CoPs applying to hydraulic fracturing and CSG developments were released by the NSW Government in 2012 to strengthen the controls applying to gas exploration and production. There is also a draft CoP for CSG Exploration.

16.4 Peri-Urban Community Concerns About Fracking in NSW and Robust Legislation

In NSW and Queensland there were and are attempts to evade the legislative and regulatory framework. As the New South Wales Legislative Council General Purpose Standing Committee Report (No. 5) Inquiry into coal seam gas released in May 2012 shows most of these evasions affect peri-urban communities (NSW Parliament 2012). In the Foreword the Chair, the Hon. Robert Brown MLC, from the Shooters Party found generically that;

> This Inquiry received nearly 1,000 submissions and took evidence from approximately 130 witnesses. The evidence highlights a number of recurrent themes. With particular reference to property rights, there is a marked lack of equity between landholders and mining companies with regard to land access.
>
> The Committee therefore recommends that the Petroleum (Onshore) Act 1991 [the primary legislation granting CSG exploration licences] be reviewed with a view to strengthening landholder rights and achieving a fair balance between the rights of landholders and coal seam gas operators. The practices of coal seam gas companies are variable at best, and on the whole have been less than acceptable. This was the case not only with regard to negotiating land access, but also with regard to community consultation.
>
> The actions of successive NSW governments also leave room for improvement. Governments have not done enough to provide accessible and factual information about the development of the industry, which has contributed to a high level of alarm amongst communities affected by coal seam gas exploration. In addition, it is clear that the industry's development has outpaced the ability of governments to regulate it, particularly in relation to technical practices such as the storage and disposal of 'produced' water and fracking [*sic*] fluids. To address the concerns around fracking, the Committee recommends that the ban on fracking remain in place until the National Industrial Chemicals Notification and Assessment Scheme assesses the safety of fracking chemicals. The Government also needs to do more to monitor the industry and ensure compliance with the regulatory regime. (NSW Parliament 2012 p. xiii)

Specifically, 35 recommendations were made. Word length considerations only permit those most relevant to the subject matter of this paper.

The key issues considered in this report, and the Committee's recommendations, are summarised in the following paragraphs:

> **Water**
>
> A key question faced during this Inquiry was whether coal seam gas activities could contaminate or deplete water resources. The scientific evidence on this question is contested. The Committee considers that the uncertainty about the likelihood of these impacts occurring underscores the need for more data to be gathered and analysed in regions where exploration is taking place. To this end the NSW Government should actively engage with the Commonwealth's Independent Expert Scientific Committee, and request that regional-scale water assessments be finalised as a matter of urgency in regions where exploration is taking place (Recommendation 1). In addition, some of the data needed to assess cumulative water impacts is held by coal seam gas companies and is considered by some coal seam gas companies to be commercial in confidence. Gaining access to this data should be a priority for the Commonwealth's Independent Expert Scientific Committee (see also Recommendation 1).

Fracking
Inquiry participants expressed particular concerns about fracking and its potential to heighten the risks of water contamination and depletion. It would be premature for the Government to lift its moratorium on fracking before the chemicals used are tested, and a stringent regulatory framework is put in place. The Committee is also concerned that any leaks or spills of fracking fluids or produced water could contaminate water resources. The Committee therefore recommends that the open storage of fracking fluids and produced water be banned (Recommendations 8 and 10).

Remediation
Coal seam gas companies must be held accountable for remediation in the event of deleterious environmental impacts. The Committee recommends that an effective model be developed to hold coal seam gas companies to account for the full costs of remediating any potential environmental impacts, such as water contamination or depletion, even if such impacts occur decades into the future p. xiv.

Community Engagement
A number of Inquiry participants, and key stakeholders such as local councils and indigenous communities, are disgruntled about the lack of genuine community engagement in relation to the coal seam gas industry in New South Wales. In many instances community consultation appears to have been inconsistent, poorly timed and restrictive. As one means to improve its engagement with regional communities, the Committee recommends that the NSW Government establish regional 'shop fronts'.

Land Access and Compensation
Many Inquiry participants are concerned that coal seam gas companies will take an aggressive approach to enforcing their access rights. Despite evidence to the contrary from several coal seam gas companies, the Committee cannot dismiss the evidence that some operators have attempted to pressure landholders for access, nor the possibility that companies may force access in the future. As such, the Committee believes that the Petroleum (Onshore) Act 1991 must to be reviewed with a view to strengthening landholder rights (Recommendation 16) p. xv.

Agriculture
Numerous Inquiry participants said that coal seam gas development cannot coexist with agriculture and food production in many areas across the State, and called for 'no go' zones to be established. However other Inquiry participants, such as the NSW Government, called for 'balanced coexistence' between resource development, agricultural production and environmental protection. To achieve 'balanced coexistence' the Government has developed Strategic Regional Land Use Plans. The Committee is concerned that only two Plans have been completed to date, and recommends that the development of the remaining Plans, including for coastal areas, be expedited (Recommendation 24) p. xvi.

Regulation
Inquiry participants identified a number of claimed deficiencies in the regulatory regime including fragmentation across government agencies, inadequate monitoring and enforcement, ineffective complaints handling, and insufficient resourcing. In addition, there is a potential conflict of interest in the role played by the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS). To address these deficiencies, the Committee has therefore made several recommendations, drawing on Queensland's experience of regulating the coal seam gas industry.

The Committee recommends that a new Industry Unit be established within the Division of Resources and Energy, DTIRIS. The Unit should function as a 'one-stop-shop' on coal seam gas issues responsible for issuing licences, driving policy development and acting as a 'knowledge bank' within Government. In addition, a new Compliance Unit should be established in the Environment Protection Authority with responsibility for monitoring coal seam gas activities, investigating incidents, and taking enforcement action where required (Recommendation 31).

> As noted by the Ombudsman, there are 'obvious challenges' for DTIRIS in its responsibilities for promoting the industry and issuing licences, as well as conducting monitoring and enforcement activities. There should instead be a clear division between the agency or agencies responsible for monitoring the coal seam gas industry to ensure compliance with industry regulation, and taking enforcement action where required, and the agency or agencies charged with supporting the industry's development and issuing licences. NSWLC Inquiry into coal seam gas (2012) p. xvi

In other words, to counteract the perceived conflicts of interest of DTIRIS' functions of being a development consent body which also provides paid industry services that partially fund its operations. Aside from the need to address fragmentation, the Committee considered it imperative that the Government act to address the potential conflict of interest in the role played by DTIRIS.

16.5 Peri-Urban Community Concerns About Fracking in Queensland and Robust Legislation

In Queensland community concerns in peri-urban areas about fracking also resulted in increased CSG-LNG legislation and enforcement. Briefly, according to the Queensland Government Business and Industry portal;

The Queensland Government has put in place laws to:

- Protect groundwater and the Great Artesian Basin – Landholders and rural communities depend on groundwater and the Great Artesian Basin. The Office of Groundwater Impact Assessment (OGIA) provides the groundwater management functions previously carried out by the Queensland Water Commission. OGIA is responsible for assessing potential future cumulative impacts on groundwater and developing management responses that help to minimise those impacts.
- Adopt a precautionary approach – The Queensland Government has introduced an adaptive environmental management regime. This allows for the alteration of environmental conditions placed on a project on the basis of new information and/or research as it becomes available.
- Control water quality – The Queensland Government has banned the use of evaporation dams and strengthened conditions around the treatment and use of CSG water. These measures further protect the Great Artesian Basin, creeks and rivers, and farming land.
- Prohibit harmful chemicals – CSG operators are not allowed to use the petroleum compounds benzene, toluene, ethylbenzene and xylene – also known as BTEX – as a deliberate component of hydraulic fracturing fluids.
- Protect landholders' water quality – CSG operators must measure the water quantity in landholders' water bores before CSG activities start and during CSG extraction. This provides baseline information for monitoring impacts over time and compensation if bores are affected.

Also a range of enforcement tools and penalties are in place to deal with environmental incidents and compliance breaches. The Queensland Government has also established the CSG Compliance Unit (formerly the LNG Enforcement Unit) to monitor CSG operators and ensure that they are in compliance with industry laws and regulations (Queensland Government Business and Industry Portal 2014).

16.6 The Impacts of Predicted Large Scale Development of Shale Gas in Queensland

Relative to contested concerns about the economic benefits, such as thousands of jobs especially in regional and peri-urban areas, expressed during the NSW Legislative Council Inquiry into CSG, albeit in shale gas, recent proposed expansion in shale gas exploration in Queensland seems to contradict the predictions of the Inquiry. The first shale gas well in Australia began operation in the Cooper Basin in South Australia in October 2012. According to the United States Energy Information Administration's (EIA) 2013 survey of world shale deposits, Australia has great potential for the production of shale gas: 'With geologic and industry conditions resembling those of the USA and Canada, Australia has the potential to be one of the next countries with commercially viable shale gas and shale oil production' (Ross and Darby 2013, p. 9).

Whereas probably Queensland is the most promising potential source of shale gas, a study of shale gas in Australia found that while it is likely to be plentiful in Australia, the lack of infrastructure in this country (relative to the United States) is likely to add to production costs making shale gas production less feasible (Cook et al. 2013). However, more recent private sector estimations of Queensland's prospective shale gas deposits in January, 2014 have solicited the following article in Bloomberg news online, headed, 'Shale's 'Next Big Play' Draws U.S. Gas Producer to Australia.' It was qualified with the tag-line '…shale-s-next-big-play-draws-magnum-to-australia-s-cooper-basin.html.'

Paton (2014), a Bloomberg on-line correspondent, reports:

> Australia has the most attractive shale gas prospects outside North America, according to Magnum Hunter Resources Corp. (MHR), a Houston-based producer that says it has scoured the world looking for deposits of the gas that has revolutionized energy supply in the U.S.

Paton (2014), quoted Kip Ferguson, executive vice president of exploration at Magnum Hunter Resources Corp, who said in an interview in Sydney:

> We've looked at Colombia, we've looked at Mexico, we've looked at Argentina, we've looked at Poland, and we've looked at China of course. 'None of those areas are prepared to allow the unconventional technologies to develop these plays. They aren't as far advanced as Australia.' (Paton 2014)

Further;

> The Cooper Basin, an area straddling the border of South Australia and Queensland states, has also lured investment from Chevron Corp. and BG Group Plc (BG/) ahead of expected shortages of the fuel to feed more than $60 billion of liquefied natural gas projects in eastern Australia that will ship to Japan, South Korea and China.

With such determined intentions of massive capital investment and proposed economic benefits, the contested terrain between major regional economic development and potential large scale vitiation and diminution of available groundwater remains unresolved. Furthermore, with the gradual contraction of infrastructure projects in the Australian minerals sector, dwindling coal prices and exports in Queensland and NSW (and iron prices in WA), as well as the downscaling of China's economic growth, economic pressures on state governments may result in a softening of state CSG and shale gas environmental regulation affecting peri-urban areas. This is so, notwithstanding recent improved legislation and regulation in NSW and Queensland relative to groundwater quality and quantity. It is not suggested in this paper that these governments are biased towards private sector CSG and shale gas companies, but that economic reality will have to prevail perhaps to the detriment of the environment. Notwithstanding the take-up of CSG and shale gas extraction, the risks associated with the processes remain and the risks must be comprehensively assessed, but more importantly they must be managed to avert the vitiation of groundwater and aquifers as well as addressing the impacts on communities in peri-urban locations as most CSG and shale gas development is likely to occur near these.

16.7 Complexity of Assessing and Managing Risks for CSG and Shale Gas Extraction

As outlined above, the process of assessing and managing risks associated with the extraction of CSG and shale gas is complex because there is no one comprehensive CSG and shale gas specific risk assessment approach that encompasses community concerns and consultation and the entire CSG shale gas extraction process. In addition, as outlined above, in NSW there are two contradictory risk assessment requirements. Similarly, in Queensland there is no all-encompassing risk assessment methodology that addresses all of the above concerns. Complications also arise in both jurisdictions because of the competing interests of gas producers and communities and the highly politically charged government decision making processes. As explained above, governments are caught between an economically driven imperative to extract CSG and shale gas and a community objective to prevent the vitiation of potable water, groundwater and aquifers.

Relative to divergence of the two legislatively mandatory NSW (CoPs) there are contradictory risk assessment requirements for fracking and gas wellhead extraction methods: On the one hand the *Code of Practice for Coal Seam Gas Fracture Stimulation Activities* requires a Fracture Stimulation Management Plan (FSMP) that must be in place prior to the commencement of a fracture stimulation activity and, on the other hand, 'The FSMP is a non-technical document which is designed to demonstrate to the NSW Government and other stakeholders that the titleholder will appropriately manage the risks associated with the fracture stimulation activity and comply with the mandatory requirements of this Code' (NSW Government 2012a, b, p. 2). Further, mandatory requirements of the CoP are:

> The FSMP must demonstrate that all risks to the environment, existing land uses, the community and workforce, as a result of the fracture stimulation activity, are managed through an effective risk management process that includes identification of hazards, assessment of risks, implementation of control measures and monitoring of the integrity and effectiveness of the control measures. (NSW Government 2012a, b, p. 2).

In addition, 'The FSMP should incorporate a risk assessment conducted in accordance with relevant Australian or international standards to identify the risks posed by the fracture stimulation activity and to ensure that the likelihood and consequence of these risks is properly understood.' And as a mandatory requirement, 'The FSMP must include a risk assessment complying with AS/NZS ISO 31000:2009 Risk management – Principles and Guidelines (NSW Government 2012a, p. 5).' On the other hand, contradictively under Section 16 of the COP 16, Application of Australian and international standards under mandatory requirements states that;

> Titleholders must comply with the following standards in so far as these standards are of an equal or higher standard than those identified elsewhere in this Code and do not conflict with the NSW regulatory framework: a) AS/NZS ISO 31000:2009 Risk management – Principles and guidelines; b) NSW Code of Practice for Coal Seam Gas Well Integrity. (NSW Government 2012b)

This declares that compliance relies on the higher criteria of Standards which are erroneously not identified in the CoP and on risk management standards in the NSW Code of Practice for Coal Seam Gas Well Integrity (NSW Government 2012b) which does not mention ISO 31000 at all. The latter CoP only refers to a generic risk assessment. Therefore as a result, the implication is that if the mandatorily required risk assessment based on ISO 31000 is not implemented there is no infringement of the NSW regulatory framework. Consequently, owing to the fact that no specific risk assessment is required by either of the two relevant Queensland CoPs, better risk management outcomes may be produced by implementing an environmentally specific risk assessment approach in conjunction with TBL.

16.8 Limitations of ISO 31000 to Assess Risks of CSG and Shale Gas Extraction

ISO 31000 has been heavily criticised. For example, typical critiques are:

> Initial reviews of the ISO 31000 have been promising. Touted as a well-written standard, the layman's terminology used transcends limitations of other standards directly written for existing Risk Management executives and professionals. Easily understood by layman and executives alike, the ISO 31000 offers companies a process-oriented manual easily utilized company-wide. However, drawbacks of the ISO 31000 Risk Management Standard include:
>
> - Not control-oriented/does not offer practical implementation tools for Risk Managers to create reliable risk data

- Complete risk identification is not guaranteed
- No risk taxonomies, heat maps or templates provided
- Published without certification.

The ISO definition would seem to suit the relatively simple 'business' risk situations rather than the broader and far more complex multi-dimensional relationships that exist with the risks posed to communities in emergencies or disasters. Risk Management-ISO 31000 (2013)

In addition, ISO 31000, while strong on communication and consultation attributes, does not have a risk assessment capability which makes the laborious process of imported risk tools necessary (as noted above). Furthermore, ISO 31000 does not include the identification of hazards, nor does it recognise hazards; a critical flaw in the requirements for robust risk assessment for environmental (and occupational safety and health) management. Further, as noted above, because it is mainly focused on organisational risks it recognises risk as positive and negative: Whereas for environmental (and occupational safety and health) purposes all risks are always negative; there is no such thing as a positive risk. Therefore it would seem imminently sensible to 'marry' a dedicated 'hard' environmental risk assessment (ERA) for environmental and community risks such as the tool developed by the United Kingdom (UK) Environmental Agency for coal bed methane CBM (known in Australia as CSG) and enhanced coal bed methane (ECBM) which in the UK is the recovery of CBM by injecting carbon dioxide, nitrogen and/or chemicals (known in Australia as hydraulic fracturing or fracking), with the 'soft' TBL social, environmental and economic attributes.

The reasoning underpinning the joining of the two approaches is that while the UK Environmental Agency ERA tool is robust in identifying environmental and community hazards as well as risks, it does not include consultation with affected communities, nor does it consider the social and economic costs that might impact on communities affected by CSG extraction whereas TBL does.

16.9 The Efficacy of the United Kingdom Environmental Agency ERA Tool to Assess and Manage Risks for CSG and Shale Gas Extraction

As well as CBM and ECBM the UK Environmental Agency ERA tool also applies hazard identification and risk assessments for coal mine methane (CMM) recovery for operational coal mines as well as for abandoned mine methane (AMM) after coal mines cease operations. Each of these is subject to the same iterative risk assessment process discussed here only for CBM and ECBM and as an example of the ERA process only the CBM process is mentioned here. Briefly, the ERA covers the following stages which may apply to each phase of CBM production (Fig. 16.3) including the exploration, appraisal, operation and abandonment stages:

- groundworks
- water acquisition

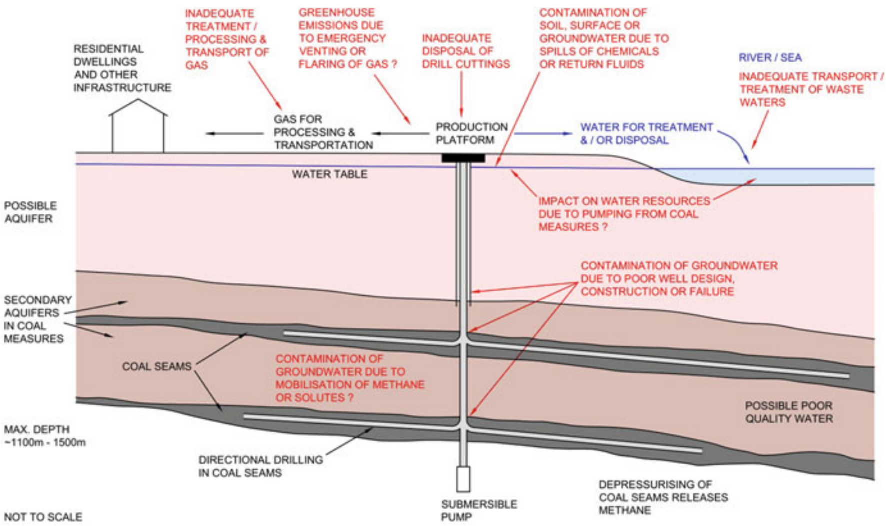

Fig. 16.3 Potential environmental risks from CBM production activities (Source: Environment Agency, UK (2014))

- chemical mixing
- borehole design, installation and integrity
- hydraulic fracturing
- management of fluids, including produced water and flowback fluids
- gas management including onsite compressors, combustion plant, and clean-up plant
- land stability
- well closure and abandonment

A well-established approach to determine the potential risks from CBM production was adopted using a standard source–pathway–receptor model. This approach can be summarised as follows:

- identification of hazards
- identification of consequences
- estimation of the probability of the hazards occurring
- estimation of the magnitude of the unmitigated risk with industry standard controls in place
- identification of risk management options
- estimation of the residual risk after the use of regulatory controls

To aid this process a conceptual model of the environmental risks posed by a single well pad and borehole was produced. This model, which is shown in Fig. 16.3, identified the main sources, pathways and receptors presented during the CBM lifecycle (Environment Agency, UK 2014, p. 8).

16.10 The Risk Magnitude Matrix: Calculating Risk Scores from Probability and Consequences

Risks are then classified according to the magnitude of risk premised on the magnitude of unmitigated risk which is a combination of the probability or likelihood of an event occurring and the consequences or severity for people and the environment if it does. The accompanying risk magnitude matrix has a vertical consequence column which ranges from very low, low, medium through to high whereas the horizontal rows of probability columns also range from very low to high in various permutations in each of the subsequent horizontal rows (Table 16.1). Three colours are used to indicate combinations of consequences and probabilities; light blue for low; yellow for medium and orange for high. Definitions of probabilities are; very low – rarely encountered, never reported or highly unlikely; low – infrequent occurrences; medium – can be expected to occur several times per year; high – repeated occurrences: Whereas definitions of consequences are; very low – slight environmental effect that does not exceed a regulatory standard; low – minor environmental effect which may breach a regulatory standard, but is localised to the point of release with no significant impact on the environment or human health; medium – moderate, localised effect on people and the environment in the vicinity of the incident; high – a major environmental incident resulting in significant damage to the environment and harm to human health (Environment Agency, UK 2014, p. 9).

16.11 Qualitative vs Quantitative Risk Assessment Approaches

The methodology of combining probabilities and consequences to determine a qualitative risk category instead of a quantitative score is commonly used for environmental and occupational safety and health risk matrices and is an acceptable practice worldwide as is the use of the intensity of colour to indicate the magnitude of risk. What is missing from this approach is frequency and duration of risk exposure in combination with consequence and probability, and therefore arguably the approach is only bi-dimensional and too unsophisticated in that it also should consider

Table 16.1 Risk magnitude matrix

	Probability			
Consequence	Very low	Low	Medium	High
Very low	Low	Low	Low	Low
Low	Low	Low	Medium	Medium
Medium	Low	Medium	Medium	High
High	Medium	Medium	High	High

Source: Environment Agency, UK (2014)

frequency and duration. Undisputedly, irrespective of probability and consequences these will expand the magnitude of risk exposure if frequency and duration increase. Consequently, the risk of probability and consequences will increase. Notwithstanding, arguably countervailing the bi-dimensionality of the approach is its easiness in that almost anyone from a worker to a senior manager can use it quickly to provide instantaneous risk assessments unless they are illiterate and/or colour blind. Similarly, small mining contractor businesses could use it after a small amount of training. Also, it's relatively easy application to a multitude of risks stands in sharp contrast to ISO 31000 which could take weeks or even months to assess risks of this nature. Further, the complex numerous requirements and large process cycles of ISO 31000 is more suited to large organisations and probably are too unmanageable for small businesses.

The results for environmental risks categorised in the Risk Magnitude Matrix are then summarised in separate tables for CBM, AMM and CMM for overall risks for those three categories in terms of the exploration, appraisal, operation and abandonment phases of the CBM/CSG extraction process comprising risk assessments of overall environmental risks (Table 16.2 portrays a partial overview of the extent of major risk exposure categories which in total number more than 40).

Table 16.2 Overall environmental risks – coal bed methane

	Exploration	Appraisal	Operation	Abandonment
Source (hazard) – what is the agent or process with the potential to cause harm?	Negative environmental impact to water as a resource, wildlife and their habitats, the atmosphere, human health, property and infrastructure caused as a direct result of an activity undertaken as part of one of the four phases of CBM extraction			
Pathway – how might the receptor come into contact with the source?	Uncontrolled release of pollutants to ground, air or water, physical disturbance of ground or infrastructure			
Receptor – what is at risk?	Groundwater, surface water, wildlife and their habitats, the atmosphere, human health, property and infrastructure			
Harm – what are the harmful consequences if things go wrong?	Breach of an environmental standard; loss or damage to a habitat or resource; injury, ill health or death; damage to property or infrastructure; air pollution			
Probability of exposure – how likely is this contact?	Low	Medium	Medium	Low
Consequence – how severe will the consequences be if this occurs?	Medium	Medium	High	Low
Magnitude of risk – what is the overall magnitude of the risk?	Medium	Medium	High	Low

(continued)

Table 16.2 (continued)

	Exploration	Appraisal	Operation	Abandonment
Justification for magnitude	The process is new to the UK and its particular geology. There is mixed evidence from overseas activity. Independent experts note the potential consequences are high if the process is not regulated properly or industry best practice is not followed			
Current regulatory controls – on what regulatory basis can the environment agency impose controls?	Water Resources Act 1991			
	Water Framework Directive (2000/60/EC) Groundwater Daughter Directive (2006/118/EC) Mining Waste Directive (2006/21/EC)			
	The Environmental Permitting (England and Wales) Regulations 2010 (as amended)			
	Control of Pollution (Amendment) Act 1989			
	The Waste (England and Wales) Regulations 2011 – registration of waste carrier and brokers			
Current regulatory controls – on what basis can others impose controls?	Town and Country Planning (Development Management Procedure)(England) Order 2010			
	Town and Country Planning (Environmental Impact Assessment) Regulations 2011			
	The Environment Agency is a statutory adviser to the Minerals Planning Authority on planning applications and Environmental Impact Assessments			
	Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996			
	Borehole Sites and Operations Regulations 1995			
	The Hydrocarbons Licensing Directive Regulations 1995			
	The Petroleum Act 1998			
	The Coal Industry Act 1994			
Residual risk –what is the magnitude of the risk after management?	Low. The Environment Agency will use appropriate controls under the legislation above (where it is the competent authority) to manage the identified risks, supported by monitoring and compliance work (for example, site inspections)			

Source: Environment Agency, UK (2014)

16.12 TBL Incorporating GRI Social, Environmental and Economic Assessment Indicators

Owing to the fact that there are no standardised formats for the application of TBL, a suitable approach should be chosen and the most appropriate come from generic sustainability models. There are many sustainability assessment methodologies for evaluating the performance in the extractive industries including CSG and shale gas mining organisations. Those that stand out are the Global Reporting Initiative (GRI 2002; updated in 2013 to GRIG4) and development of standards (OECD 2002), the key drivers for adoption of sustainability management in economies globally (Singha et al. 2012 p. 282). TBL in terms of social, environmental and economic assessment is compatible with GRI which since 2003 has been endorsed by the Business Council of Australia which represents a large number of major companies that in Australia use GRI in conjunction with TBL. It is also used worldwide (BCA

2013). However, TBL does not inherently possess the metrics that are necessary to produce quantitatively measurable data. Nonetheless, as well as environmental attributes found in GRI and ERA and social and economic features inherent to GRI and TBL, each of these and other related features must be measurable. Qualitative data gathered for the social, environmental and economic attributes of TBL is measurable providing that recognised methods, such as community semi-structured focus groups, mixed method survey instruments with scaled items, such as Likert scales, as well as open ended qualitative items are used. Azapagic (2004) developed a framework for sustainability indicators for the mining and minerals industry which is also compatible with GRI (Singha et al. 2012, p. 282). Significantly, it is also fully compatible with TBL. Indicators and composite indicators are increasingly recognised as a useful tool for policy making and public communication in conveying information on a country's performance in fields such as environment, economy, society, or technological development' (Singha et al. 2012).

16.13 Composite Indicators for Sustainability

The construction of composite indicators involves the selection of various methods/tools at different stages. 'However, this may result in various issues of uncertainty due the selection of data, erroneous data, data imputation methods, data normalisation, standardisation, weighting methods, weights' values and aggregation methods' (Singha et al. 2012, p. 287). Yet, in the literature implementing composite indicators is regarded as the most appropriate way for evaluating sustainable development.

Composites indices can be constructed with or without weights depending on its application. Indices are very useful in focusing attention on and often simplify the problem. Use of uncertainty and sensitivity analysis can assist in identifying the gaps and check the robustness of the composite indicator, which further enhances the transparency and credibility of the indices. Tools for sensitivity analysis should evaluate the output variation in models and also be able to apportion composite indicator quantitatively or qualitatively, to different types of variation in the study (Singha et al. 2012 p. 287).

Therefore, for the purposes of this paper composite sustainability indicators are chosen, drawing on the ERA, as the principal environmental tool, in conjunction with GRI indicators as the preferred methodology to inform the social, environmental and economic attributes of TBL when applied to peri-urban well development and CSG extraction.

16.14 Conclusions

This chapter has briefly detailed the complexity of the contest between energy security and groundwater security owing to the potential increase in coal seam and shale gas projects in NSW and Queensland peri-urban areas. Competing environmental and economic imperatives, briefly outlined above, may determine that Australia's scarce groundwater supplies could be adversely impacted. On the one hand, the projected decline of the Australian minerals and boom suggests that alternative, possibly cheaper, supplies of 'unconventional' gases may provide a much needed boost to the Australian economy, in particular in the labour market in regional areas where hitherto small towns may be at the forefront of peri-urban expansion as a result.

In some locations in NSW, and more so in Queensland, peri-urban development is already evident, in the first instance due to the increase in coal mining production, and to a smaller degree in CSG and shale gas exploration and to a lesser extent in production. However, this paper has suggested that due to the seemingly unavoidable entry of large scale overseas CSG, and especially shale gas, producers, the production of shale gas will increase exponentially in peri-urban areas in particular. Accordingly, unless legislation and Codes of Practice are strictly adhered to by these producers and/or rigorously enforced by government the evidence produced in this paper proposes that the impacts on groundwater could be severe. In addition, pro-active robust all-encompassing risk assessment and management is essential in this regard.

References

Azapagic A (2004) Developing a framework for sustainable development indicators for the mining and minerals industry. J Clean Prod 12:639–662

Bureau of Resources and Energy Economics (2013) Gas market report. Bureau of Resources and Energy Economics, Canberra, Australia

Environment Agency, UK (2014) Report – an environmental risk assessment for coal bed, coal mine and abandoned mine methane operations in England. Environment Agency, Bristol, UK

NSW Government (2012a) Code of practice for coal seam gas fracture stimulation activities. NSW Government, Sydney, Australia

NSW Government (2012b) Code of practice for coal seam gas well integrity. NSW Government, Sydney, Australia

NSW Parliament (2012) Legislative council, vol 5, General purpose standing committee report. New South Wales Parliamentary Library, Sydney, Australia

O'Kane M (2013) Initial report on the independent review of coal seam gas activities in NSW. NSW Government, Sydney, Australia

O'Kane M (2014) Final report of the independent review of coal seam gas activities in NSW. NSW Government, Sydney, Australia

Queensland Department of Natural Resources and Mines (2014) Queensland's petroleum and coal seam gas 2013–14. Queensland Department of Natural Resources and Mines, Brisbane, Australia
Queensland Water Commission (2012) Underground water impact report for the Surat Cumulative Management Area, Brisbane, Australia
Ross C, Darby P (2013) Research paper unconventional gas: coal seam gas, shale gas and tight gas. Research Service, Victorian Parliamentary Library, Department of Parliamentary Service, Melbourne, Australia

Articles

BCA (2013) Sustainability: a guide to triple bottom line accounting. Common Ground Publishing, Sydney, Australia
Singha RK, Murtyb HR, Guptac SK, Dikshit AK (2012) An overview of sustainability assessment methodologies. Ecol Indic 15:281–299
Sydney Morning Herald (2012) 11 May Fairfax Press, Sydney
Sydney Morning Herald (2014) 18–19 Oct. Fairfax Press, Sydney
Sydney Morning Herald (2015) 14 Mar. Fairfax Press, Sydney

Internet Sources

Alderman P (2014) NSW coal seam gas industry – major new developments proposed – Nov 2014, viewed 26 July 2015. http://www.piperalderman.com.au/publications/resources-update/article/6769
Australian Government (2014) National Assessment of Chemicals Associated with coal seam gas extraction in Australia, viewed 12 Dec 2014. http://www.nicnas.gov.au/communications/issues/fracking-hydraulic-fracturing-coal-seam-gas-extraction/information-sheet
Cook P, Beck V, Brereton D, Clark R, Fisher B, Kentish S, Toomey J, Williams J (2013) Engineering energy: unconventional gas production report for the Australian Council of Learned Academies, ACOLA. Viewed 1 May 2014. http://acola.org.au/PDF/SAF06FINAL/FinalReportEngineeringEnergyJune2013.pdf. Independent Inspections, 2013
Geoscience Australia (2013) Atlas of Australian mineral resources, mines and processing centres, viewed 4 Dec 2014. http://www.australianminesatlas.gov.au/aimr/commodity/blackcoal.html
GRI – Global Reporting Initiative (2002a) The global reporting initiative–an overview. Global Reporting Initiative, Boston, USA. Viewed 15 May 2015. www.globalreporting.org 2004
NSW Government (2011) Atlas of New South Wales, viewed 4 Dec 2014. http://atlas.nsw.gov.au/public/nsw/home/topic/article/coal.html
OECD – Organisation for Economic Co-operation and Development (2002). An update of the OECD composite leading indicators. Short-term Economic Statistics Division, Statistics Directorate/OECD. Viewed 15 May 2015. http://www.oecd.org 2004
Queensland Government Business and Industry Portal (2014) CSG-LNG legislation. Viewed 8 May 2014. http://www.business.qld.gov.au/industry/csg-lng-industry/regulatory-framework-csg-lng/csg-lng-legislation
NSW Office of Water (2014) Viewed 4 May 2014. http://www.water.nsw.gov.au/Water-management/Groundwater/Water-and-coal-seam-gas/Water-and-coal-seam-gas
Paton J (2014) Shale's 'Next Big Play' draws U.S. gas producer to Australia. Viewed 5 May 2014. http://www.bloomberg.com/news/2014-01-16/shale-s-next-big-play-draws-magnum-to-australia-s-cooper-basin.html

Part VI
Wastewater and Irrigation

Chapter 17
Use of Recycled Water for Irrigation of Open Spaces: Benefits and Risks

Muhammad Muhitur Rahman, Dharma Hagare, and Basant Maheshwari

Abstract The supply and sustainable use of recycled water may play an important role in enhancing urban water supplies in many water-scarce parts of industrialised countries like Australia because of the reduced treatment cost relative to seawater desalination and imported surface water. One such reuse option includes application of recycled water in the irrigation of urban open spaces. In 2009–2010, in Australia, the state-wide average of recycled water use in urban irrigation was 27.2 % and the nation-wide average was 14 % of the total recycled water produced. In Sydney, New South Wales (NSW) approximately 3.8 GL of recycled water is used for irrigating sports fields, golf courses, parks, landscapes and racecourses and, by 2015, it is expected that the recycled water will meet 12 % of the total water demand in greater Sydney. Despite significant benefits of recycled water, there are several concerns related to environmental and health risks. If not properly managed, recycled water could deteriorate soil health in terms of increased salinity and sodicity, heavy metal accumulation and decreased hydraulic conductivity of soil. However, there are tools to reduce risks due to urban irrigation using recycled water; such as, national and state-wide standards of recycled water quality for urban irrigation, sustainable urban water management strategy and the pollutant control framework. In this chapter, recycled water usage for urban open space irrigation was discussed in the international and national contexts. Also, benefits and risks associated with recycled water usage in open space irrigation were examined and possible control measures were discussed.

Keywords Recycled water • Irrigation • Urban open spaces • Water quality • Environmental risk

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17.1 Introduction

Recycling is one of the viable options to attain sustainable management of wastewater. The merits of recycled water are diverse and include reducing pressure on existing fresh water supplies, minimising effluent disposal to surface or coastal waters and provisioning a constant volume of water other than rainfall-dependant sources (Chen et al. 2012). The supply and use of recycled water may play an important role in enhancing urban water supplies in many water-scarce parts of industrialised countries because of its reduced treatment cost relative to seawater desalination and imported surface water. The technological improvement and economic affordability of wastewater treatment has made wastewater recycling a reality and broadened the most sustainable use of recycled water. One such reuse option includes the application of recycled water in the irrigation of urban open spaces.

Recycled water is the treated wastewater after removing solids and certain impurities. Characteristics of recycled water depend on its source, treatment level and geographic location. Recycled water characteristics can be classified according to its physical, chemical and biological aspect. The biological aspect is important when health effects are considered. Otherwise, physical and chemical characteristics are crucial to understand the environmental effects of using recycled water. Important recycled water characteristics are pH, total dissolved solids (TDS), salinity, sodium adsorption ratio (SAR) and heavy metals. These parameters directly influence the salt accumulation in the soil and also the sodicity and its effect on soil.

17.1.1 Characteristics of Recycled Water for Using in Irrigation

Various domestic and commercial activities at the source of wastewater generation contribute towards elevated levels of salt in wastewater. In other words, composition of recycled water depends on the original composition of the municipal water supply and nature of residential and commercial communities contributing to the wastewater, and varies from community to community. In the conventional wastewater treatment process, the majority of mineral salts pass through the wastewater treatment system unaffected, unless reverse osmosis is used as one of the treatment processes (Aiello et al. 2007; Rebhun 2004). Hence, in most cases recycled water exhibits relatively higher amounts of salts, chemical contaminants and pathogens (in secondary treated recycled water) that are potentially detrimental to soils or plant growth and pose a risk to the environment and public health. According to DEC (2004), recycled water for irrigation is classified as low, medium and high strength based on the concentrations of nitrogen, phosphorus, BOD_5, TDS and other potential contaminants (Table 17.1). It is expected that for a certain class of recycled water strength, all the constituents fall within the given range. However, the strength of recycled water to be used in urban irrigation should also agree with plant type,

Table 17.1 Classification of recycled water for irrigation according to its strength (Dec 2004)

Parameters	Strength of recycled water (mg/L)		
	Low	Medium	High
TDS	<600	600–1000	1000–2500
Total nitrogen	<50	50–100	>100
Total phosphorus	<10	10–20	>20
BOD_5	<40	40–1500	>1500
Metals, pesticides	Five times the value mentioned in ANZECC and ARMCANZ (2000) is considered as high strength		
Grease and oil	>1500 mg/L is considered as high strength		

tolerance of the plant to contaminants, site characteristics, management of the site such as water balance for the site, relevant environmental objectives for any receiving water, existing ambient water quality and conditions under which a discharge is likely to occur.

In Australia, in most of the cases, recycled water is tertiary treated before using it in urban irrigation. As shown in Table 17.2, data collected from Sydney Water shows levels of different contaminants in the recycled water are within the range of Australian Standards for urban irrigation. Amounts of contaminants present in the recycled water of some overseas countries are also highlighted in Table 17.2. Data presented in the table reveals the wide range of contaminants present in recycled water. This is because of the variability in community and water usage pattern based on geographical position, as discussed earlier. However, some contaminants (such as, electrical conductivity and TDS) shown in the table are significantly higher than drinking water standards. According to NRMMC-EPHC-AMC (2006), electrical conductivity (EC), TDS, Na^+ and Cl^- are 0.1 dS/month, <500 mg/L, 180 mg/L and 250 mg/L, respectively in town (drinking) water. In addition, higher levels of certain anions and cations are also observed in recycled water. The impact of higher amounts of salt in recycled water used for irrigation is discussed in Sect. 17.4.

17.2 Current Status of Use of Recycled Water for Urban Irrigation

Urban irrigation with recycled water helps to attain water sustainability, which subsequently leads a city to grow as a liveable city. Knowledge of the current status of recycled water use in urban irrigation in the context of geographical distribution is important to understand and improve the use and quality of recycled water in urban irrigation. In this section recycled water use in urban irrigation practiced in different developed countries is reviewed. Later, the current status of using recycled water in urban irrigation in Sydney and overall Australia is discussed.

Table 17.2 Key characteristics of recycled water for irrigation

Parameter	Unit	Recycled water characteristics (International)[a]	Recycled water characteristics (Australian)[b]	Recycled water standard for irrigation (Australian)[c]
Total Salinity, EC	dS/m	0.51–2.7	0.803	0.65–1.3[d]
Total dissolved solids (TDS)	mg/l	358–1800	495	600–1000[e]
Sodium adsorption ratio (SAR)		1.9–11	5.4	10–18[e]
BOD5	mg/l	6–13.2	<2	40–1500[e]
Aluminum	mg/l	0.0–0.17	0.033	5
Arsenic	mg/l	0.00062–0.005	<0.001	0.1
Boron	mg/l	0.0005–0.00118	0.048	0.5
Cadmium	mg/l	0–0.22	0	0.01
Cobalt	mg/l	0.001–4.8	0.001	0.05
Copper	mg/l	0.00273–5.76	0.001	0.2
Iron	mg/l	0.103–25.7	0.026	0.2
Lead	mg/l	0–0.2	<0.001	2
Manganese	mg/l	0.003–7.35	0.039	0.2
Molybdenum	mg/l	0.004–0.004	<0.001	0.01
Nickel	mg/l	0.003–3.05	0.003	0.2
Selenium	mg/l	0.053–0.053	<0.005	0.02
Zinc	mg/l	0.035–2.2	0.033	2
Sodium	mg/l	84.9–350	96	230–460[e]
Chloride	mg/l	43.9–564.4	113	350–700[e]
Total N	mg/l	8.6–11.71	5.8	5–50
Total P	mg/l	0.6–11.1	0.021	0.5–10[f]

[a]Adrover et al. (2010) and Dikinya and Areola (2010)
[b]Treated by Sydney water (2011–2012); data collected by personal communication
[c]DEC (2004)
[d]Water salinity rating: low
[e]For moderately tolerant plant, i.e. lucerne
[f]Total P loads in wastewater from intensive animal industries are likely to vary between 10 and 500 mg/L

17.2.1 International

Recycled water use in urban irrigation is gaining popularity throughout the world as an alternate to using fresh water. Currently, most of the developed countries have availed themselves of the use of recycled water as an indicator of water sustainability. In the implementation of recycled water in urban irrigation, guidelines developed by World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) are mostly followed by different countries. Australia, many Middle Eastern and Mediterranean European countries, and many states of

United States of America (USA) also have water reuse guidelines or regulations (Anderson 2003; Exall 2004; Sato et al. 2013; Angelakis and Gikas 2014).

In USA, 41 states have set guidelines for using recycled water for urban irrigation. It includes unrestricted and restricted irrigation in 28 and 34 states, respectively (Feigin et al. 1991). Typically, secondary treatment and disinfection is the minimum level of treatment required for unrestricted irrigation of urban landscapes. However, in some cases, additional treatment including coagulation, oxidation, and filtration are practiced (Feigin et al. 1991). In Florida, USA, in 2005, 462 golf courses, covering over 56,000 acres of land, were irrigated with recycled water. Recycled water was also used to irrigate gardens of 201,465 residences, 572 parks and 251 schools (Haering et al. 2009). According to Olivieri et al. (2014), in California, the state wide survey indicated that use of recycled water increased 2.2 times (from 400 to 862 Mm^3/year) within two decades (from 1989 to 2009). About 37 % of the produced recycled water was used in agricultural purpose and about 17 % was used for landscape irrigation. In southern California, recycled water was used for irrigating mainly golf courses and lawns. An extensive survey conducted by Tanji and Grattan (2007) shows that in 2002, on average 21.1 % of total recycled water was used for landscape irrigation. However, the proportion of total recycled water used for landscape irrigation in 2003 in southern California were 17 % in the Los Angeles region, 34 % in the Santa Ana region, 78 % in the San Diego region and 34 % in the San Francisco Bay region. The authors emphasise that there is potential to use the recycled water in landscape irrigation in arid and densely populated areas, such as the Los Angeles basin. It was proposed to replace the currently used fresh water with recycled water in irrigating golf courses, lawns, trees, shrubs, ground covers, vines, ornamental plants and flowers.

In Canada, although few have been reported in the literature (Exall 2004), recycled water is being used for irrigating golf courses and municipal lands in many regions. CWRS (1999) reported that over 200 golf courses used recycled water for irrigation. Among them three were in Alberta, three in British Columbia, two in Ontario and one in Nova Scotia. The irrigation was mainly conducted from April to October. In the golf courses of Alberta, 114,000–150,000 m^3/season of recycled water was used; in British Columbia it was 150,000 m^3/season and in Nova Scotia 250,000 m^3/season.

In Europe, a considerable development of using recycled water occurred in the coastline and islands of the semi-arid southern regions, and in the highly urbanised areas of the wetter northern regions (Bixio et al. 2006). About 70 % of the wastewater generated in Europe is recycled (Sato et al. 2013). The use of recycled water was quite different between these two regions. In southern Europe, for example, recycled water was used for agricultural irrigation and for urban or environmental applications, whereas, in northern Europe, the uses were mainly for urban or environmental applications, or industrial purposes (Angelakis and Gikas 2014). Recycled water use in urban environmental applications is shown in Fig. 17.1 for different countries in Europe. As shown in the figure, many of the European countries are currently meeting 30 % or more of their urban irrigation demand from recycled water.

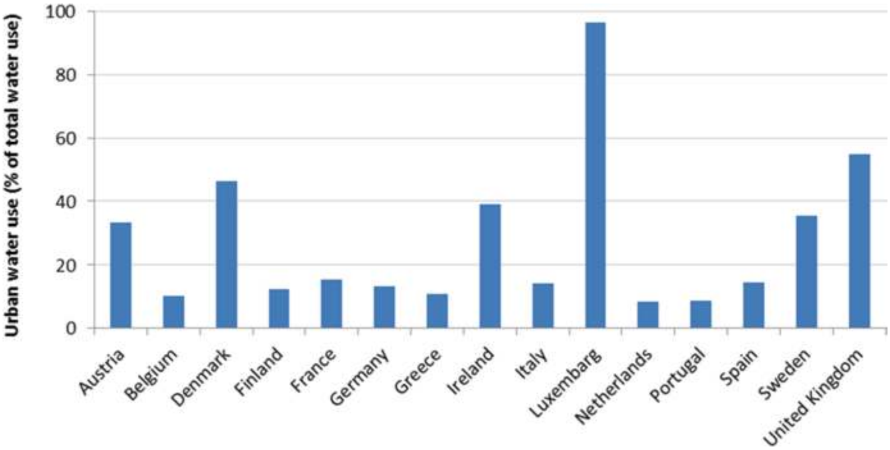

Fig. 17.1 Urban water use as a percent of total produced recycled water in different countries in Europe (After Bixio et al. 2006)

17.2.2 In Australia

In Australia, different states developed their own approaches to manage recycled water. Australia was established with a 3 tier government system, namely, a federal government, 6 states and 2 territory governments, and about 700 local governments (Radcliffe 2010). The management of public open spaces are under the jurisdiction of local governments. The local governments receive the recycled water from state owned wastewater treatment facilities. Wastewater reuse for the purpose of irrigation of agricultural crops, amenity planting and recreational facilities started in the late 1990s (Radcliffe 2010). Until the 1990s no major Australian city had advanced sewage treatment other than secondary treatment and some cities were still piping primary treated effluent into high energy coastlines and relying on dispersion. In 1999, the largest water recycling project commenced in Australia. This is the Virginia Pipeline Scheme where 22,000 ML of advanced treated recycled water had been contracted from the Bolivar STP near Adelaide, South Australia to irrigate market gardens on the Northern Adelaide Plains (Dillon 2000). At present, a national guideline for recycled water quality and end uses, *Australian Guidelines for Water Recycling*: *Managing Health and Environmental Risks* developed in 2006, provides a generic framework for the management of recycled water (NRMMC-EPHC-AMC 2006).

The overall picture of wastewater recycling is promising for different capital cities in Australia. Table 17.3 shows the amount of recycled water as a percent of total sewage produced for five major cities of Australia (Radcliffe 2010). As shown in the table the recycling of wastewater rose sharply between 2001–2002 and 2007–2008 in the case of Melbourne and Adelaide. On the other hand for cities Sydney,

Table 17.3 Percentage of water recycled in major cities in Australia (After Radcliffe 2010)

Major city	% recycling			Stated objectives on 2003
	2001–2002	2005–2006	2007–2008	
Sydney	2.3	3.5	4.4	10 % recycling by 2020
Melbourne	2.0	14.3	23.2	20 % recycling by 2010
Brisbane	6.0	4.8	6.3	17 % recycling by 2010
Adelaide	11.1	18.1	30.6	33 % recycling by 2025
Perth	3.3	5.3	6.4	20 % recycling by 2012

Brisbane and Perth only marginal increases were recorded. However, as per the author, all these cities have set some targets to achieve in the coming years from 2007 to 2008.

In Australia, most of the recycled water is reused in agriculture. In 2004, irrigated agriculture accounted for approximately 67 % of Australia's total water usage. Nearly 50 % of the water used for irrigating pasture and fodder crops, and 13 % used for horticulture and viticulture (vegetables = 4 %, fruit = 5 %, grapevines = 4 %) (Hamilton et al. 2005). In 2009–2010, 37 % of recycled water was used in agriculture followed by sewerage and drainage services, which used 30 %. Distribution of other sectors is shown in Fig. 17.2a. It is interesting to see that the purpose for which recycled water is used in 2009–2010 (ABS 2012) has been considerably changed than it was in 1993–1997 (Dillon 2000). This includes reducing the reuse of recycled water in mining from 32 to 3 %, and increasing the sewerage and drainage services from 3 % to 30 %. The reason of this change may be because of discrepancies in the definition of sectors when calculating the reuse of recycled water (Hamilton et al. 2005). For example, according to the Australian Bureau of Statistics (ABS 2006, 2010, 2012), the 'effluent' is estimated as all regulated discharge from the water supply, sewerage, and drainage industries. Thus, some of these discharges would be non-sewage effluent. In practice, 'effluent' refers to treated sewage only. Thus some of the changes in the recycled water use can be attributed to the differences in methods of calculation. Nevertheless, the data in Fig. 17.2 appears to indicate that lately more and more recycled water is being used for irrigating open and agricultural fields.

In the case of using recycled water for urban irrigation, there are significant differences in reuse between states, with NSW, Victoria and Queensland using higher amount compared to other states and territories (Table 17.4). It is evident from the table that in 2004–2005 to 2008–2009, state-wide average of recycled water use in urban irrigation was 30 % of the total, which is 28.9 and 26.7 % for the whole Australia; in 2009–2010, state-wide average was 27.2 % and the nation-wide average was 14 % of the total recycled water. In 2009–2010, in the Australian Capital Territory (ACT) usage of urban irrigation (GL/year) is reduced compared to other reported years. Again the "% usage of total water" shows significantly low, because other sectoral use of recycled water, such as "sewerage and drainage services" increased significantly (from 3.9 GL/year in 2008–2009 to 30.8 GL/year in 2009–2010).

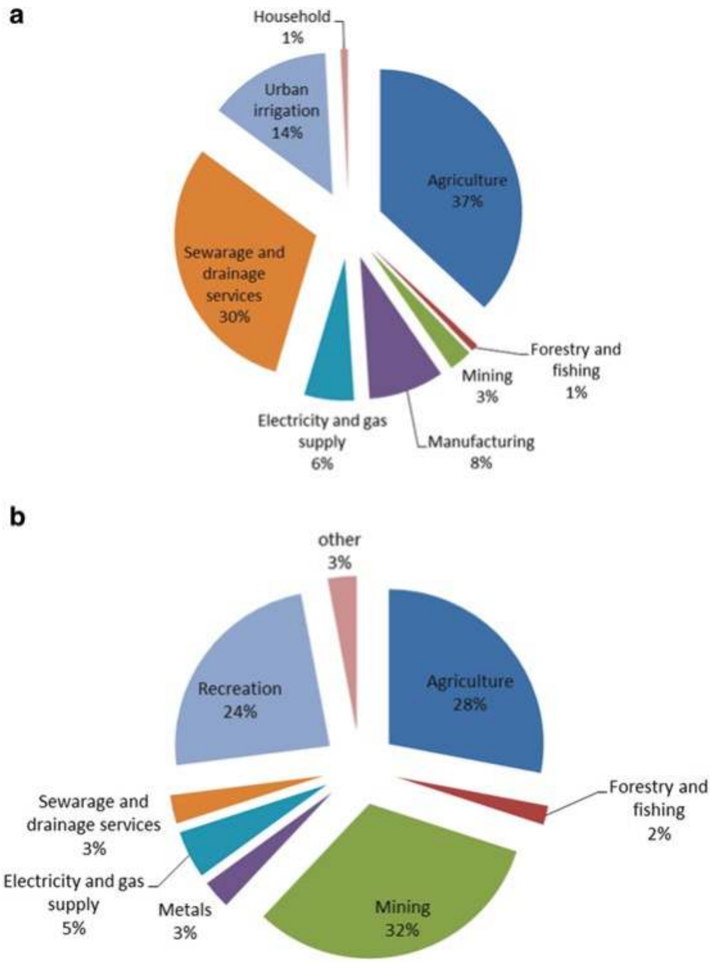

Fig. 17.2 Sectoral distribution of recycled water use in Australia in (**a**) 2009–2010 (ABS 2012) and (**b**) 1993–1997 (Dillon 2000)

17.2.3 In Sydney

In Sydney recycled water has been used for irrigation since 1960s. In 2011, Sydney Water supplied about 3.8 GL of recycled water for irrigating farms, sports fields, golf courses, parks, landscapes and racecourses and by 2015, it is expected that the recycled water will meet 12 % of total water demand in greater Sydney (Sydney Water 2013). It seems that Sydney has improved the recycling target from its objective stated on 2003 (Table 17.3). Thus the increasing use of recycled water, particularly for irrigating urban open spaces, in the place of fresh water, is one of the important goals of the local and state governments to achieve sustainable

Table 17.4 Annual volume and percent use of recycled water (of total produced recycled water) in urban irrigation (ABS 2006, 2010, 2012)

	2004–2005		2008–2009		2009–2010	
States and territories	GL/year	% of total	GL/year	% of total	GL/year	% of total
NSW	9.76	19.61	11.69	18.74	15.68	12.37
VIC	24.30	34.88	32.88	33.60	9.88	10.10
QLD	15.67	35.02	8.60	20.21	16.64	27.16
SA	1.48	7.24	5.29	18.26	2.95	9.21
WA	6.62	43.38	9.37	50.23	3.37	19.26
TAS	0.45	10.53	0.52	8.04	2.62	40.34
NT	1.33	71.98	1.55	83.82	1.22	99.03
ACT	0.56	25.35	0.32	7.66	0.15	0.49
Australia	60.13	28.88	70.22	26.71	52.50	14.04

Table 17.5 Application rate of recycled water for urban open space irrigation (Sydney Water 2010)

Name of the site/field	Number of years of irrigation	Application rate (AR, ML/ha/year)
Nepean Rugby Park	17	2.50
Ashlar Golf Club	37	4.50
Dunheved Golf Club	11	1.05
Castle Hill Golf Club	28	2.07
Kiama Golf Club	13	5.11
Liverpool Golf Club	7	2.53
Richmond Golf Club	51	3.52
UWS Hawkesbury Campus	51	1.12
Warwick farm racecourse	31	0.60

management of water. About 1 GL of recycled water per annum is used in Sydney and Illawarra for irrigating farms, golf courses, sports fields, parks and a racecourse (Sydney Water 2011). Overall, as per 2011 data, Sydney Water operates 17 recycled water schemes. These include the residential dual reticulation scheme at Rouse Hill; the Wollongong Recycled Water Scheme that supplies recycled water for industrial and irrigation use; and other schemes that supply recycled water for use in agriculture and on playing fields and golf courses.

The amount of recycled water used in greater Sydney varies, depending on the weather. The application rates as well as number of years of irrigation of some of the fields in Sydney are listed in Table 17.5. Past and projected scenarios of recycled water use for different sectors in Sydney are shown in Fig. 17.3. According to the Metropolitan Water Directorate (2014), in mid-2010, use of recycled water was saving about 33 GL of water that might otherwise come from drinking water supplies. Implementation of the Replacement Flows Project at St Marys from October 2010 increased recycling by 18 GL/year and by 2030 it is projected that 100 GL of water will be recycled each year.

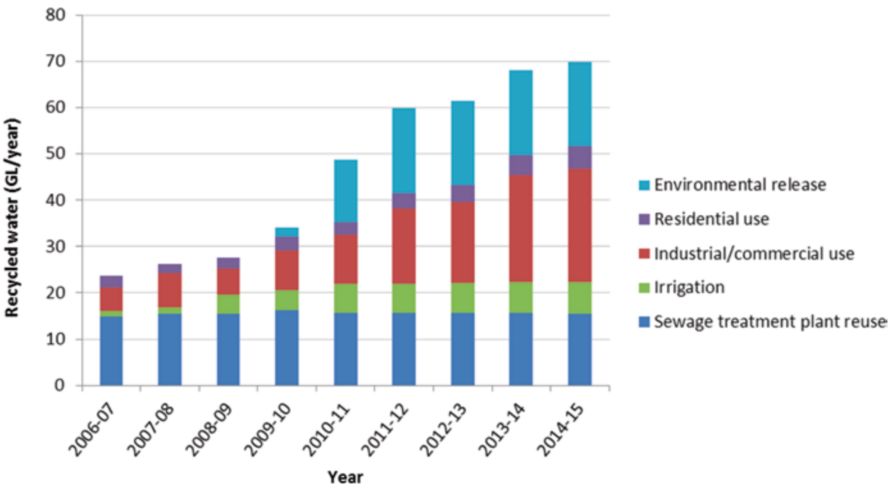

Fig. 17.3 Past and projected use of recycled water in Sydney (Metropolitan Water Directorate 2014)

17.3 Benefits of Using Recycled Water in Irrigation

Benefits of using recycled water in urban irrigation are its availability year round and the presence of some organic material and nutrients which are beneficial to plant growth. Different communities, local governments and policy makers tend to use recycled water for beneficial purposes (such as urban irrigation, and environmental flows) rather than disposing it in the ocean. However, benefits from recycled water still depend on its efficient management for irrigation scheme. Apparent benefits of using recycled water for irrigation are detailed in the following sections.

17.3.1 Water Security

Water security can be defined as making sure that all water users get continuous access to a suitable quality of water (Productivity Commission 2011). In a country like Australia, where sources of water varies because of variable rainfall and inflows to river, alternate sources of water are needed to ensure water security. According to the Productivity Commission (2011), the following actions may increase water security in Australia:

- Building wastewater recycling plants, desalination plants or dams that will add to available water,

- Developing regulatory options so that the users, such as irrigators, may purchase irrigation water in an easy and efficient manner, and
- Reducing water consumption through demand management activities, such as water restrictions or community campaigns to preserve water.

On the basis of the above three actions, recycled water might be a viable source for agriculture near urban areas, which has the advantage of flowing uniformly throughout the year and being relatively consistent in quality. Also, if the recycled water can be stored during winter this can represent a valuable economic commodity (Dillon 2000).

As discussed earlier, New South Wales, Australia has progressed well with the recycling of treated wastewater for urban irrigation (Table 17.4). For a clear picture of how much potable water can be saved by replacing it with recycled water, the irrigation approach for golf courses can be discussed. Maintaining a quality golf course includes the maintenance of good quality landscapes which includes fairways and surrounding roughs. Unlike trees and shrubs, turf grasses have very little capacity to store water and withstand periods of drought. Golf course turf usually needs water applied at least twice per week in the summer. Any deficit in rainfall must be supplemented with irrigation. A typical golf course requires 378.5–3,785 m^3 of water per week in summer to maintain healthy vegetation. The hilly terrain and irregular shape of golf course makes applying water and water retention, and irrigation uniformity difficult. Water audits performed across the country suggest that many golf courses use 20–50 % more irrigation water than necessary (Alliance for water efficiency 2014). Therefore, recycled water has great potential to tackle the situation in a well-managed golf course saving potable water. This is also highlighted in Table 17.5, where recycled water use in different golf courses is shown.

Besides obtaining recycled water from centralised wastewater treatment for irrigation of open spaces, sewer mining is an alternate source of recycled water. Sewer mining involves extracting the wastewater before it reaches the centralised wastewater treatment plant and treating it at a decentralised treatment facility (Water Corporation 2013). Sewer mining schemes in Sydney are producing over 1 GL of recycled water each year. With four major projects now completed and another eight under way, this alternative water source is helping save precious potable water supplies (Metropolitan Water Directorate 2014). Among the completed four projects, Pennant Hills Golf Club supplies 1 ML/year of recycled water to irrigate greens and fairways, Sydney Olympic Park Authority supplies 8 ML/year of recycled water to irrigate Sydney Olympic Park and Newington Estate, and Kogarah Council uses around 1.6 ML/year to irrigate parks, playing fields and Beverly Park Golf Course (Metropolitan Water Directorate 2014). However, for the successful implementation of sewer mining, care should be taken so that the quality of produced recycled water is inspected by regulatory agencies.

17.3.2 Nutrient Value of Recycled Water

An advantage of using recycled water for irrigation is its nutrient value comprising nitrogen (N) and phosphorus (P) (Table 17.1). While Sakadevan et al. (2000) reported an increased yield of dry matter because of recycled water irrigation, and Toze (2006) reported increased metabolic activity of soil microorganism, nutrients of recycled water have two distinct advantages:

- Controlling eutrophication of surface water; and
- Could potential supplement fertiliser required for plant growth.

Eutrophication control of surface water is indirectly related to recycled water use in irrigation. The impact is indirect, because it is compared in a manner that when nutrient rich recycled water is disposed in surface water (Greenway 2005) this may contribute to the process of eutrophication. Therefore, in agricultural areas and especially in dry climates, an alternative to the usual wastewater treatment with biological nutrient removal would be the reuse of these waters for irrigation; therefore the effective nutrient removal would occur through uptake by crops (Sala and Mujeriego 2001).

Recycled water has the potential to be used as fertiliser when used as irrigation water. Fasciolo et al. (2002) reported that average garlic yields irrigated with treated wastewater were 10 % higher than those irrigated with well water. According to Vazquez-Montiel et al. (1996), yields of Maize crop increased 33 % when secondary treated recycled water was used instead of fresh water. According to Sala and Mujeriego (2001), nutrient contribution in the soil increases with each application of recycled water. The greater the irrigation dose, the higher the contribution, given a certain nutrient concentration. Because of this, it is very important to generate frequent information on these nutrient contributions during the irrigation season, so that conventional fertilisers would only be applied either as a complementary source of nutrients if the irrigation could not cope with all the crop needs, or as a source of material for balancing the ratio between nutrients (Sala and Mujeriego 2001). The same study showed that in the Costa Brava area, North East Spain, where recycled water is supplied for irrigating three golf courses, information about the content of nutrients in the recycled water is generally given every month, so the users can adapt their fertilisation plans to what is being applied to the irrigation water. Table 17.6 summarises the nutrient contributions by the irrigation water on two golf courses in

Table 17.6 Typical contribution of nutrient in a golf course due to recycled water irrigation (Sala and Mujeriego 2001)

Element	Contribution by irrigation water	Recommended contribution	% contribution by irrigation water
Nitrogen, kg N/ha.year	108	166	65
Phosphorus, kg P_2O_5/ha.year	121	100	121
Potassium, kg K_2O/ha.year	160	166	96

1997 located on the Costa Brava which are using recycled water. It is clear from the table that among three nutrients, only Nitrogen should be supplied additionally as a form of fertiliser to meet the recommended need. Periodic monitoring of nutrient status in soil to avoid imbalanced nutrient supply is also highlighted by other researchers (Pedrero et al. 2010; Mohammad and Ayadi 2005; Vazquez-Montiel et al. 1996).

17.4 Risks of Using Recycled Water in Irrigation

Despite the significant benefits of recycled water, there are several concerns related to environmental and health risks. If not properly managed, irrigation induced runoff and rainfall runoff from irrigated areas may cause eutrophication of surface water. Due to increased level of salt in the recycled water there is a risk of root zone salinisation (Rahman et al. 2014a, 2015a, 2016) In addition, excessive leaching of salt from rootzone may cause an increase in contaminants in the groundwater. For restricted use of recycled water in urban recreational areas (such as golf courses), care should be taken to avoid direct human contact or limit the exposure to recycled water at the time of irrigation; for unrestricted uses (such as for irrigating landscape of parks, playgrounds and schoolyards) recycled water quality should be of relatively high quality. Opinions of the community using these recreational facilities cannot be overlooked and should be incorporated in the management plan of using recycled water for urban irrigation. Overall, concerns related to using recycled water are discussed below.

17.4.1 Soil Health

One of the major concerns related to recycled water irrigation is the increase of salinity including sodicity and bicarbonate hazards in irrigated fields. Salinity is the concentration of soluble salts in water that are measured as total dissolved solid (TDS) or electrical conductivity (EC). EC is an indirect measurement of TDS in the irrigation water or soil extract. Electrical conductivity of soil extracts can be based on a 1:5 soil:water extract ($EC_{1:5}$) or a saturation paste extract (EC_e). EC_e is commonly used as an indicator of plant tolerances. However, because $EC_{1:5}$ are much easier to obtain, conversion factors are often used to convert soil $EC_{1:5}$ to EC_e.

Irrigation salinity problems are often compounded by the effects of sodium (Na^+) on the dispersion of soil colloids, resulting in a loss of soil structure. This phenomenon decreases the leaching potential of the salt and accelerates the build-up of salts within the rootzone. Na^+ also affects the saturated hydraulic conductivity. Soil colloid dispersion is affected by the ratio of Na^+ to the divalent cations calcium (Ca^{2+})

and magnesium (Mg^{2+}) in the irrigation water, a ratio known as the sodium adsorption ratio (SAR), which is given by:

$$SAR = \frac{\left[Na^{+}\right]}{\sqrt{\left(\left[Ca^{+}\right]+\left[Mg^{+}\right]\right)/2}} \tag{17.1}$$

where, Na^{+}, Ca^{2+}, and Mg^{2+} are in meq/L.

From an environmental point of view, among different salts in recycled water such as sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{2-}), chloride (Cl^{-}), magnesium (Mg^{2+}), sulphate (SO_4^{2-}) and bicarbonate (HCO_3^{-}), sodium and chloride are the most important salts. This is because they are more likely to remain as ions in soil solutions and contribute to the effects of salinity. Plants are affected by salts via soil salinity (NRMMC-EPHC-AMC 2006). As water evaporates from soils or is used by the plants, salts are left behind. This phenomenon increases the concentration of salts in the soil with time, until it influences the amount of water a plant can take up from the soil due to the osmotic effect it creates.

Several studies have been reported indicating increases of salinity due to recycled water irrigation. Distinct long term effects of recycled water use in terms of salinity is observed by Dikinya and Areola (2010). After 3 years of irrigation with recycled water, the electrical conductivity in soil increased from 105.1 to 235 µs/cm (about 123 % increases), cation exchange capacity (CEC) of soil decreased from 9.21 to 8.61 cmol/kg and Na^{+} increased from 2.95 to 5.75 meq/100 g of soil. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination. Jahantigh (2008) reported a similar result of salinity increase after irrigating with recycled water for 5 years. He reported an increase of 95 % (from 2.3 to 4.5 µS/cm) salinity. Klay et al. (2010) conducted a study to find out the increase of salinity due to the use of treated wastewater for irrigation. The result showed an increase of salinity with irrigation period. Data was collected at different depths and at different time periods (i.e. 3 months, 2 years, 7 years, 8 years, 12 years and 14 years). After 14 years of irrigation, the salinity increased with depth. At the top soil (0–30 cm), the salinity increased from 0.16 to 1.12 µS/cm, which is around 600 % increase. Decrease of cation exchange capacity after long term irrigation was reported by Adrover et al. (2010). A total of 11 % and 2 % decrease in CEC was reported for the irrigation period of 20 years and 2 years respectively. Xu et al. (2010) investigated the long term effect of recycled water irrigation for up to 20 years. The authors reported that the EC values of the top soil profile varied with the time of irrigation. EC values of 51.6, 78.6, 113.2 and 122.7 µS/cm were observed for irrigation time 0, 3, 8 and 20 years of irrigation. Increase of salinity in terms of EC, Na^{+} and Cl^{-} are also reported by other researchers (Xu et al. 2010; Yang et al. 2006; Gloaguen et al. 2007; Leal et al. 2009; Alarcón and Pedrero 2009; Wang et al. 2003).

As with agriculture, several investigators reported the risk of accumulation of salt in open spaces because of long term irrigation with recycled water. Candela et al. (2007) investigated the effect of recycled water irrigation in a golf course in

Spain for 2 years. They observed that Na^+ increased in the top 60 cm of soil profile due to water application and evapotranspiration. The salinisation in unsaturated zone increased by 1300 mg NaO_2 (Sodium superoxide) per kg and Cl^- increased in aquifer water by approximately 400 mg/year. After 4 years of investigation, to find the effects of recycled water on nine golf courses in southern Nevada, Devitt et al. (2007) reported that the soil salinity levels followed a sinusoidal seasonal curve, where 70 % of all the peaks occurred in summer. So, temporal distribution has effect on the salinisation to some extent. The result indicates that the management should control the uniformity of the irrigation system and an amount of fresh water application to maintain sufficient leaching to reduce salinity.

Although the increase of soil salinity because of the treated wastewater irrigation is convincing, the phenomenon depends on variability of soil characteristics. As salts are highly soluble they infiltrate and accumulate in the deeper layer of the soil. When, the soil EC is less than the EC of recycled water, a little portion of the residual dissolved solid is accumulated on the soil particle and most of the salt is leached from soil and accumulates in the groundwater (Klay et al. 2010). The movement of soil solution depends on soil type and different hydraulic properties of soil. When comparing the salt accumulation data in fields irrigated with recycled water with that of fresh water, soil characteristics, textures, irrigation history as well as soil profiling should be consistent. Otherwise, it is very difficult to say that soil condition is directly associated with the application of treated water (Aiken 2006; Stevens et al. 2003).

Authors of this chapter conducted a laboratory scale column study to compare the salt accumulation in the soil profile due to recycled water and town water irrigations (see Rahman et al. 2014b). Soil samples were collected from two fields (D33 and Yarramundi) located in University of Western Sydney, Hawkesbury campus, Australia. Two types of soil, namely, D33 (silty loam) and Yarramundi (loamy sand) soil were used for the experiment (Fig. 17.4). The experiment was conducted for a period of 330 days. Six columns of the same dimensions were prepared for each type of soil. Three of the columns were used for recycled water application; the other three were used for town water application. Irrigation water (recycled and town water) was applied at the same frequency in respective columns, as in practice. At the end of the study period, soil samples were collected from every 5 cm of the soil profile from each of the 12 columns. The soil samples were analysed for 1:5 soil water electrical conductivity ($EC_{1:5}$) and SAR.

Results of $EC_{1:5}$ and SAR for D33 and Yarramundi columns for both recycled and town water applications are presented in Fig. 17.5. As expected, $EC_{1:5}$ (Fig. 17.5a, b) in top 0.05 m for both types of soil columns had more salt accumulation, which is because of the occurrence of more evaporation at the soil surface. Salinity in soil due to recycled water application showed higher $EC_{1:5}$ than that of town water application. D33 soil with recycled water application caused an increased accumulation of salt (in terms of $EC_{1:5}$) by about 2.5 times in the soil of upper portion of the column (0–0.05, 0.05–0.10, 0.10–0.15, 0.15–0.20 m) compared to town water application. Soil samples collected from the lower portion of the soil column (0.20–0.25, 0.25–0.30 m) showed relative salt accumulation by about 2.1 times. In the case

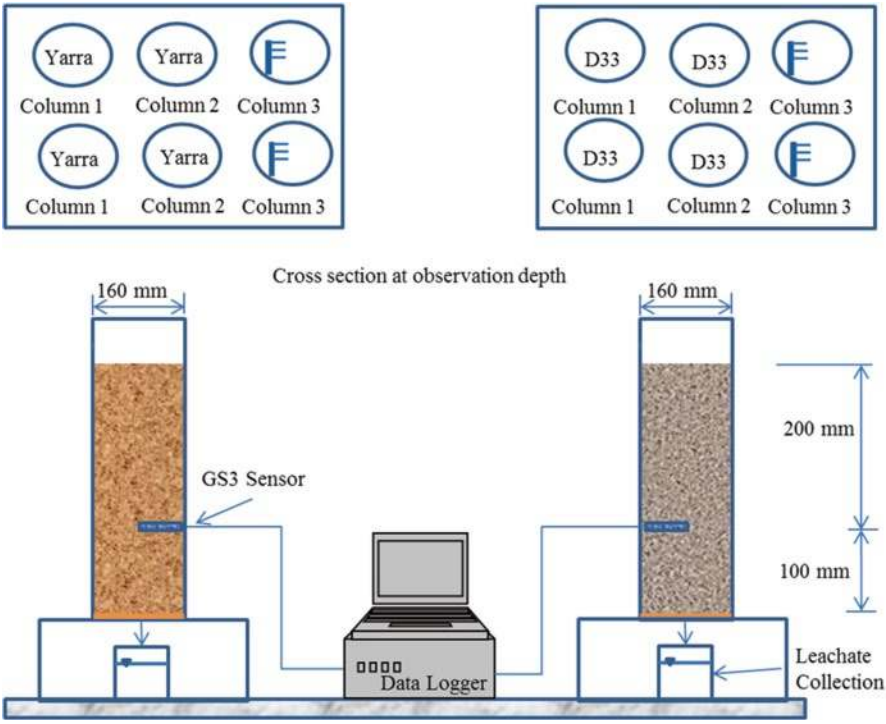

Fig. 17.4 Schematic of column setup to study soil salinisation due to recycled water irrigation (Rahman et al. 2014b)

of Yarramundi soil, recycled water application caused salt accumulation by about 1.9 times in the soil of upper portion of the column (0–0.05, 0.05–0.10, 0.10–0.15, 0.15–0.20 m) compared to town water application. It was about 2.3 times for samples collected from the column depths of 0.2–0.3 m. In case of SAR, for D33 soil (Fig. 17.5c), recycled water caused 3.6 times more SAR in the soil of depth 0–0.2 m than the town water irrigation; SAR was 3.8 times more in the soil samples collected from the column depth of 0.2–0.3 m. In the case of Yarramundi soil, recycled water application caused 5.4 times more SAR in the soil of upper portion of the column (0–0.2 m) compared to town water application; it was about 6.5 times more for samples collected from the column depths of 0.2–0.3 m. It is clear from the above result that variability of salinity and sodicity in coarse textured soil (Yarramundi) is more when compared to fine textured soil (D33). Results from this experiment will help in understanding patterns of salt accumulation and occurrences of sodicity throughout a soil profile of these specific soil types. The results will also help to avail management options such as reduction of salinity in soil by using town water.

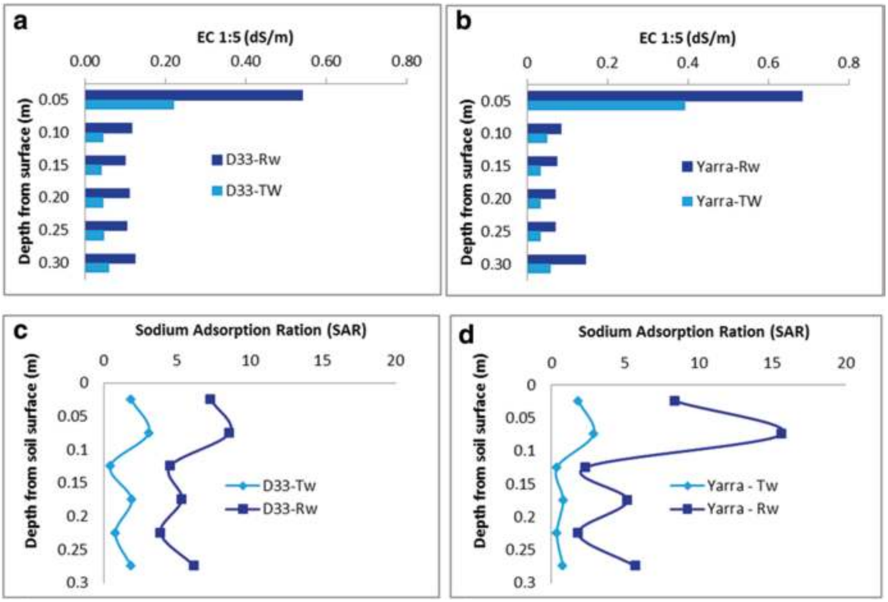

Fig. 17.5 Average soil salinity and sodium adsorption ratio (*SAR*) in the silty loam (D33) and loamy sand (Yarramundi) column profile (Note: *RW* is recycled water, *TW* is Town water; D33 and Yarra are soil from D33 field and Yarramundi field, respectively; (**a**, **b**) are after Rahman et al. 2014b)

Heavy metal accumulation in soil due to recycled water irrigation is another concern for the assessment of soil health. Smith et al. (1996) investigated the effect of irrigation with secondary treated municipal effluent on the accumulation of heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) for 4 and 17 years. The non-effluent irrigated area was served as the control area and provided reference concentrations to assess the extent of contamination. They concluded that irrigation with recycled water did not increase the heavy metal values and suggested that it may take between 50 and 100 years for heavy metal levels (mainly Cd) in effluent-irrigated soil to reach the threshold values (Australian guidelines) for environmental concern.

Rattan et al. (2005) reported an irrigation scheme in peri-urban agricultural fields irrigated for 5, 10 and 20 years with recycled water in India to investigate the heavy metal accumulation. The result is shown in Fig. 17.6. Recycled water irrigation over 20 years resulted into a significant build-up of Zn (7.4 times), Cu (5.2 times), Fe (6.5 times), Ni (3.8 times) in soils over adjacent tubewell water irrigated soils; whereas Mn was reduced by 1.8 times. Soils receiving sewage irrigation for 10 years exhibited significant increases in Zn, Fe, Ni and Pb, while only Fe in soils was positively affected by sewage irrigation for 5 years.

Similar investigations were conducted by Xu et al. (2010) where the highest levels of Cr, Cu, Ni and Zn were found at 30–40 cm horizons in plots irrigated with effluent for 8 years. In plots with irrigation lengths of 20 years, the highest concen-

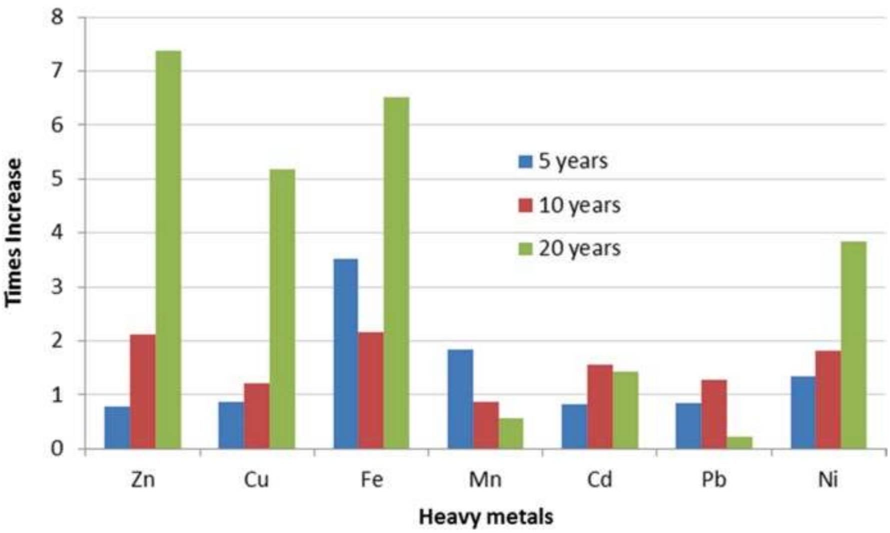

Fig. 17.6 Typical effect of period of recycled water irrigation on the build-up of heavy metals over tubewell water irrigated soil (After Rattan et al. 2005)

trations occurred at deeper depths of 40–50 cm. It was also observed that longer irrigation time (20 years) caused a decrease of metal levels in soil profiles compared with that of 8-year irrigation, which may occur because of leaching.

Among other problems of soil health due to recycled water use in irrigation is the impact on saturated hydraulic conductivity of soil. A decreased hydraulic conductivity may influence the increase of salinity. Gonçalves et al. (2007) reported that after 2 years of irrigation, the hydraulic conductivity decreased from 48 to 30.73 mm/h. Similar studies were conducted by Levy et al. (1999) and Aiello et al. (2007). Some investigators (Estevez et al. 2010) reported less or no effect of soil salinisation due to recycled water application in open spaces. However, to be on the safe side, an intensive management and long term monitoring was recommended to avoid mass loading of salt and nutrients in soil (Tanji 1997; Zhang et al. 2006).

17.4.2 Public Health

Probably, microbial contamination is the most discussed and researched issue relating to recycled water irrigation; one reason may be the risk of human contamination considered to be greater than that associated with chemical compound (Hamilton et al. 2005; Toze 2006; Derry et al. 2006). Potential microorganisms in recycled water include pathogens, viruses, bacteria, protozoa and helminths; they may pose risk to human health when raw vegetables irrigated with recycled water are consumed (Toze 2006). Contamination from open space irrigation may occur due to spray-drift exposure and hand to mouth exposure. Derry et al. (2006) reported a risk of human exposure from recycled water irrigation in the campus of University of Western Sydney (UWS), Australia. The authors identified infants and young children of a day care in the campus, who sometimes visit livestock such as deer and sheep in areas irrigated with recycled water, as most susceptible to waterborne infections. The same study suggested precautionary measures including hand washing before eating food and after coming back from a field visit and using gumboots during field visits to avoid possible contamination.

In addressing the health risk from recycled water, QMRA (Quantitative Microbial Risk Assessment) models are widely used by many researchers (Donald et al. 2009; O'Toole et al. 2009; Hamilton et al. 2006, 2007). Hamilton et al. (2006) used QMRA for estimating the annual risk of virus infection associated with the consumption of raw vegetables irrigated with recycled water. Across the various crops, effluent qualities, and viral decay rates considered, the annual risk of infection ranged from 10^{-3} to 10^{-1} when recycled water irrigation ceased 1 day before harvest and from 10^{-9} to 10^{-3} when it ceased 2 weeks before harvest. The model presented a useful starting point for managing risk associated with spray irrigation of certain crops with recycled water. Although QMRA is considered as an essential component of microbial risk assessment of recycled water scheme, the model has some cons; it is tedious and technically demanding. This disadvantage is overcome by including another model RIRA (Recycled water irrigation risk assessment) as part of QMRA assessment process (Hamilton et al. 2007). RIRA is designed to accommodate a wide range of scenarios. The model uses pathogen specific dose-response models to calculate the annual risk of infection, when the pathogen of interest and the exposure scenario is defined. Another study addressing microbial contamination from recycled water was conducted by Donald et al. (2009). The approach provided an additional way of modelling the determinants of recycled water quality and elucidating relative influence of these determinants on a given disease (namely, gastroenteritis) outcomes. The conceptual model was comprised of six elements, i.e. recycled water and distribution pathways, exposure pathways and populations, cumulative end-user dose, identified toxicity and pathogenicity pathways, individual covariates and health endpoints. Through sensitivity analysis the authors identified three nodes that contributed most to the occurrence of gastroenteritis. These include, cumulative end user dose to pathogen, age of patients, exposure period to pathogen and quantity of pathogen intake.

17.4.3 Community Perspective

Recycled water usage schemes, because of the perceived risk, are sometimes questioned by the community associated with the scheme. There are instances, where a recycled water usage scheme was resisted by communities in Australia, USA and The Netherlands (Hurlimann and McKay 2006) resulting in the abandonment of such projects. Greater understanding of social factors in a policy context will facilitate planning and sound management of recycled water usage schemes. One suitable approach to achieve this objective is community consultation.

An assessment of risk perception related to tertiary treated recycled water usage was carried out by Derry and Attwater (2006) through a questionnaire survey at the campus of UWS, which involved 72 staff, 189 students and 72 residents. The majority of respondents (97 % of staff, 91 % of students and 100 % of residents) considered the irrigation of grass, trees and shrubs to be acceptable, while 83 % of staff and 74 % of students accepted the idea of using recycled water for sports oval irrigation. The lowest acceptance was recorded for irrigating food crops (14 % of staff, 24 % of students and 32 % of residents). When the respondents were asked about the regional planning of recycled water usage by Water Management Authority (Sydney Water), only 15 % responded that they were aware. This indicates in order to reduce perception of risk associated with the use of recycled water the Authorities should focus on providing timely and accurate information, and have a process of implementation which is perceived as fair; the authors suggested signage, talks at meetings or displays at sustainability centres as an option.

Similar investigation in the regional level was conducted by Po et al. (2005) in Perth and Melbourne. Ninety three participants (one from each household) from three different socio economic groups (i.e. lower, medium and higher) were selected for a questionnaire survey. Results showed that more than 95 % of participants responded that it was acceptable to use recycled water in public parks and golf courses. More than 80 % agreed that it was acceptable to use recycled water for watering lawns and gardens or pasture land. At Mawson Lakes, South Australia, Hurlimann and McKay (2005) surveyed 136 households to investigate the community attitude towards the reuse of recycled water. Results showed that Mawson Lakes community was on average willing to pay $17.80 annually for a continual green appearance of public open spaces. The response of householders in a sense of the economic aspect of reuse schemes (i.e. willingness to pay) is helpful for future planning. In Sydney, Marsden Jacob Associates (2014) conducted a survey on 1240 households to investigate the economic viability of recycled water schemes. Results showed that Sydney households are on average willing to pay between $2.65 and $48.38 per year for an additional 10–40 GL per year of recycled water by 2030. However, the recycled water should be used by business, industry, Councils, or the environment (in the form of environmental flows). The survey also found that the households were less willing to pay to use the recycled water in Western Sydney homes for the purposes of toilet flushing and watering the gardens. The finding of the survey is concurrent to that of Hurlimann and McKay (2007) in that people do not like to use recycled water when the proposed use comes into personal contact.

17.5 Recycled Water Use for a Liveable City

The term 'liveable city' refers to the quality of life or wellbeing of its inhabitants (Johnstone et al. 2012). The liveability of a city sometimes associated with different elements that improve the quality of life including comfort, security, welfare, and sustainable water and environment. Sustainable management of urban water is

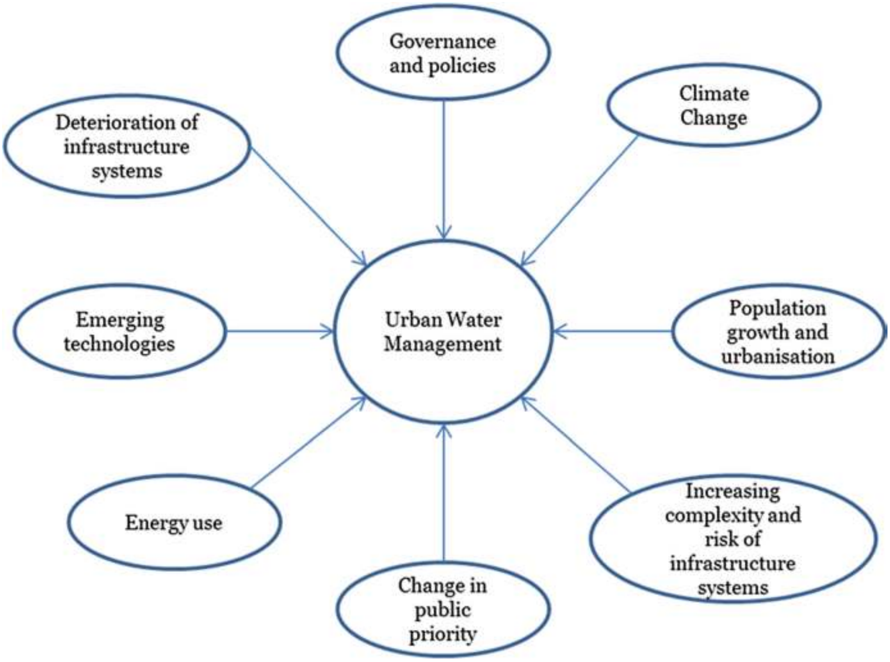

Fig. 17.7 Issues and future challenges in urban water management (After Howe et al. 2011)

necessary to ascertain that the city would be liveable in the future. City planners and scientists should make sure that the residents will have a clean supply of water and a healthy environment in which to live. As well as the supply of water from conventional sources (i.e. surface and groundwater), it is important to establish alternate sources for an uninterrupted supply of water and sustainable usage. Recycled water usage schemes as a part of urban water management are considered to be possible options to achieve this goal.

Urban water management is a holistic way to design and manage urban water systems (Van der Steen 2011). Urban water management for future cities should be adopted by considering social, economic and environmental perspectives of sustainability. According to Van der Steen (2011), the increasing population of cities puts major demands on urban services, including the supply of water and the management of wastewater. Population growth and urbanisation are leading to increased demand for water and wastewater services, increased pollution, changes in land use and many other pressures (Fig. 17.7) in cities around the world. However, many cities in advanced countries like Australia have progressed significantly to overcome basic water scarcity and service issues through the adoption of sustainable technologies. According to Brown et al. (2009), the communities in 'water sensitive cities' would be *driven by the normative values of protecting intergenerational equity with regards to natural resources and ecological integrity*, *as well as by concern that*

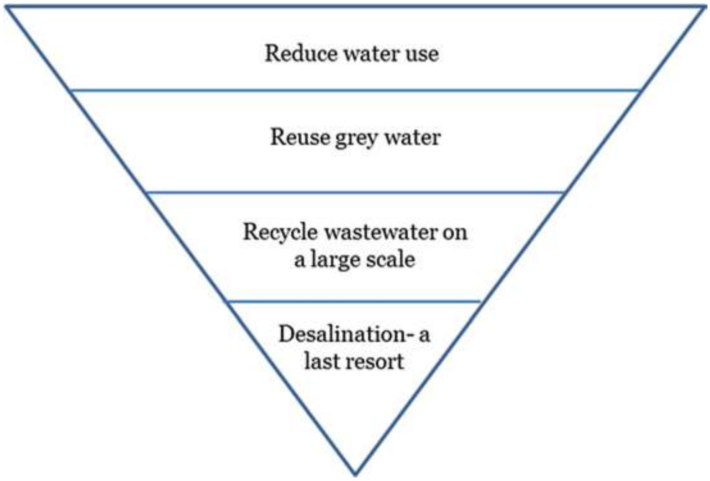

Fig. 17.8 Water source hierarchy (After Hurlimann 2007)

communities and environments are resilient to climate change. However before achieving the goal of becoming water sensitive, cities go through different transition phases including 'water supply city', 'sewered city', 'drained city', 'waterways city', and 'water cycle city' (for a review of this literature see Brown et al. 2009). The transition phases are cumulative and associated to increased level of sustainable water management.

For a sustainable water management strategy in Australia, Hurlimann (2007) proposed a Water Source Hierarchy – 'Reduce, Reuse, Recycle, Desalination' (Fig. 17.8). The hierarchy rates management options in order of least impact to the environment; reducing water consumption is of minimal environmental impact, reuse may have some environmental impact, increasing with recycling, then desalination which has the greatest environmental impact and should be considered as a last resort (Hurlimann 2007). The hierarchy also agrees with the recommendations proposed by the Productivity Commission (2011) to maintain water security (discussed in Sect. 17.3.1). In addition to reducing water consumption by users, controlling contaminant load at source (contributed by the user) may reduce adverse impact on the environment. Reducing contaminant load at source (i.e. source control of pollutant) is helpful to reduce pollutant load in wastewater treatment plant and in its output (i.e. recycled water). Thus the source control of pollutants (i.e. salinity) would help eliminating some risks associated with the end use of recycled water such as soil and human health risk due to recycled water irrigation in urban open spaces as discussed earlier. Rahman et al. (2015b) proposed an assessment framework to evaluate the salinity sources that may have significant impact on the rootzone salinity (in terms of total dissolved solid and sodium ion concentration) when recycled

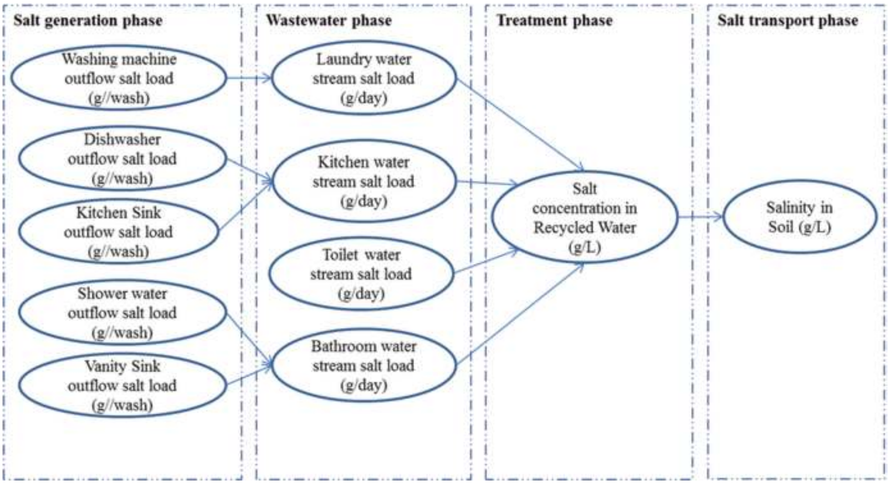

Fig. 17.9 Framework for source management of Greygums oval irrigated with recycled water (Rahman et al. 2015b)

water is used for irrigating sporting ovals in Sydney, Australia. The framework includes four phases (Fig. 17.9):

- Salt generation phase – consists of domestic appliances (salt sources) that contribute towards the salt load in the wastewater.
- Wastewater phase – consists of various wastewater streams including different streams of grey and black water.
- Treatment phase – consists of the treatment plant that produces recycled water.
- Salt accumulation phase – includes the process of salt accumulation in the root-zone due to recycled water irrigation.

Results show that by reducing the TDS load from washing machines alone by 50 % reduces the TDS concentration in soil by approximately 9 % and this can be increased to a 19 % reduction by reducing the TDS loads from both washing machines and toilet water, simultaneously. Also observed was that using environmental friendly detergents reduce the TDS load to the laundry streams four to seven times and Na^+ load about twice than any popular brand detergents. Moreover, using environmental friendly liquid detergents reduced the TDS load by 1.6 and Na^+ load by 3.6 times than when using environmental friendly powder. However, the authors suggested that viability of using environmental friendly products should be considered with economic sustainability, as generally these products are more expensive than the popular brands. The study highlighted that any strategies which help in the reduction of salt in the wastewater stream from washing machines will be beneficial in managing the soil salinity as a result of recycled water use for irrigating urban open spaces.

17.6 Conclusions

This chapter highlighted the extent of use of recycled water (treated wastewater) worldwide. As discussed, use of recycled water in the irrigation of open and sports fields is increasing. Water authorities in different cities are increasingly supply the recycled water for irrigation purposes instead of simply disposing the recycled water in the ocean. In 2009–2010, in Australia, the state-wide average of recycled water use in urban irrigation was 27.2 % and the nation-wide average was 14 % of the total recycled water produced. In Sydney, New South Wales, it is expected that by 2015 the recycled water will meet 12 % of the total water demand in greater Sydney. Several community surveys indicated the overwhelming support for use of recycled water for irrigation applications (Hurlimann and McKay 2005). This is reflected in many surveys that local communities support the usage of recycled water in irrigating open spaces and are willing to pay more for such use in extended form in the future. There are both beneficial and adverse impacts arising from the use of recycled water for irrigation. The benefits of using recycled water in urban irrigation include year round supply of irrigation water and supplement of nutrient for plant growth. Recycled water use in irrigation of urban open spaces has some negative impacts, because of the risks associated to the accumulation of salt and other unwanted contaminants in the soil. However, in advanced countries like Australia, the challenge of proper management of recycled water is undertaken and risks associated with its usage are well tackled. It is expected that recycled water use in urban areas will go beyond its conventional usage for open space irrigation including parks and recreational areas. Recycled water has the potential to irrigate urban pocket wetlands and green precincts, and other under-utilised land such as road reserve, rail corridors and road median strips. Irrigating rooftop gardens with recycled water is another application of recycled water. Major cities around the world have realised the potential for using recycled water for irrigating urban landscape. As a result, supply of recycled water for irrigation purposes will significantly increase in the near future. This necessitates the use of appropriate management practices which will protect the health of plants, soil and human beings. There is a need for considerable research in the area of development of appropriate management practices.

References

ABS (Australian Bureau of Statistics) (2006) Water Account for Australia 2004–2005

ABS (Australian Bureau of Statistics) (2010) Water Account for Australia 2008–2009

ABS (Australian Bureau of Statistics) (2012) Water Account for Australia 2009–2010

Adrover M, Farrús E, Moy G, Vadell J (2010) Chemical properties and biological activity in soils of mallorca following twenty years of treated wastewater irrigation. J Environ Manag 95:S188–S192

Aiello R, Cirelli GL, Consoli S (2007) Effects of reclaimed wastewater irrigation on soil and tomato fruits: a case study in Sicily (Italy). Agric Water Manag 93:65–72

Aiken JT (2006) A soil microbial response to urban wastewater application-bacterial communities and soil salinity. PhD Thesis. Western Sydney University, Sydney

Alarcón J, Pedrero F (2009) Effects of treated wastewater irrigation on lemon trees. Desalination 246:631–639

Alliance for water efficiency (2014) Golf course water efficiency introduction. http://www.allianceforwaterefficiency.org/golf_course.aspx. Accessed 15 Nov 2014

Anderson J (2003) The environmental benefits of water recycling and reuse. Water Sci Technol: Water Supply 3(4):1–10

Angelakis A, Gikas P (2014) Water reuse: overview of current practices and trends in the world with emphasis on EU states. Water Util J 8:67–78

ANZECC & ARMCANZ (2000) Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy. Australian & New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand, Australia

Bixio D, Thoeye C, De Koning J, Joksimovic D, Savic D, Wintgens T, Melin T (2006) Wastewater reuse in Europe. Desalination 187(1):89–101

Brown RR, Keath N, Wong THF (2009) Urban water management in cities: historical, current and future regimes. Water Sci Technol 59:5

Candela L, Fabregat S, Josa A, Suriol J, Vigues N, Mas J (2007) Assessment of soil and groundwater impacts by treated urban wastewater reuse. A case study: application in a golf course (Girona, Spain). Sci Total Environ 374:26–35

Chen Z, Ngo HH, Guo W (2012) A critical review on sustainability assessment of recycled water schemes. Sci Total Environ 426:13–31

CWRS (Centre for Water Resources Studies) (1999) Reuse of renovated municipal wastewater for golf course irrigation. Prepared for PEI Department of Technology and Environment. CWRS Internal Report No. 99–11. Dalhousie University, Halifax

DEC (Department of Environment and Conservation) (2004) Use of effluent by irrigation. http://www.water.nsw.gov.au/Urban-water/Recycling-water/Sewage

Derry C, Attwater R (2006) Risk perception relating to effluent reuse on a university campus. Water 33:57–62

Derry C, Attwater R, Booth S (2006) Rapid health-risk assessment of effluent irrigation on an Australian university campus. Int J Hyg Environ Health 209:159–171

Devitt D, Morris M, Bird R (2007) Spatial and temporal distribution of salts on fairways and greens irrigated with reuse water. Agron J 99:692

Dikinya O, Areola O (2010) Comparative analysis of heavy metal concentration in secondary treated wastewater irrigated soils cultivated by different crops. Int J Environ Sci Technol 7:337–346

Dillon P (2000) Water reuse in Australia: current status, projections and research. In: Proceedings of water recycling Australia, pp 19–20

Donald M, Cook A, Mengersen K (2009) Bayesian network for risk of diarrhea associated with the use of recycled water. Risk Anal 29:1672–1685

Estevez E, Cabrera M, Fernandez-Vera J, Hernandez-Moreno J, Mendoza-Grimon V, Palacios-Diaz MP (2010) Twenty-five years using reclaimed water to irrigate a golf course in gran canaria. Span J Agric Res 8:95–101

Exall K (2004) A review of water reuse and recycling, with reference to Canadian practice and potential: 2. Applications. Water Qual Res J Can 39(1):13–28

Fasciolo GE, Meca MI, Gabriel E, Morábito J (2002) Effects on crops of irrigation with treated municipal wastewaters. Water Sci Technol 45(1):133–138

Feigin A, Ravina I, Shalhevet J (1991) Irrigation with treated sewage effluent: management for environmental protection. Springer-Verlag, New York

Gloaguen TV, Forti M, Lucas Y, Montes CR, Goncalves RAB, Herpin U, Melfi AJ (2007) Soil solution chemistry of a brazilian oxisol irrigated with treated sewage effluent. Agric Water Manag 88:119–131

Gonçalves RAB, Folegatti MV, Gloaguen TV, Libardi PL, Montes CR, Lucas Y, Dias CTS (2007) Hydraulic conductivity of a soil irrigated with treated sewage effluent. Geoderma 139:241–248

Greenway M (2005) The role of constructed wetlands in secondary effluent treatment and water reuse in subtropical and arid Australia. Ecol Eng 25:501–509

Haering KC, Evanylo GK, Benham B, Goatley M (2009) Virginia cooperative extension. Publication No. 452-014. https://pubs.ext.vt.edu/452/452-014/452-014_pdf.pdf

Hamilton AJ, Boland AM, Stevens D, Kelly J, Radcliffe J, Ziehrl A, Paulin B (2005) Position of the Australian horticultural industry with respect to the use of reclaimed water. Agric Water Manag 71(3):181–209

Hamilton AJ, Stagnitti F, Premier R, Boland AM, Hale G (2006) Quantitative microbial risk assessment models for consumption of raw vegetables irrigated with reclaimed water. Appl Environ Microbiol 72:3284

Hamilton AJ, Stagnitti F, Kumarage SC, Premier RR (2007) Rira: a tool for conducting health risk assessments for irrigation of edible crops with recycled water. Comput Electron Agric 57:80–87

Howe CA, Butterworth J, Smout IK, Duffy AM, Vairavamoorthy K (2011) Findings from the SWITCH (SustainableWaterManagementin the Cityof the Future) Project 2006–2011. http://www.switchurbanwater.eu/outputs/pdfs/Switch_-_Final_Report.pdf

Hurlimann A (2007) Time for a water re-'vision'. Aust J Environ Manag 14(1):14–21

Hurlimann A, McKay J (2005) Contingent valuation by the community of indirect benefits of using recycled water: an Australian case study. Water Sci Technol: Water Supply 5(3–4):95–103

Hurlimann AC, McKay JM (2006) What attributes of recycled water make it fit for residential purposes? The Mawson Lakes experience. Desalination 187:167–177

Hurlimann A, McKay J (2007) Urban Australians using recycled water for domestic non-potable use—an evaluation of the attributes price, saltiness, colour and odour using conjoint analysis. J Environ Manage 83:93–104

Jahantigh M (2008) Impact of recycled wastewater irrigation on soil chemical properties in an arid region. Pak J Biol Sci 11:2264–2268

Johnstone P, Adamowicz R, Haan FJ, Ferguson B, Wong T (2012) Liveability and water sensitive city-science-policy partnership for water sensitive cities. Cooperative Research Centre for Water Sensitive Cities, Melbourne. ISBN 978-1-921912-17-7

Klay S, Charef A, Ayed L, Houman B, Rezgui F (2010) Effect of irrigation with treated wastewater on geochemical properties (saltiness, c, n and heavy metals) of isohumic soils (zaouit sousse perimeter, oriental tunisia). Desalination 253:180–187

Leal RMP, Herpin U, Fonseca AF, Firme LP, Montes CR, Melfi AJ (2009) Sodicity and salinity in a Brazilian oxisol cultivated with sugarcane irrigated with wastewater. Agric Water Manag 96:307–316

Levy G, Rosenthal A, Tarchitzky J, Shainberg I, Chen Y (1999) Soil hydraulic conductivity changes caused by irrigation with reclaimed waste water. J Environ Qual 28:1658–1664

Marsden Jacob Associates (2014) Economic viability of recycled water schemes-Technical Report 2: Community values for recycled water in Sydney. Australian Water Recycling Centre of Excellence, Brisbane
Metropolitan Water Directorate (2014) 2010 Metropolitan Water Plan. New South Wales Government. http://www.metrowater.nsw.gov.au/. Accessed: 15 Nov 2014
Mohammad MJ, Ayadi M (2005) Forage yield and nutrient uptake as influenced by secondary treated wastewater. J Plant Nutr 27(2):351–365
NRMMC-EPHC-AHMC (2006) Australian guidelines for water recycling: managing health and environmental risks (phase 1)
O'toole J, Sinclair M, Leder K (2009) Transfer rates of enteric microorganisms in recycled water during machine clothes washing. Appl Environ Microbiol 75:1256
Olivieri AW, Seto E, Cooper RC, Cahn MD, Colford J, Crook J, Debroux J-F, Mandrell R, Suslow T, Tchobanoglous G (2014) Risk-based review of California's water-recycling criteria for agricultural irrigation. J Environ Eng. doi:10.1061/(ASCE)EE.1943-7870.0000833
Pedrero F, Kalavrouziotis I, Alarcón JJ, Koukoulakis P, Asano T (2010) Use of treated municipal wastewater in irrigated agriculture—review of some practices in Spain and Greece. Agric Water Manag 97(9):1233–1241
Po M, Nancarrow BE, Leviston Z, Poter NB, Syme GJ, Kaercher JD (2005) Predicting community behaviour in relation to wastewater reuse: what drives decisions to accept or reject? CSIRO, Perth
Productivity Commission (2011) Australia's urban water sector, report no. 55, final inquiry report. Canberra
Radcliffe J (2010) Evolution of water recycling in Australian cities since 2003. Water Sci Technol 62:4
Rahman MM, Hagare D, Maheshwari B, Dillon P (2014a) Continuous real-time monitoring of salt accumulation in the soil due to recycled water irrigation. Water 41(1):63–68
Rahman MM, Hagare D, Maheshwari B (2014b) Impact of recycled water use compared to town water in urban irrigation: a long-term column study. In: Proceedings of international conference on peri-urban landscapes: water, food and environmental security, PERI-URBAN 2014, 8–11 July 2014, Sydney
Rahman MM, Hagare D, Maheshwari B, Dillon P (2015a) Impacts of prolonged drought on salt accumulation in the root zone due to recycled water irrigation. Water Air Soil Pollut 226:90
Rahman MM, Hagare D, Maheshwari B (2015b) Framework to assess sources controlling soil salinity resulting from irrigation using recycled water: an application of Bayesian belief network. J Clean Prod 105:406–419
Rahman MM, Hagare D, Maheshwari B (2016) Bayesian Belief Network analysis of soil salinity in a periurban agricultural field irrigated with recycled water. Agric Water Manag. doi: http://dx.doi.org/10.1016/j.agwat.2016.03.003 (in press)
Rattan RK, Datta SP, Chhonkar PK, Suribabu K, Singh AK (2005) Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater—a case study. Agric Ecosyst Environ 109:310–322
Rebhun M (2004) Desalination of reclaimed wastewater to prevent salinization of soils and groundwater. Desalination 160:143–149
Sakadevan K, Maheshwari BL, Bavor HJ (2000) Availability of nitrogen and phosphorus under recycled water irrigation. Aust J Soil Res 2000(38):653–664
Sala L, Mujeriego R (2001) Cultural eutrophication control through water reuse. Water Sci Technol 43(10):109–116
Sato T, Qadir M, Yamamoto S, Endo T, Zahoor A (2013) Global, regional, and country level need for data on wastewater generation, treatment, and use. Agric Water Manag 130:1–13
Smith C, Hopmans P, Cook F (1996) Accumulation of cr, pb, cu, ni, zn and cd in soil following irrigation with treated urban effluent in Australia. Environ Pollut 94:317–323
Stevens DP, Smart M, Mclaughlin M (2003) Effects of long-term irrigation with reclaimed water on soils of the northern Adelaide plains, south Australia. Aust J Soil Res 41:933–948

Sydney Water (2010) Annual report 2010 [Online]. Available: www.sydneywater.com.au. Accessed 8 Aug 2011
Sydney Water (2011) Recycling water for irrigation [Online]. www.sydneywater.com.au. Accessed 8 Aug 2011
Sydney Water (2013) Irrigating with recycled water-Penrith City Council. Available: https://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdq2/~edisp/dd_046317.pdf. Accessed 8 Dec 2013
Tanji K (1997) Irrigation with marginal quality waters: issues. J Irrig Drain Eng 123(3):165–169
Tanji KK, Grattan SR (2007) Salt management guide for landscape irrigation with recycled water in coastal southern California: a comprehensive literature review. Southern California Salinity Coalition (SCSC) and National Water Research Institute (NWRI), CA
Toze S (2006) Reuse of effluent water—benefits and risks. Agric Water Manag 80:147–159
Van der Steen P (2011) Application of sustainability indicators within the framework of Strategic Planning for Integrated Urban Water Management, UNESCO-IHE Institute for Water Education, Delft. www.switchtraining.eu/switch-resources
Vazquez-Montiel O, Horan NJ, Mara DD (1996) Management of domestic wastewater for reuse in irrigation. Water Sci Technol 33(10):355–362
Wang Z, Chang A, Wu L, Crowley D (2003) Assessing the soil quality of long-term reclaimed wastewater-irrigated cropland. Geoderma 114:261–278
Water Corporation (2013) Sewer mining-information sheet. ISBN 1740437527. https://www.watercorporation.com.au/-/media/files/residential/water%20supply%20and%20services/water%20forever%20south%20west/fact-sheet-sewer-mining-water-forever-sw.pdf
Xu J, Wu L, Chang AC, Zhang Y (2010) Impact of long-term reclaimed wastewater irrigation on agricultural soils: a preliminary assessment. J Hazard Mater 183:780–786
Yang YL, Han LB, Zhang Q, Su DR (2006) Effects of reclaimed water irrigation on the physical and chemical characteristics of saline-alkaline earth in Tianjin. J Beijing For Univ 28:85–91
Zhang HS, Zhang K, Han L, Su D, Wang N, Li Y (2006) Effects of reclaimed water irrigation on soil environment of greenbelt. J Beijing For Univ 28:78–84

Chapter 18
Global Experiences on Wastewater Irrigation: Challenges and Prospects

Mohammad Valipour and Vijay P. Singh

Abstract The need for irrigated agriculture is growing day by day and the largest water withdrawals from renewable water resources are for irrigation. In addition, the available water resources are decreasing and we need to use non-conventional water resources for irrigation due to looming water crisis (Raschid-Sally and Jayakody, Drivers and characteristics of wastewater agriculture in developing countries: results from a global assessment. International Water Management Institute, Colombo, 35p, (IWMI Research Report 127), 2008). However, the volume of treating and using wastewater is limited due to the lack of adequate data and knowledge and/or negative effects of improper wastewater management (i.e. use of untreated wastewater). A comprehensive evaluation of what has been done is necessary in order to explore wastewater irrigation and to avoid trial-and-error policies. Although a study of wastewater irrigation from crops, soil, groundwater, health, irrigation equipments, modern technologies, and other environmental aspects is useful, management studies in comparison with other aspects can help lead to more reliable and more extensive findings and finally a better decision on using wastewater for irrigation. The chapter presents challenges and prospects that may help decision making for the use of wastewater in irrigation.

Keywords Crop • Environment • Health • Irrigation • Soil • Wastewater

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18.1 The Concept of Using Wastewater for Irrigation

More than 60 % of the global population could suffer from water scarcity by 2025 or 2030 (Qadir et al. 2007; Rijsberman 2006; Wallace 2000). Renewable water resources per capita have decreased for all regions in the world with the exception of Caucasus and Eastern Europe (see also Redondo and Lomax 1997), as shown in Fig. 18.1.

Figure 18.1 shows alarms of water crisis in the future; if the trends are as shown (due to uncontrolled population growth); renewable water resources per capita were significantly higher for maritime Southeast Asia than for mainland Southeast Asia in the first half of century; however, these have become less in mainland Southeast Asia in recent years. Renewable water resources per capita were significantly higher for

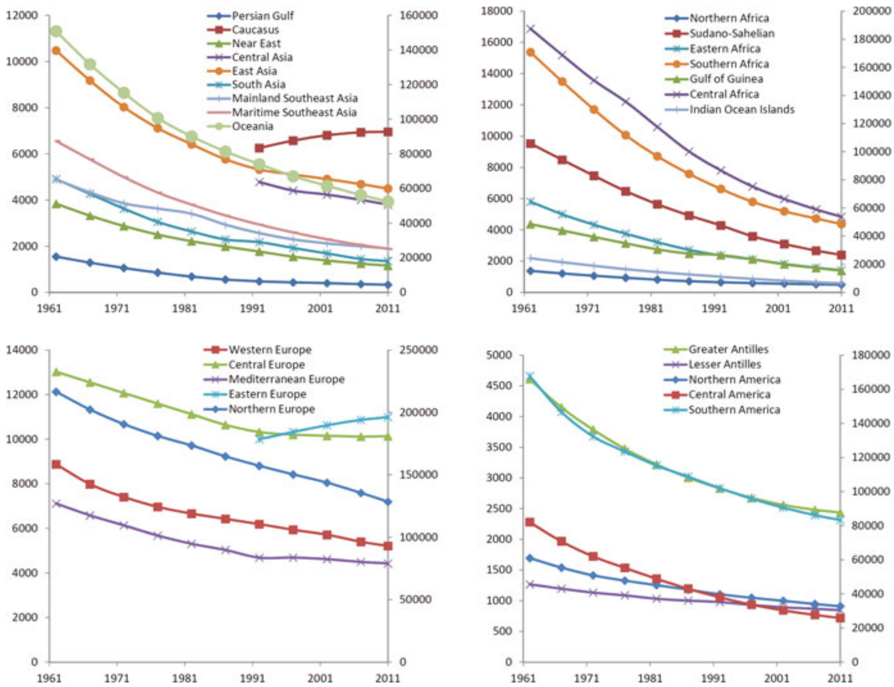

Fig. 18.1 Status of average renewable water resources per capita (m³/inhab/year) in different regions of the world: Asia and Oceania: the *left axis* belongs to Caucasus, East Asia, Central Asia, Near East, and Persian Gulf; and the *right axis* belongs to Oceania, Maritime Southeast Asia, Mainland Southeast Asia, and South Asia; all over Africa: the *left axis* belongs to Southern Africa, Sudano-Sahelian, Eastern Africa, and Northern Africa; and the *right axis* belongs to Central Africa, Gulf of Guinea, and Indian Ocean Islands; Europe: the *left axis* belongs to Eastern Europe, Central Europe, Western Europe, and Mediterranean Europe; and the *right axis* belongs to Northern Europe; Americas: the *left axis* belongs to Greater Antilles and Lesser Antilles; and the *right axis* belongs to Southern America, Central America, and Northern America (in Caucasus, Central Asia, and Eastern Europe, volumes of renewable water resources per capita have been calculated for years after 1991 due to collapse of the USSR)

Central America than for Northern America in the 1960s and 1970s; however they have become less in North America from the middle of the 1980s. The figure also shows that a warning sign is emerging for the Persian Gulf, Near East, North Africa, Central America, and North America. Meanwhile, water requirements for food production will significantly increase in order to eradicate poverty in developing countries by 2030 and 2050 (Fig. 18.2). Thus, we will be facing a serious challenge in the near future.

The greatest water withdrawal is due to the agricultural sector (Fig. 18.3a). However, there have been decreases in water withdrawals over the past three decades due to population and industrial growth (Fischer et al. 2007). Contrasting with Fig. 18.2, it shows the importance of agricultural water management now and in the future. Compared to rainfed agriculture, irrigation is advancing (Valipour 2012a, b, c, 2014a, b, c, 2015a, b, c, d, e, f, g, h, i, 2016a, b; Valipour et al. 2012, 2013, 2015; Valipour and Eslamian 2014; Yannopoulos et al. 2015; Mahdizadeh Khasraghi et al. 2015). In addition, Fig. 18.3a confirms the growth of other sectors compared to the agricultural sector. However, a considerable increase is citable for Czech, Canada, Croatia, and Denmark (Fig. 18.3b). This leads to increased pressure on renewable water resources and must be adjusted by appropriate management policies.

It may be noted that there is an increase in irrigation water withdrawal for Macedonia and Mongolia with respect to Fig. 18.2. Nevertheless, the area equipped for irrigation per cultivated area (irrigation systems growth) has increased and also more than 40 % of irrigation potential has not yet been developed (Fig. 18.3c).

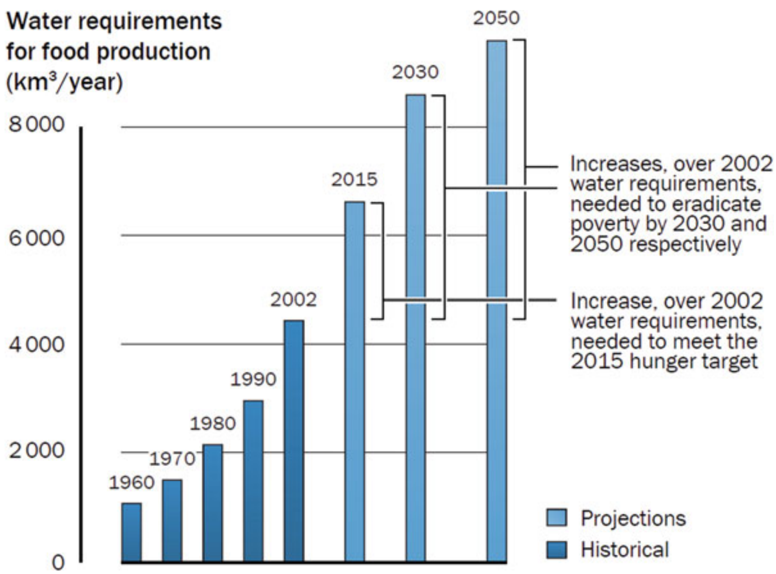

Fig. 18.2 The requirements for water in agriculture in developing countries will need to increase in order to meet the Millennium Development Goal (half, between 1990 and 2015, the proportion of people who suffer from hunger). To decrease hunger the outputs in agriculture will need to increase, and thus the water use. The data has been calculated for developing countries with minimum set of calories (Stockholm Environment Institute 2005)

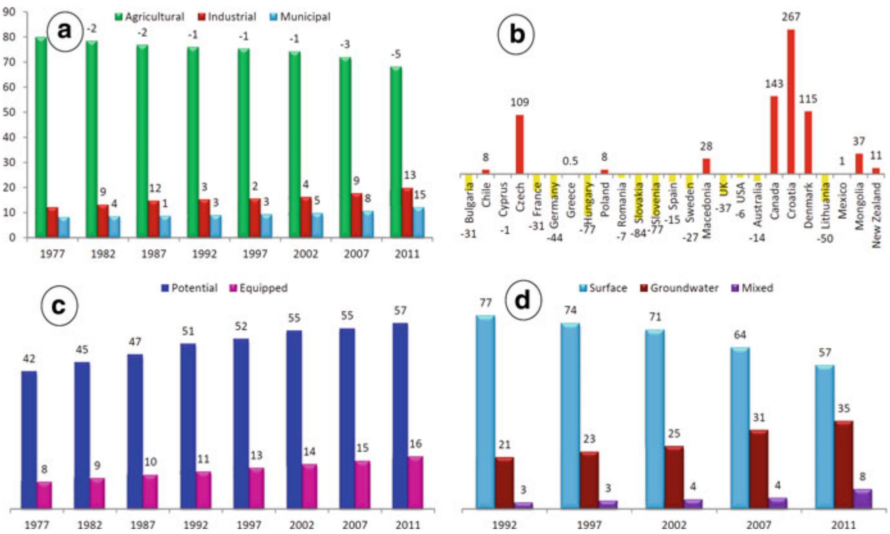

Fig. 18.3 Status of irrigation in the world (**a**) role of each sector in water withdrawal; *Agricultural* indicates agricultural water withdrawal as percent of total water withdrawal (%), *Industrial* indicates industrial water withdrawal as percent of total water withdrawal (%), *Municipal* indicates municipal water withdrawal as percent of total withdrawal (%), the values are changes in comparison with the previous period (%), (**b**) changes of water withdrawal for irrigation (%) during 2002–2011, (**c**) *Potential* indicates percent of irrigation potential equipped for irrigation (%), Equipped is area equipped for irrigation to cultivated area (%), (**d**) pressure on water resources in the previous two decades, *Surface* indicates percent of area equipped for irrigation by surface water (%), *Groundwater* indicates percent of area equipped for irrigation by groundwater (%), *Mixed* indicates percent of area equipped for irrigation by mixed surface water and groundwater (%)

Furthermore, developed irrigation potential is more than 100 % – Algeria (112 %), Barbados (152 %), Cyprus (109 %), Libya (175 %), and Malta (160 %) and it may apply for other countries in the future based on considerable growth of this index in recent years (FAO 2013; You et al. 2011). Therefore, compared to the decrease in agricultural water withdrawal (Fig. 18.3a), there is an increase in the tendency for irrigation for agriculture (Fig. 18.3c) in order to provide more food (Fig. 18.2), and this again underlines the water crisis for irrigation.

The question arises how irrigation water requirements should be met? Compared to surface water resources, the use of groundwater is increasing because of climate change, population growth and excessive water consumption, and as shown in Fig. 18.3d, irrigation is not exempt from this issue (Doll et al. 2012; Green et al. 2011; Siebert et al. 2010). This leads to greater pressure on groundwater resources. In addition, development of dams (Fig. 18.4) may impact groundwater levels (Heidarian et al. 2011).

Although the development of dams can increase groundwater levels in some conditions, it is also alarming for countries with considerable water resources dependency ratio (Fig. 18.4), because the water resources of more than 60 % of countries depend on other countries (upstream). Many advantages of the develop-

Fig. 18.4 The above chart shows status of average dam capacity (km^3) in the previous half of century (after 1992, dam capacity of Russia has been added to Europe) and the below chart shows number of countries with different dependency ratios in the world (The world data are the average of all continents)

ment of dams withstanding, dams limit countries with a considerable dependency ratio. Thus, the use of conventional waters is limited and is difficult from day to day. In addition, the cost of virtual water is too high (Dominguez 2010) and is not affordable for most developing countries. Therefore, wastewater, as a non-conventional water resource, can help provide for a proportion of irrigation water and reduce pressure on conventional water resources. However, wastewater should be treated in order to comply with the standards of irrigation water quality (WHO 1989, 2006). As shown in Fig. 18.5, more than half of wastewater is not treated and even all of the treated wastewater is not used, whether for irrigation or other sectors.

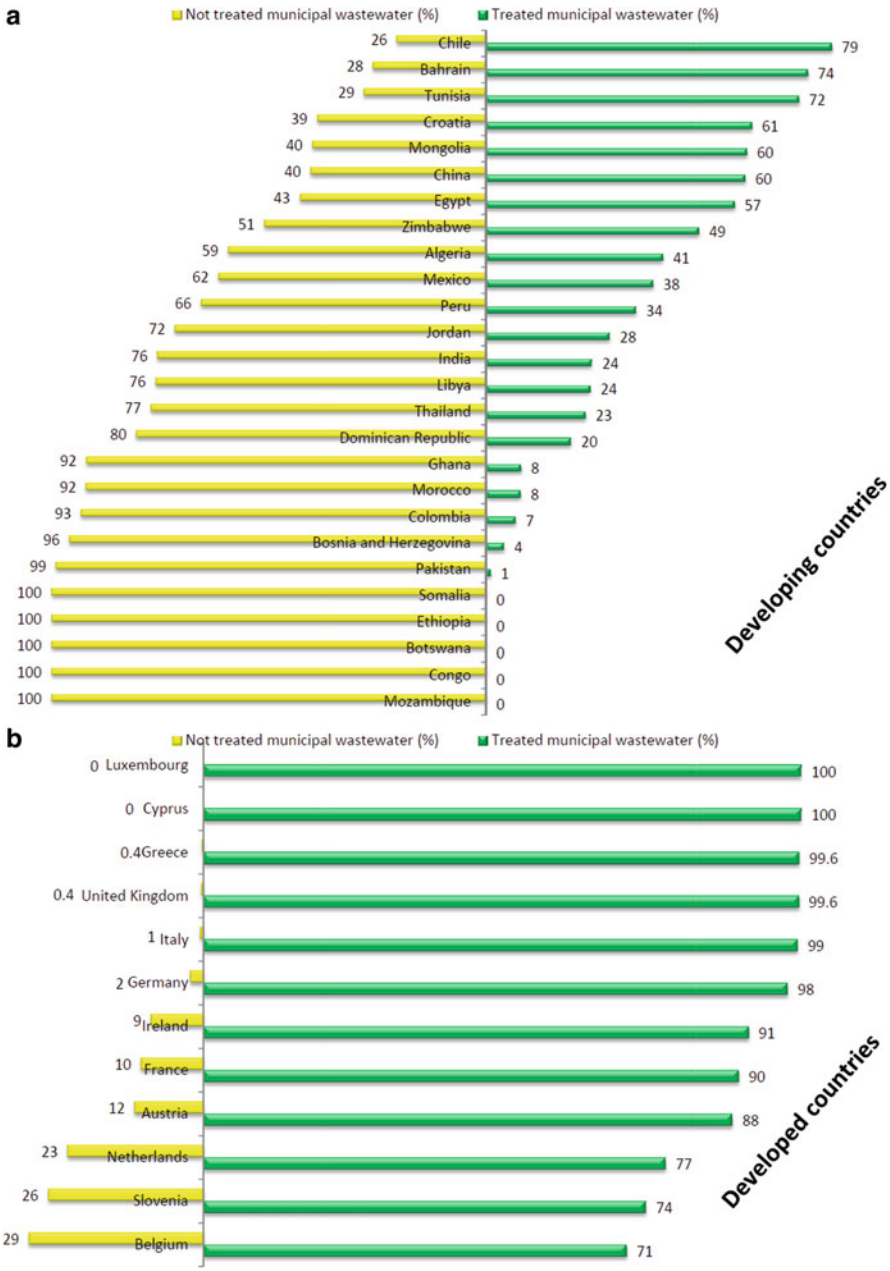

Fig. 18.5 Status of average collected municipal wastewater based on total available data for all countries in the recent two decades from 1992 to 2011

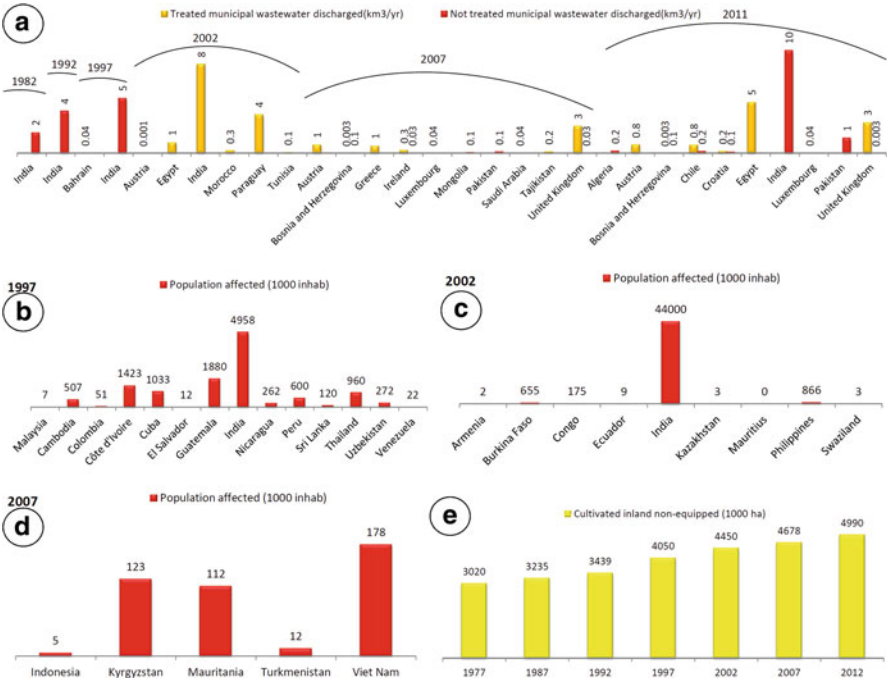

Fig. 18.6 Challenges and prospects for wastewater, (**a**) all of available data for discharged wastewater to inlands, wetlands, and coastal areas, (**b**–**d**) affected population to disease due to discharge of wastewater and water pollution, (**e**) available data for cultivated inland (non-equipped for irrigation) in the same regions that wastewater is discharged (Fig. 18.5a), note that the actual values are very higher than presented data and these are only reported data

Figure 18.6a shows that the volume of discharged wastewater (not treated) is increasing in India and Pakistan (with 76 % and 99 % non-wastewater treated respectively, based on Fig. 18.5) as well as the volume of discharged wastewater (treated) is increasing for Egypt (with 57 % wastewater treated based on Fig. 18.5) and Austria. However, with respect to Fig. 18.5, one can see the United Kingdom (with 99.6 % wastewater treated), Luxembourg (with full wastewater treated), and Bosnia and Herzegovina without increase in discharged wastewater (treated and not treated).

Although data on discharged wastewater are very limited (Sato et al. 2013), the information on wastewater or lack thereof is also an alarm for health and environmental issues. As shown in Fig. 18.6b–d, a considerable percentage of the population has been affected by water pollution and discharged wastewater, and the affected population is increasing due to the increase of this trend (compare the status in India in Fig. 18.6a with Fig. 18.6b, c). Based on Fig. 18.5, Congo, Colombia, Peru, and Thailand, with considerable affected population (Fig. 18.6b, c), have low treated wastewater (0, 7, 34, and 23, respectively). However, the volume of non-equipped cultivated area (rainfed agriculture) has increased (Fig. 18.6d) in the

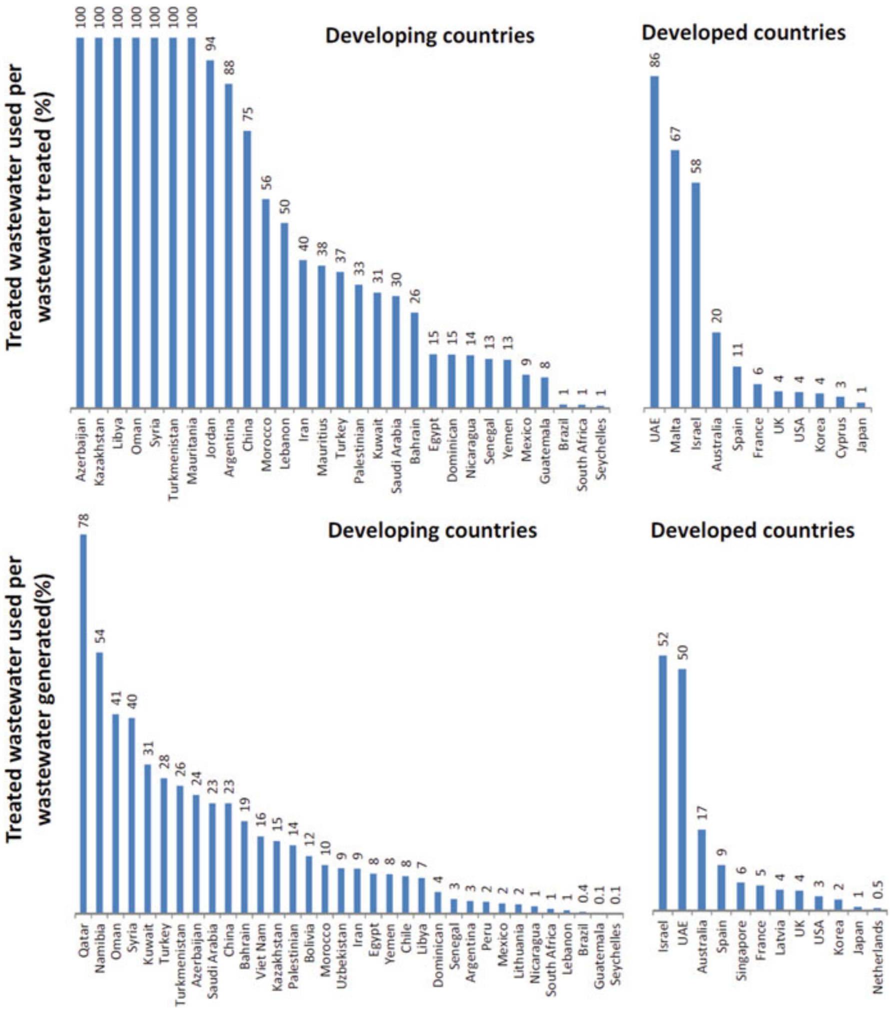

Fig. 18.7 All available data for treated wastewater used (not only for irrigation but also for all sectors as using wastewater for irrigation is lower than these data) in the world note that these data are approximately (in a few cases reporting year for wastewater used is not matched to reporting year for generated or wastewater treated)

same regions in which we see the discharge of wastewater (Fig. 18.6a) as well as the growth of diseases due to this discharge (Fig. 18.6b–d). This is interesting when we know that these areas have good potential for wastewater irrigation (Kivaisi 2001; Morari and Giardini 2009; Siracusa and La Rosa 2006; Verhoeven and Meuleman 1999). Despite what has been mentioned above, Fig. 18.7 shows that the use of wastewater for irrigation is quite low throughout the world.

Although all of the wastewater treated in Azerbaijan, Kazakhstan, Libya, Oman, Syria, and Turkmenistan is used, the volumes of wastewater used per generated wastewater are 24 %, 15 %, 7 %, 41 %, 40 %, and 26 %, respectively, for these countries. Further, the disposal of untreated wastewater increases the risk of diseases in these countries (see Kazakhstan, Turkmenistan, and Mauritania in Fig. 18.6c, d). A comparison of Peru, Guatemala, Uzbekistan, Nicaragua, and Viet Nam in Figs. 18.6b–d and 18.7 (considerable population affected and low wastewater treated and used) highlights the importance of proper use of treated wastewater instead of its disposal.

In some developing countries, city planners and administrators view wastewater as a disposal problem. They are not concerned with the impact on the livelihoods it presently generates or with the health of stakeholders. Politics and corruption play an important role in the decision to construct expensive treatment plants that often fail to function properly, if at all, once they are commissioned (Bhamoriya 2004). Strong traditional water rights, lack of urban planning, and weak institutions are constraints to the improvement of wastewater management in some urban and peri-urban areas (Huibers et al. 2004).

Although a considerable part of wastewater is refined in the United Kingdom, France, the Netherlands, Bahrain, Egypt, Mexico, and Peru (Fig. 18.5), the wastewater used in these countries is too low (Fig. 18.7). While the volumes of wastewater used are 100 % and 94 % for Libya and Jordan, respectively (Fig. 18.7), the volumes of wastewater treated are only 24 % and 28 %, respectively (Fig. 18.5). In general, average volumes of wastewater used per wastewater generated and wastewater used per wastewater treated are 15 % and 41 % in the world (based on the available data in Fig. 18.7). Now, the question arises: Why is the use of wastewater for irrigation low? How can it be increased? For answering these questions we should critique the previous studies to identify the challenges and prospects of using wastewater for irrigation.

18.2 Assessment of Wastewater Irrigation from Different Aspects

Wastewater irrigation has been studied from many different aspects. This section provides a review of the important results of the various aspects of using wastewater for irrigation (for period from the 1970s to 2013). The meaning of “wastewater” in this chapter is “wastewater treated” or else “untreated wastewater” has been used.

18.2.1 Health

There are many investigations on the connection of wastewater irrigation and health. Because of the potential public health risks involved, Katzenelson et al. (1976) recommended strong wastewater treatment measures, including effective bacterial and viral inactivation through disinfection for all cases of sewage irrigation or land disposal near residential areas. In addition, according to the findings, during reclaimed water irrigation the uptake of chemicals to food grown in the soil will be an important exposure route for human risk assessment (Weber et al. 2006). Policy efforts should be geared toward updating the knowledge, skills and attitudes of producers through frequent training and workshops, so that untreated wastewater irrigation farmers would better appreciate health-related risks of waste water irrigation and how to adopt risk mitigating strategies (Owusu et al. 2012). However, some works were related to limited regions, particularly in Asia and Africa. In Asia, for instance, in Israel, field soils, receiving either raw city wastewater or normal irrigation water, were found to be rich in pathogenic and potentially pathogenic CH-resistant fungi, including dermatophytes (Ali-Shtayeh et al. 1998). In the other research, exposure to wastewater with high Giardia concentrations carries an increased risk for (asymptomatic) Giardia infection, as in Pakistan (Ensink et al. 2006). In Republic of Korea, agricultural activity was thought to be safer after 1–2 days, when a paddy field was irrigated with reclaimed wastewater. Also, children were found to have a greater risk of infection with *E. coli* (An et al. 2007). In an examination in China, Khan et al. (2008) showed wastewater irrigated grown plants were contaminated with heavy metals and exceeded the permissible limits for vegetables set by SEPA and WHO. Baghapour et al. (2013) found that the effluent physicochemical quality in Iran was appropriate for irrigation; however, considering the microbial parameters, the effluent quality reduced dramatically which shows that pathogens in effluent can be a threat to the public health. Wastewater irrigation is the main source of metal accumulation in food crops in Pakistan, which on human consumption may lead to adverse health outcomes on a large scale. Hence, there is a dire need to strictly monitor wastewater irrigation systems and also tube-well irrigated systems and develop different strategies to prevent the accumulation of heavy metals in food crops that may ultimately minimise chronic health risks to the exposed population (Khan et al. 2013).

In Africa, El-Gohary et al. (1998) characterized the concentration of some elements of wastewater and concluded that bacteriological examination of the dried sludge indicated a reduction of nine logs of faecal coliform and faecal streptococci as compared to thickened sludge. Analysis of Ni, Cu, Pb and Cr in the dried sludge in Egypt indicated that their concentrations were within permissible limits. There are also some works on the connection between malaria and wastewater irrigation. For instance, Agunwamba (2001) observed that the occurrences of diarrhoea, typhoid fever and malaria among the groups were used as indices of irrigation farmers and consumers. The health status of farmers and consumers in Nigeria was poorer than that of non-farmers and non-consumers. Also, some studies focus on public health impacts of wastewater irrigation. The negative human health impacts can be minimized when good management practices are implemented, as in Morocco and Palestine (Fatta et al. 2004). In Zimbabwe, Mutengu et al. (2007) found that the public health risk of soil contamination by heavy metals and health risks by plant uptake of heavy metals seemed to be negligible probably because of the source of effluent. Keraita et al. (2007a) carried out a study on untreated wastewater irrigation in Ghana and their results showed that cheaper and simple irrigation methods need to be developed and assessed in order to reduce health risks. Such methods are more likely to succeed in informal urban irrigation settings, where low tenure security prevents farmers from investing in sophisticated methods or on-site treatment ponds. In another research in Ghana, Keraita et al. (2007b) showed cessation of untreated wastewater irrigation before harvesting is not effective in reducing contamination during wet season. In other study in Ghana, Qadir et al. (2010) proposed isolation of industrial effluents to reduce the most harmful wastewater components, to minimise pathogens, and to protect consumers from agricultural produce for developing countries.

18.2.2 Groundwater

Many investigations focused on the connection between wastewater irrigation and quality of groundwater. There are some works in Americas on this topic, for example, in the U.S.A., Mooers and Alexander (1994) found essentially no relationship between the source of Cl and NO_3 in the vicinity of irrigation fields. However, the most investigations belong to Mediterranean countries and Asia.

In Mediterranean countries, Esteller et al. (2001) concluded that main differences between the intervals were modifications of CO_2 interchange and the behaviour of sodium. In Spain the synergic effect of different processes involved was a good level of purification. Kass et al. (2005) showed that salinity and composition of groundwater in the water table region in Israel were highly variable over a distance of less than 1 km and were controlled by irrigation water and the processes in the overlying unsaturated zone. Abd El Lateef et al. (2006) showed that fertile soil and desert soil were widely variable in water holding capacity, organic matter, pH value, $CaCO_3$, salinity, cation exchange capacity, and soil bulk density in the topsoil. In Egypt, groundwater was examined for the presence of pathogenic bacteria, faecal coliform bacteria and helminth ova. Although no associated microbiological risk has been observed in aquifers due to the effective soil filtration, the soil–water interaction may render groundwater quality inappropriate for use due to the salinity increase in Spain (Candela et al. 2007). Examination of physical and chemical parameters in Tunisia showed an increase in the concentrations of nutrients in groundwater below the irrigation zone, which confirmed again the infiltration of wastewater effluents (Bouri et al. 2008). McNeill et al. (2009) showed that the utilisation of cesspits for wastewater disposal in Palestine had a negative impact on the underlying groundwater, so the construction of a wastewater network and treatment plant is imperative.

In Asia, for instance, in China nitrate enters groundwater via wastewater irrigation and groundwater flow from non-leveelined canals. High hardness and linearity among major ionic species in groundwater indicate the dissolution and mixing processes along the groundwater flow path (Chen et al. 2006). Jalali et al. (2008) showed in Iran that if wastewater was applied to soil for a long enough period, leaching concentrations will reach groundwater at elevated levels. Wu and Cao

(2010) informed that concentrations of metals in groundwater from wells were lower than the China Groundwater Quality Standard and the WHO guideline values for drinking water, but a substantial build up of Hg and Cd in river sediments and wastewater-irrigated soils was observed. During long-term sewage irrigation, principal component analysis for organ chlorine pesticides (OCPs) content in groundwater in China showed that the occurrence and distribution of OCPs in groundwater systems can mainly be attributed to the influence of flow field of groundwater and also to the current pesticide use (Zhang et al. 2013).

18.2.3 Crops

Oron and DeMalach (1987) showed the maximum yield of cotton in Israel was obtained under twin row planting (in comparison with single rows), irrigated twice a week with a commercial amount of effluent. In Sweden, a wastewater treatment system, using willow coppice crops as recipients, thus combining treatment and biomass production for energy purposes, can be a realistic economic alternative for small and medium sized treatment plants, compared with conventional technical systems (Rosenqvist et al. 1997). When the treated effluent was used to irrigate crops in Jordan, a very low coliform count was found on fruit skin. However, there was an increase in eggplant production, probably due to the nutritive value of the effluent (Al-Nakshabandi et al. 1997). In other research in Jordan, Shahalam et al. (1998) showed that the yields resulting from the use of wastewater without fertiliser were compatible with those with the use of freshwater with fertiliser. Haruvy et al. (1999) claimed that agricultural yields and/or prices in Israel may decrease according to differences between levels of nutrients needed by crops and those available in wastewater irrigation.

Some works reported the negative aspect of wastewater irrigation for crops. For instance, Murillo et al. (2000) deduced that olive trees rapidly responded to wastewater application. The wastewater use in Spain significantly reduced olive yield, compared to that obtained in the control fields. However, other works indicated a positive role of wastewater irrigation for crops. In Egypt, significant differences were found between treatments in root length, shoot height and root and nodule dry weight (Sayed 2003). At both the laboratory scale and full scale, the anaerobic treatment is suitable for the treatment of Pisco wastewater (The *Pisco wastewater* system consists of mains, mostly running from the south toward the north to the stabilisation of lagoons for treatment), and that the nutrient content of treated water can be beneficial for plant growth, reducing the need for fertilisers in Chile (Jeison et al. 2003). Al-Lahham et al. (2003) showed that microbial contamination increased at tomato surface and scar, while the fruit flesh was totally uncontaminated. The tomato fruit size and weight increased in both varieties with the increasing percentage of treated wastewater. The pH was not affected, but the firmness, TSS, and weight loss decreased as a function of the increasing treated wastewater percentage in Jordan.

Agronomic results indicated no major limitations to the use of tertiary effluent as an irrigation source in an ornamental (one case) plant nursery. In Italy, the nutrient content of the tertiary effluent was able to maintain good plant growth as well as fertigated water for most of the tested species (Lubello et al. 2004). Strict protection measures, stringent guidelines and an integrated system for the treatment and recycling of wastewater are needed to minimise the negative impacts of wastewater irrigation on cops, as in Iran (Qishlaqi and Moore 2006). Kiziloglu et al. (2007) claimed that the contents of P, Zn, Cd, and pH were increased in cultivated plants by wastewater irrigation. In Brussels, wastewater irrigation decreased leaf dry matter P and Zn in Broccoli, but increased Cd and Co in sprouts leaves. In Greece the high heavy metal content in the edible plant parts, and the heavy load of FC and E. coli are high health risk factors. In China the quality of crops that made use of treated sewage was not distinctively different from that of those that did not use treated sewage but yields for the former were much higher than they were for the latter (Wang et al. 2007). In Italy the negligible microbial contamination of fruit and washing solution (up to 40 MPN/100 mL) suggested that the treated wastewater can be used as a valid alternative for irrigation of tomatoes (Aiello et al. 2007). Kiziloglu et al. (2007) found in Turkey that wastewater increased yield and the N, P, K, Fe, Mn, Zn, Cu, B, and Mo contents of cabbage plants.

Rusan et al. (2007) found in Jordan that continuous irrigation with wastewater led to the accumulation of salts, plant nutrients and heavy metals beyond crop tolerance levels. Compared to soils irrigated with groundwater, the results of soils irrigated with wastewater revealed a significant decrease in the soil pH and an increase in salt, the organic matter content and CEC in the soil and macro and micro element concentrations in the leaves and may improve plant growth, reduce fertiliser application and increase productivity of poorly fertile soils in Turkey (Kiziloglu et al. 2008). In China, Chiou (2008) claimed that the high total nitrogen of reclaimed water from secondary treatment made it unfavourable for crop growth. In the Republic of Korea Chung et al. (2008) indicated in the soils and crops after wastewater irrigation, high-molecular weight polycyclic aromatic hydrocarbons PAHs (PAHs have been identified as carcinogenic and mutagenic, and are considered pollutants of concern for the potency of potential adverse health impacts; the same holds true of their presence at significant levels over time in human diets.) were not detected, but low-molecular weight PAHs were only detected at trace levels. No significant contamination was recorded on fruits harvested by irrigated olive trees in Italy, even under the worst-case conditions (Palese et al. 2009).

Pedrero and Alarcon (2009) indicated that the possibility to mix reclaimed wastewater with well water was a good solution to avoid the problems of wastewater irrigation. In Spain the high salinity and Boron concentration were the main problems for lemon trees (Pedrero and Alarcon 2009). Non-significant injuries caused by salts and/or heavy metals were observed on the shoot growth of trees irrigated with wastewater irrigation. Application of wastewater irrigation in Tunisia significantly increased the concentration of N, P and K in the leaves, whereas heavy metals (Zn and Mn) showed a significant increase only after the second year of irrigation (Bedbabis et al. 2010a). Irrigation with wastewater over 4 years did not affect free acidity, and specific ultraviolet absorbance on olive (Bedbabis et al. 2010b). In Italy and Serbia, low levels of E. coli and no helminth eggs were found in treated wastewater used for irrigation. Only one potato sample was positive for E. coli during the 2-year study. Potatoes, irrespective of the irrigation method and type of water applied, were safe for consumption (Forslund et al. 2010).

During a field experiment using wastewater irrigation in India, Gupta et al. (2010) showed a decrease in total chlorophyll and total amino acid levels in vegetables and an increase in amounts of soluble sugars, total protein, ascorbic acid, and phenol except *Boron*. Loutfy et al. (2010) showed all the studied contaminants in Egypt were much higher in henna and rosemary plants irrigated with wastewater, while in the case of Moghat (dried powder of peeled roots of Glossostemon bruguieri plants) samples, no difference was observed between freshwater irrigated samples and wastewater irrigated samples. Despite enriched As, Cr and Ni in some paddy soils from andesite and serpentinites in Taiwan, Hseu et al. (2010) found these metals were not clearly accumulated in rice. The irrigation of olive trees and vegetable crops with treated wastewater in Jordan did not show any adverse effect on the chemical properties of fruits and leaves (Al-Hamaiedeh and Bino 2010). de Paula et al. (2010) showed that surplus wastewater pasture irrigation in Brazil caused minor increases in the physiological status of the soil microbial community but no detectable damage to the pasture or soil.

The average length of seedlings watered with drinking water and raw wastewater was similar in Mexico (Rojas-Valencia et al. 2011). In Iran, Moradmand and Beigi Harchegani (2011) claimed that soil and sweet chilli plant concentrations of lead and nickel were not significantly affected by wastewater irrigation. Pereira et al. (2011) showed that in the U.S.A. wastewater irrigation had a greater influence on the micro-nutrient than macronutrient concentration in citrus leaves, following the order: B > Zn > Mn and Ca > Cu > Mg > P > K. The physico-chemical quality of lagoon-treated wastewater was acceptable, whereas the bacteriological quality and helminths quality were not satisfactory. The reuse of wastewater irrigation improved yield and provided variable nutrients supply, depending on the year and element in West Africa (Irenikatche Akponikpe et al. 2011). Evett et al. (2011) concluded that successful irrigation of any tree species in Egypt demanded careful irrigation system design, irrigation scheduling based on the best scientific knowledge available, on-site measurement of weather data, and ongoing maintenance and repair of the irrigation system from pump intake to emitters and/or spaghetti tubing.

Lantana species is sensitive to saline reused water, while Polygala is a tolerant species. Thus, Polygala can be irrigated with reused saline water with acceptable growth and aesthetic results, while Lantana cannot be recommended for nursery growth or landscape use, when this type of water is used for irrigation, as in Spain (Banon et al. 2011). Moraetis et al. (2011) showed the fertilisation potential of wastewater was considerable, especially for N and K. In Greece, the total NPK fertilisation of the maize field with wastewater resulted in 6 times more N, 2 times less P and 50 times more K than conventional fertilisation rates. In Republic of Korea, Chung et al. (2011) found that the contents of Cd and Pb in brown rice were lower than the permitted limits in grains.

Application of sewage water increased the yield of Rabi crops compared to irrigation with well water; it also increased the total N, P, K and organic carbon content of soil. On the other hand, the indiscriminate long term use of sewage effluent for crop production could result in the concentration that may become phytotoxic. The use of sewage water with physical treatment can increase water resources for irrigation which may prove to be beneficial for agricultural production in India (Singh et al. 2012). In Italy Cirelli et al. (2012) concluded that the microbiological quality of the products was generally maintained, although the E. coli content in wastewater irrigation was often over the standard. The experimental system used wastewater irrigation to grow tomatoes successfully under semi-arid conditions, resulting in a 20 % yield increase when compared to yields from crops using conventional water. Both partially improving water quality and reducing irrigation rate have been shown to have positive impacts on social and environmental concerns, without harming agricultural productivity for alfalfa in Mexico (Chavez et al. 2012).

Kalavrouziotis et al. examined the capacity of cultivated plant species to accumulate heavy metals, and indirectly evaluate the soil pollution level. The highest water use efficiency for wheat, obtained in the 75 % wastewater containing irrigation treatment under the fertilised condition and the raw wastewater-irrigated treatment under the non-fertilised condition in Bangladesh, demonstrated the most effective use of water in these treatments (Mojid et al. 2012). Keser and Buyuk (2012) indicated wastewater in Turkey was not suitable for irrigation of parsley, because it had negative effects on plant and caused heavy metal accumulation. Herbaceous crops irrigated with wastewater can produce appreciable biomass and energy yields. This is also an environmentally and economically sound way of wastewater disposal in Italy (Zema et al. 2012). de Oliveira Marinho et al. (2013) found in Brazil that the production of marketable rose stems was higher in the tests using nitrified and anaerobic effluent than those using either fertilised or unfertilised water. There was no significant difference between the use of treated effluents and topdressing for reduction in the mineral fertilisers spending. Keser (2013) showed that the use of wastewater for irrigation in Turkey increased heavy metal content in both *Lepidium sativum* L. and *Eruca sativa* (Mill.) and affected their physiological and morphological properties. Jang et al. (2013) found that the wastewater irrigation did not present significant environmental risks for the rice paddy agroecosystem, although long-term monitoring is needed to fully characterise its effects. In Morocco, Hirich et al. (2013) showed stomatal conductance and growth parameters were affected by deficit irrigation treatments rather than by organic matter amendment. Mojid and Wyseure (2013) reported that irrigation in Bangladesh using wastewater was proposed for improving soil fertility as well as for alleviating water scarcity with the exception of some crops whose edible parts came in direct contact with wastewater and/or were eaten uncooked.

18.2.4 Soil

In the field experiments in the U.S.A., calcium amendments may be useful in both increasing the tolerance of plants to sodic wastewater irrigation and increasing soil infiltration rates (Howe and Wagner 1996). The coliform count on the soil surface due to wastewater irrigation in Jordan decreased drastically with depth (Al-Nakshabandi et al. 1997). Shahalam et al. (1998) found in Jordan that wastewater irrigation applied for a season had no significant effect on a silty loam soil. Simulation of both ponded and sprinkler irrigation in Italy with municipal wastewater resulted in reduced infiltration and increased surface ponding compared to the application of fresh water (Viviani and Iovino 2004). It is worth noting that all the phenomena leading to the formation of a denser level of concentration of heavy metals with lower conductivity at the surface of soil profiles might in general also be ascribed to the mechanical effect of water, irrespective of the extent and type of TDS of the wastewater applied in Italy (Coppola et al. 2004).

Negative effects of heavy metals have not been felt up to now, and the rate of accumulation predicts some effects in 10–30 years of continuing practices of wastewater irrigation in Israel (Rebhun 2004). In Iran, Heidarpour et al. (2007) showed that the most important concern was the increase of EC in the top soil layer with subsurface irrigation with treated wastewater, as this might inhibit plant growth. In addition, wastewater irrigation significantly affected potassium, while phosphorus and total nitrogen were not significantly affected. Kiziloglu et al. (2007) found in Turkey that application of wastewater increased soil salinity, organic matter, exchangeable Na, K, Ca, Mg, plant-available P, and micro-elements and decreased soil pH. Wang et al. (2007) concluded that treated sewage irrigation in China had no significant effect on the loess soil, and no cases of illness resulting from contact with the treated sewage were reported. With treated sewage irrigation, a slight increase in the organic content of the soil was observed. Wastewater application in Italy resulted in increased microbial contamination (Escherichia coli 3000 MPN/100 mL; Faecal Streptococci 1200 MPN/100 mL) in the soil surface (Aiello et al. 2007). The rapid mineralisation of testosterone shows that this steroid is less persistent but due to its lower sorption in the solid phase may leach more readily into the soil profile during wastewater irrigation (Stumpe and Marschner 2007).

Kiziloglu et al. (2008) showed that the major disadvantage of wastewater irrigation in Turkey was the accumulation of immobile heavy metals in the soil. In the U.S.A., soils have experienced periods of local saturation and soil transport, which are reflected by the distribution of redoximorphic features and A-horizon thickness across the study area. Both organic matter content and soil pH have increased considerably (Walker and Lin 2008). In China, Chiou (2008) concluded that in terms of reuse impact in soil contamination, the most possible heavy metal caused accumulation was arsenic. Although heavy metals-containing wastewater irrigation ceased more than 10 years ago, the soil in the Zhangshi Wastewater Irrigation Area in China is still heavily polluted by Cd and to a lesser degree by Zn and Cu, in light of the China Environmental Quality Standards (Zhang et al. 2008). In Iran, Jalali et al.

(2008) determined that the average exchangeable sodium percentage (ESP) of soils increased during leaching from 9 to 21 and 28.8–29.7 after applying 5.0 and 3.5 L (about 7 and 6 pore volumes) of wastewater to the soils columns, respectively. Lado and Ben-Hur (2009) showed in Israel that leaching of loamy and clay soils with effluent that contained high concentrations of suspended solids led to a significant reduction in hydraulic conductivity, caused by trapping of more suspended solids in the large numbers of small pores in the soils. In Jordan, Al-Hamaiedeh and Bino (2010) concluded that soil leaching with fresh water was highly recommended, because it reduced the accumulation of salts and organic matter in the soil. The heavy metal indicates that their mobility and their adsorption will depend on the metallic contents of wastewater, organic carbon tenors, clay fraction and irrigation time in Tunisia (Klay et al. 2010).

Tarchouna et al. (2010) showed that despite the very sandy texture of irrigated (with treated wastewater) soils studied, both saturated and unsaturated hydraulic conductivity exhibited a significant diminution in the irrigated soil compared to the reference one in Mediterranean countries. In the U.S.A., Xu et al. (2010) argued that the increase of available soil profile heavy metals was not hazardous due to the leaching of metals, owing to the light soil texture and the low organic matter content of the plots studied. In regard to soil conditions, neither the soil nitrogen nor carbon was significantly impacted by wastewater irrigation (Hunt et al. 2011). Muyen et al. (2011) showed that irrigation can be a very attractive proposition, particularly for arid and semi-arid regions of Australia, if used with proper and adequate management plans in place but the degree of treatment particularly about N can be an important consideration. In Iran, Fluvaquentic Endoaquepts (a type of local plants) was highlighted to be a major contributor of the load and contamination rate of trace metals regarding geoaccumulation index, contamination factor, and degree of contamination (Rezapour and Samadi 2011). In another study in Israel, it appears that after each irrigation season, the potential activity of the microbial community returned to levels similar to or even slightly lower than those of freshwater-irrigated soil during the wet season, suggesting that the periodic irrigation did not significantly change the soil microbial activity (Elifantz et al. 2011). Morugan-Coronado et al. (2011) found in Mediterranean countries that electrical conductivity and sodium content of soil increased but no remarkable changes in soil organic carbon and microbial biomass carbon were seen due to the low organic carbon content of water used for irrigation.

In Mexico, soils irrigated with raw and wastewater treated showed an increase in the concentration of N, P, K, Fe, Zn, and Cu (Rojas-Valencia et al. 2011). In Iran, Rezapour et al. (2012) found with the exception of lower slope position, which indicated a remarkably increasing pattern of smectite (a type of clay minerals) in response to wastewater irrigation and unfavorable drainage condition, the relative abundance of clay minerals in view of the peak position and intensity followed almost the same pattern in both wastewater-irrigated and control landscape. Samia et al. (2012) noted that Cr, Cu, Al, Zn, and Cd mobility depended on the clay yield. However, the polycyclic aromatic hydrocarbons and Pb mobility are also related to humic substance quantities. In Tunisia, Cr and Cu have affinities both to clay and humic substance quantities.

Kayikcioglu (2012) detected a decrease in the microbial activities in soil, depending on irrigation with wastewater in Mediterranean countries. Adrover et al. (2012) claimed that after more than 20 years of treated wastewater irrigation, no negative changes have been observed in the evaluated soil properties of the Island of Mallorca in Spain, with the exception of an increase in the soil pH caused by greater sodium supply. In China, Shi et al. (2012) found that due to the spatial distribution of Fluoroquinolones (Fluoroquinolones are broad-spectrum antibiotics that play an important role in treatment of serious bacterial infections) in wastewater irrigation was a potential source of antibiotics. In the other research in China, Li et al. (2012) successfully applied two types of widely used wastewaters treated with fluidised-bed reactor (FBR) and biological aerated filter (BAF) processes. Laurenson et al. (2012) predicted in New Zealand that managing salt, in particular sodium and potassium, in wastewater would be necessary in order to maintain the soil physical, chemical and biological health in the long term. In Nigeria Egwu and Agbenin (2013) found that reports of excess Pb concentrations in leafy vegetables raised in soils were consistent with high free Pb^{2+} activities maintained in the soil solution by these predominantly sandy-textured soils. In Israel, Nadav et al. (2013) detected that the lowest degree of water repellency was consistently exhibited by the soil with the highest specific surface area irrigated with the highest quality wastewater. Gatica and Cytryn (2013) found that although recent studies seem to indicate that irrigation with wastewater did not significantly induce antibiotic resistance reservoirs in soil, the impact of the abovementioned factors was not yet clear in the context of mobile genes transfer between wastewater-associated bacteria and soil.

18.2.5 Environment

In Jordan, because the As-Samra stabilisation pond system receives wastewater irrigation more than twice the designed capacity in terms of biological and hydraulic loadings, the effluent contains high levels of organic matter in which coliforms and other heterotrophic bacteria could survive the sudden stress imposed by chlorine (Al-Nakshuhundi et al. 1997). Laposata and Dunson (2000) found that the wastewater effluent irrigation in the U.S.A. was not acutely toxic to terrestrial salamanders under natural conditions. Toze (2006) showed that the use of wastewater reduces the pressure on the environment by reducing the use of environmental waters but the presence of pathogens and chemical contaminants as well as salinity and impacts on soil structure are the factors that need to be considered. The study of wastewater irrigation in Israel supports the collaboration among economic entities and indicates economic and environmental advantages which can serve decision-makers (Axelrad and Feinerman 2009). McNeill et al. (2009) found in Palestine that the reuse of wastewater can improve environmental conditions and enhance agricultural activities. Rezapour et al. (2011) showed that in Iran although heavy metal levels were below the permitted range, it seems that proper management of wastewater irrigation along with periodic analysis of heavy metals and their bioavailability are required to guarantee ecosystem health. In Viet Nam Trinh et al. (2013) indicated that wastewater reuse in the agricultural sector had good potential as a climate change adaptation strategy. The authors showed that wastewater effluent can be used to irrigate at least to 22,719 ha of paddy rice (16 % of the rice-cultivated area in the city) at three crops per year. The fertilising properties of the water would eliminate part of the demand for synthetic fertilisers, providing a maximum of 22 % of the nitrogen (N) and 14 % of the phosphorus (P) requirement for the winter–spring crop. On a yearly basis, recovery of wastewater could reduce the discharge of N by 15–27 % and the discharge of P by 8–17 %.

18.2.6 Irrigation Equipment

Adin and Sacks (1991) showed that the clogging rate was more affected by particle size than by particle-number density in wastewater irrigation. There are differences between emitters of various manufacturers as to their sensitivity to clogging. This should be considered when choosing the emitters for the drip irrigation system, particularly for reclaimed water. The clogging hazard of an emitter with a higher discharge rate is smaller than that of a similar emitter with lower discharge rates. Clogging of the drip irrigation system was not a significant problem when treated wastewater was used for irrigation in Jordan, and was easily controlled with acid and chlorine (Al-Nakshabandi et al. 1997).

In a biochemical study in Italy, Capra and Scicolone (2007) found that the use of wastewater with a TSS greater than 50 mg/L did not permit optimal emission uniformity to be achieved. Correlations of biofilm biomass and discharge reduction after 360 h irrigation were computed that suggested that phospholipid fatty acids (PFLAs) provided the best correlation coefficient. Comparatively, in a physicochemical study in China the emitters with unsymmetrical dentate structure and shorter flow path (Emitter C) had the best anti-clogging capability (Yan et al. 2009). In an experimental study in China, chemical precipitation was found to be the primary source of emitter clogging for both the treated sewage effluent and freshwater treatments, which was mainly due to their relatively higher total dissolved solids and alkalinity. Flushing emitters and drip lines using freshwater did not efficiently alleviate emitter clogging caused by chemical precipitation (Liu and Huang 2009).

Treated wastewater reuse in agriculture is a common practice in the Mediterranean countries (particularly in Spain and Greece) and there is a considerable interest in the long-term effects of treated wastewater on crops intended for human consumption with minor disadvantages for irrigation equipment (Pedrero et al. 2010). The tested pressure compensating emitters are recommended over the non-pressure ones when applying the municipal tertiary effluent. Results recommended that an air/vacuum relief valve be used for subsurface drip irrigation to avoid ingestion of soil particles due to back siphoning. Flushing at a velocity of 0.6 m/s was adequate as found in Spain when it was performed monthly or only at the end of irrigation season (Puig-Bargues et al. 2010). In France, relations between biofilm development and velocity distribution on NPC flow paths were observed and the pipe diameter appeared to be a parameter inducing emitter clogging (Gamri et al. 2013).

18.2.7 Modern Technologies

Micro filtration filtrate (a new technology) water will not cause any clogging problem related to its EC, SAR, and ESP, as found in Kuwait (Al-Shammiri et al. 2005). Lopez et al. (2006) showed that the microbial quality of treated effluents in membrane filtration was higher than that of local well-water used for irrigation; after simplified treatment, in order to save the agronomic potential of organic matter and nutrients present in urban wastewater, olive trees were irrigated with effluents produced by skipping biological processes and this resulted in a yield increase of 50 % in storage reservoirs capacity; TSS, BOD_5, COD and nutrients concentrations achieved the in-force Italian limits for wastewater agricultural reuse, and in constructed wetlands the values of TSS, BOD_5, COD, total nitrogen (TN) and total phosphorus (TP) removals were 85 %, 65 %, 75 %, 42 % and 32 %, respectively. In Europe, Bixio et al. (2006) inferred that technological innovation and the establishment of a best practice framework would help, but even more, a change was needed in the underlying stakeholders' perception of the water cycle.

The combination of aerobic biological process with physical filtration and disinfection is considered to be the most economical and feasible solution for wastewater recycling (Li et al. 2009). Bdour et al. (2009) recommended the cyclical or a closed-loop treatment system to achieve ecological wastewater treatment. There are plenty of research needs to improve the methods of wastewater treatment in Mediterranean countries. In Italy, Liberti et al. (2002) showed some parasites such as 'Giardia lamblia cysts' and 'Cryptosporidium parvum oocysts' were both affected by ultra violet (UV) radiation and that potential UV-promoted formation of disinfection by-product (DBP) did not occur according to the liquid chromatograph/mass spectrometer (LC/MS) analytical evidence. Costs ranged from 17.5 to 35 euro/1000 m^3 for effluent clarified-filtered (F) and clarified (CL), respectively. The quality of the water produced in China and Italy by the Safir field treatment system (SAFIR FTS) and membrane biobooster (MBR) treatment (Battilani et al. 2010) fulfilled the irrigation water quality standards required by the most reliable international guidelines, only the most restrictive regulation as the Italian law for treated wastewater direct reuse in agriculture (D. Lgs. 152/06) was not always fulfilled. Nevertheless, the technologies developed and tested in SAFIR proved to be an effective barrier against those pollutants which can threaten food quality and safety. The MBR and FTS technologies allowed a safe direct and indirect water reuse. The correct application of these technologies could be considered as a "quality label" guaranteeing food safety, thus fulfilling quality standards worldwide required by the retailer's organisations (Battilani et al. 2010).

When the effluent of sand filters is fed into UV disinfection, 90 mWs/cm^2 will be adequate to reach the desired disinfection target, as in Turkey (Evcimen and Kerc 2011). Recently, new software have been designed to reduce risk of using wastewater (and assessment of other environmental aspects) in civil and energy projects. Solar and H_2O_2/solar disinfection processes can be thought of as a potential means for enhancing the microbial quality of wastewater effluents used for irrigation of edible crops (Bichai et al. 2013).

18.2.8 Management

Afshar and Marino (1989) indicated in the U.S.A. that a chance-constrained linear-programming model minimised the required capacity and provided information on the reliability of the system or its failure. The net cost to municipalities of wastewater treatment and disposal can be affected substantially by economically selecting optimal sets of cropping enterprises (Segarra et al. 1996). The soil biosystem was altered with the application of sewage effluent in Canada. Monitoring data from two large effluent irrigation projects in Saskatchewan have shown that the soil biosystem is altered with the application of sewage effluent. Effluent irrigation is sustainable provided proper management practices are followed (Hogg et al. 1997). Hussain and Al-Saati (1999) showed that the use of wastewater for irrigation had a special significance due to the scarce non-renewable water resources of Saudi Arabia as well as to the presence of an appreciable amount of crop nutrients.

Angelakis et al. (1999) observed the need for sharing a common rationale for developing wastewater reclamation and reuse standards on both sides of the Mediterranean countries. The study of wastewater irrigation in Israel showed the need for setting risk-based criteria for wastewater reclamation rather than single water quality guidelines (van Ginneken and Oron 2000). Ringler et al. (2000) showed that the only countries with wastewater reuse for irrigation in Latin America and Caribbean were Argentina, Barbados, Brazil, Guatemala, and Jamaica, which indicates insufficient attention to wastewater irrigation in these regions. Jaber and Mohsen (2001) deduced in Jordan that the availability of wastewater was more than water importation and less than desalinated water and water harvesting. In some cases the most viable approach is to acknowledge irrigation as a land-based treatment method, which requires sharing of costs and responsibilities between wastewater producers, government institutions and farmers in developing countries (Martijn and Redwood 2005).

In Northern Ireland cost savings in treatment plants are much more important than cost savings and higher yield in the short rotation willow coppice plantation (Rosenqvist and Dawson 2005). Jia et al. (2006) showed that in China irrigation scheduling and proper management were more important to water quality than remedial actions, such as controlled drainage or vegetative buffers. In Nepal, according to Rutkowski et al. (2007), the negative attitude of some farmers towards wastewater stemmed from their inability to control wastewater application leading to flooding and loss of crops. Selection of suitable sites, taking into account the local stratigraphy, geology and groundwater conditions, may help in improving the performance of the soil aquifer treatment process during wastewater irrigation, as in Kuwait (Akber et al. 2008).

Angelakis and Durham (2008) emphasised the establishment of guidelines for wastewater use in Europe. After a period featured by a few initiatives for increasing the availability of local water resources and the lack of clear regulations, regional authorities in Italy have, under the pressure of several factors, planned, at a regional scale, the reuse of wastewater treated mainly in the agricultural sector (Lopez and Vurro 2008). Wastewater supplementation could increase profits by $20 million annually; alternatively, wastewater replacement could conserve 35 Mm^3 of water in local rivers each year in China (Murray and Ray 2010). Scheierling et al. (2011) deduced that achieving safe wastewater irrigation required steady progress over several decades. In Europe, treatment requirements for restricted and unrestricted irrigation would be identical, that means treatment cost for unrestricted irrigation is lower and thus this treatment level is more probable to be feasible and practicable. In unrestricted irrigation the microbiological criteria of quality are less stringent than those in the WHO 1989 guidelines. In the WHO 2006 guidelines the 6–7 log unit pathogen reduction can be achieved by treatment to a lower quality (≤104 E. coli per 100 mL, as in the case of restricted irrigation), but moreover supplemented by post-treatment health-protection control measures, such as post-harvest pathogen die-off, produce washing, produce disinfection, etc. On the other hand, the health based target can be achieved for unrestricted irrigation by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other post-treatment health-protection measures), for restricted irrigation it is achieved by a 2–3 log unit pathogen reduction (Tassoula 2011). Agrafioti and Diamadopoulos (2012) showed water recycling could reserve 19.16 Mm^3 of fresh water, which corresponded to 4.3 % of total irrigation requirements in Greece. Molle et al. (2012) concluded that an economic approach along with risk assessment would avoid disproportionate costs of grain security. Integration of both farmer and scientific knowledge would strengthen long-term predictions of practical and realistic situations, demonstrating the added value participatory modelling provides in Australia (van Opstal et al. 2012). It is strongly believed that it is more important to evaluate all the necessary parameters regarding the wastewater reuse under the model used in Greece than making decisions based mainly on measurable criteria, such as the economic ones (Bakopoulou et al. 2012). Planned reuse that seeks to maintain the benefits and minimise risks will require an integrated approach. The key to the success of endeavors to make the transition to planned strategic reuse programmers is a coherent legal and institutional framework with formal mechanisms to coordinate the actions of multiple government authorities, sound application of the ‘polluter pays’ principle, conversion of farmers towards more appropriate practices for wastewater use, public awareness campaigns to establish social acceptability for reuse, and consistent government and civil society commitment over the long term with the realisation that there are no immediate solutions (Scott et al. 2004). Institutions and organisations at the level of village or neighborhood shape the ways in which wastewater is managed through members active in these organisations (Buechler 2004).

18.3 Summation and Conclusions

Studies show that using wastewater for irrigation is considerable from various aspects and we cannot adopt an optimum decision without a comprehensive review. Figure 18.8 shows a brief about various aspects of wastewater irrigation in the different regions. Most studies have been done in Mediterranean countries (44 %) and one can see considerable wastewater treated (Cyprus, Greece, Italy, Slovenia, Tunisia, Croatia, Egypt, Algeria, and Libya) and wastewater used (Israel, Syria, Turkey, Libya, Jordan, Malta, Morocco, Palestine, and Lebanon) in this region according to Figs. 18.5 and 18.7, respectively. Moreover, Fig. 18.6b–d shows that there is no population affected in this region (or the population affected is very low). The maximum percentage of the Mediterranean countries is because they are most in the number of water-stressed countries (Near East, Northern Africa, and Mediterranean Europe) (Fig. 18.1). The second place has been allocated to Asia (24 %) and one can see a considerable wastewater treated (Bahrain, Mongolia, China, Jordan, India, and Thailand) as well as both considerable wastewater used (Iran, Qatar, UAE, Oman, Kuwait, Turkmenistan, Saudi Arabia, China, Kazakhstan, and Bahrain) and minor wastewater used (Viet Nam, Uzbekistan, Yemen, Singapore, Korea, and Japan), as shown in Figs. 18.5 and 18.7, respectively. Therefore, the status of study, treatment, and use of wastewater for irrigation is highlighted in the Persian Gulf due to water crisis conditions (Figs. 18.1 and 18.2). Meanwhile, Fig. 18.6b–d shows 13 countries with population affected (Malaysia, Cambodia, India, Sri Lanka, Thailand, Uzbekistan, Armenia, Kazakhstan, Philippines, Indonesia, Kyrgyzstan, Turkmenistan, and Viet Nam) in Asia that no suitable research has been done there (Fig. 18.8). The third place belongs to Americas (19 %) and one can see considerable wastewater treated (Chile, Mexico, Peru, and Dominican Republic) versus poor wastewater used (Dominican, Nicaragua, Mexico, Guatemala, U.S.A., Brazil, Bolivia, Chile, and Peru), as shown in Figs. 18.5 and 18.7, respectively. Meanwhile, Fig. 18.6b, c shows eight countries with population affected (Colombia, Cuba, El Salvador, Guatemala, Nicaragua, Peru, Venezuela, and Ecuador) in Americas that no suitable research study has been done there (Fig. 18.8).

In Europe, Africa, and Oceania (10 % of studies), one can see considerable wastewater treated (Luxemburg, the U.K., Germany, France, Ireland, Austria, Netherlands, Belgium, Zimbabwe) versus poor wastewater treated (Bosnia and Herzegovina, Somalia, Ethiopia, Botswana, Congo, and Mozambique) and poor wastewater used (Australia, France, the U.K., Senegal, Latvia, Lithuania, South Africa, the Netherlands, and Seychelles). Meanwhile, Fig. 18.6b–d shows that one can see five countries with populations affected (Cote d'lvoire, Burkina Faso, Congo, Swaziland, and Mauritania) in Africa where no suitable research has been done (Fig. 18.8). Although a study of wastewater irrigation from crops, soil, groundwater, health, irrigation equipments, modern technologies, and other environmental aspects is useful, increased investigation (management studies) in comparison with other aspects can help lead to more reliable and more extensive findings and finally a better decision on using wastewater for irrigation. The cases mentioned emphasise

Fig. 18.8 Various aspects of wastewater irrigation in the different regions

the need for proper recognition of challenges and prospects of wastewater irrigation to design a brighter future for more attention to this issue. In the following, a list of major challenges and prospects is presented.

18.3.1 Challenges Under Normal Conditions

The type of irrigation method selected will depend on water supply conditions, climate, soil, crops to be grown, cost of irrigation method and the ability of the farmer to manage the system. However, when using wastewater as the source of irrigation other factors, such as contamination of plants and harvested product, farm workers, and the environment, and salinity and toxicity hazards, will need to be considered. There is considerable scope for reducing the undesirable effects of wastewater use in irrigation through selection of appropriate irrigation methods (FAO 1992). Toxicity symptoms can appear in almost any crop if concentrations of toxic materials are sufficiently high. Toxicity often accompanies or complicates salinity or infiltration, although it may appear even when salinity is not a problem (FAO 1992).

Comprehensive management approaches in the longer term will need to encompass treatment, regulation, farmer user groups, forward market linkages that ensure food and consumer safety, and effective public awareness campaigns (Scott et al. 2004). Clear policy guidelines on how to optimise the benefits and minimise the risks of untreated wastewater are lacking (van der Hoek 2004). Current government policies focus on the regulation of wastewater use and wastewater treatment and are unable to offer practical solutions to the user (van der Hoek 2004). For a complete understanding of issues related to wastewater use at a basin level, the macro-, meso- and micro-levels need to be studied from a multi-disciplinary perspective addressing socio-economic, health and technical issues (Buechler 2004). It is important to recognise that in many situations where wastewater is used in agriculture, the effective treatment of such wastewater may not be available for many years (Carr et al. 2004).

The annual risk of contracting infectious diseases, including typhoid fever, rotavirus infection, cholera and hepatitis from eating raw vegetables irrigated with untreated wastewater, is in the range of 5–15 % of consumers eating such vegetables who will develop disease compared to 0.0001 % of those eating vegetables irrigated with wastewater treated effluent that meets the WHO guideline of 1000 faecal coliforms (FC)/100 mL (Fattal et al. 2004). A standard leading to "no measurable excess risk" to health is an unattainable and unhelpful medium term goal under the conditions of indirect wastewater use seen in many cities (Cornish and Kielen 2004). Despite strong government support, treated wastewater use in irrigation has faced several constraints, chief among them being problems of social acceptance, agronomic considerations and sanitation, and restrictive regulations that have tended to limit its full potential for development (Shetty 2004).

The farmers at most locations realised the contribution of wastewater to fertiliser and its availability year round at low/no cost, and hence they irrigated field crops with this water. Farmers faced the problems of odd smell, skin infection, injury to hands and legs, and damage to water lifting pumps in some areas (Mojid et al. 2010). The farmers' perceptions do not necessarily reflect the quality of water delivered to the farm. The farmers' actual and perceived capacity to control water quality, and the farmers' ability to manage the negative aspects of the wastewater that jeopardise productive agriculture are important (Carr et al. 2011).

Comprehensive wastewater collection and large treatment facilities will not be financially viable in many developing countries for many years. Therefore, it makes sense to examine the inevitable trade-offs involving the cost and potential risk reduction effects of non-treatment options and strategies that involve multiple barriers (Wichelns and Drechsel 2011). Nutrient management, choice of crops, soil properties, irrigation methods, health risk regulation, land and water rights and public education are limitations to the use of wastewater irrigation (Hanjra et al. 2012; Hussain et al. 2001, 2002).

In many developing countries, wastewater treatment is limited, as investments in treatment facilities have not kept pace with persistent increase in population and the consequent increase in wastewater volume. Thus, much of the wastewater generated is not treated, and much of the untreated wastewater is used for irrigation by small-scale farmers with little ability to optimise the volume or quality of the wastewater they receive (Sato et al. 2013).

The totality of four main parameters considered important for the quality of irrigation water, i.e. salinity, pathogens, nutrients, heavy metals, are rarely taken into account simultaneously in the evaluation of reclamation technologies. In the majority of literature, the suitability of treated municipal wastewaters for irrigation purposes is mainly based on salinity and pathogen removal (Norton-Brandao et al. 2013). A few studies, making a complete evaluation of the suitability of produced effluent for irrigation, i.e., taking all four main parameters into account, include constructed wetlands and integrated systems, which include successive treatment steps using MBR, gravel filter, granulated ferric hydroxide adsorber for heavy metals and UV (Norton-Brandao et al. 2013).

18.3.2 Prospects

Success in using wastewater treated for crop production will largely depend on adopting appropriate strategies aimed at optimising crop yields and quality, maintaining soil productivity and safeguarding the environment (FAO 1992). In terms of health hazards, treated effluent with a high microbiological quality is necessary for irrigation of certain crops, especially vegetable crops eaten raw, but a lower quality is acceptable for other selected crops, where there is no exposure to the public (FAO 1992).

Developing realistic guidelines for using wastewater in agriculture involves the establishment of appropriate health-based targets prior to defining appropriate risk-management strategies. Establishing appropriate health-based targets primarily involves an assessment of risks associated with wastewater use in agriculture, using evidence from available studies of epidemiological and microbiological risks, and risk-assessment studies. Consideration of what is an acceptable or tolerable risk is then necessary; this may involve the use of internationally derived estimates of tolerable risk, but these need to be put into the context of actual disease rates in a population related to all the exposures that lead to that disease, including other water- and sanitation-related exposures together with food-related exposure. Positive health impacts resulting from increased food security, improved nutrition, and additional household income should also be considered. Individual countries may therefore set different health targets, based on their own contexts (Carr et al. 2004).

Informed debate, that enables risks associated with different water qualities and irrigation practice to be assessed, may lead to the development of local water quality norms and wastewater management that accounts for the physical and social environments in which wastewater irrigation is actually practiced (Cornish and Kielen 2004). Proper form of wastewater irrigation not only offers an important financial gain to the growers, it may also represent a low-cost and beneficial means of using and "treating" wastewater within acceptable and controllable levels of disease risk (Cornish and Kielen 2004). An integrated water management (IWM) approach is surely needed to improve the present situation in some of urban and peri-urban areas (Huibers et al. 2004).

With appropriate regulations and wastewater treatment technology a win–win approach to safely reuse wastewater in agriculture at an affordable cost may be possible (Jimenez 2005). Increased funding for wastewater treatment and the education of stakeholders can help water scarce countries use wastewater for irrigation (Qadir et al. 2007). The gaps in knowledge of the true extent of the often informal use of wastewater at a country level must be addressed by governments through comprehensive assessments, which will allow them to evaluate trade-offs and decide on the hot spots that need immediate attention (Raschid-Sally and Jayakody 2008).

The WHO (2006) guidelines for the safe use of wastewater should be extensively applied, as they allow for incremental and adaptive risk reduction in contrast to strict water quality thresholds. This is a cost-effective and realistic approach for reducing health and environmental risks in low income countries (Raschid-Sally and Jayakody 2008).

To improve the safety of irrigation water sources used for agriculture and enhance the direct use of wastewater, it is imperative to separate domestic and industrial discharges in cities, and improve the sewage and septage disposal methods by moving away from ineffective conventional systems (Raschid-Sally and Jayakody 2008).

In addressing health risks, on the one hand, state authorities have a role to play in planning, financing and maintaining sanitation and waste disposal infrastructure that is commensurate with their capacities and responds to agricultural reuse requirements. On the other hand, as a comprehensive treatment will remain unlikely in the near future, outsourcing water quality improvements and health risk reduction to the user level and supporting such initiatives through farm tenure security, economic incentives like easy access to credit for safer farming, and social marketing for improving farmer knowledge and responsibility can lead to reducing public health risks more effectively, while maintaining the benefits of urban and peri-urban agriculture (Raschid-Sally and Jayakody 2008).

Countries must address the need to develop policies and locally viable practices for safer wastewater use to maintain its benefits for food supply and livelihoods while reducing health and environmental risks (Raschid-Sally and Jayakody 2008). Multi-criteria decision analysis with weighted goal programming can develop flexible management options that consider a given decision-maker preference in water scarce countries (Al-Juaidi et al. 2010). A combination of biophysical science, social, economic and policy analysis, and good politics and governance are required in order to reduce the impacts of wastewater-related health risks in the most effective way and to obtain win–win solutions from the sanitation, water and food crises triangle (Scott et al. 2010).

The likelihood of truly enhancing the livelihoods of households involved in agriculture, while reducing risks of producing and consuming crops irrigated with wastewater, can be increased through participatory and comprehensive discussions of scientific, economic and policy issues that comprise this important and timely topic in developing countries (Wichelns et al. 2011). Since traditional wastewater treatment methods are not capable of fully removing recalcitrant xenobiotic compounds, advanced technologies must be applied, such as Advanced Oxidation Processes (AOPs) and membrane-separation technologies, which are effective in simultaneously removing, both pathogens and xenobiotics, and perhaps their combined application may constitute today the best option for wastewater treatment and reuse schemes. Applications of AOPs and disinfection methods to recalcitrant pollutants have in anyway expanded in recent years. It is true to say though that the oxidation of the parent compounds (pharmaceuticals and other organic xenobiotics) provides only a partial indication of the efficiency of various treatment methods, since the possible generation of intermediates, more resistant to degradation, and with the characteristics of exhibiting equal or more toxic effects than the parent compounds must be considered as well (Fatta-Kassinos et al. 2011).

Currently there are a number of knowledge gaps related to the potential effects that the wastewater reuse practices might induce. These are related both with the identification of the compounds present in the treated effluent organic matter, which is also related to the gaps of knowledge in regards to degradation mechanisms and transformation products. Moreover, the puzzle in regards to risks that relate to non-target organisms in the environment, to plant and crops uptake and finally the fate and behaviour of various compounds in mixtures is only now starting to shape. Furthermore, knowledge is greatly lacking on the possibilities of pharmaceutical residues reaching humans through biomagnification in the food chain. Risk assessment protocols for antibiotics and resistant bacteria in water systems, based on better systems for antibiotics detection and antibiotic resistance microbial source tracking are also starting to be discussed (Fatta-Kassinos et al. 2011).

In developing countries, wastewater is the only water source available for irrigation throughout the year, wastewater irrigation reduces the need for purchasing fertiliser, involves less energy cost, if the alternative clean water source is deep groundwater, and enables farmers in peri-urban areas to produce high-value vegetables for sale in local markets (Sato et al. 2013).

Irrigation with treated wastewater likely will expand in developed countries, particularly in arid and semi-arid areas, where competition for freshwater supplies will continue to increase. Technical solutions and public policies generally are adequate in developed countries to accommodate increases in the treatment and use of wastewater (Sato et al. 2013).

It is likely that the demand for wastewater as a source of irrigation will increase in arid and semi-arid areas of developing countries at a faster pace than the development of technical solutions and institutions that might ensure the safe distribution and management of wastewater. Thus, the key technical and policy questions in developing countries include those pertaining to better methods for handling untreated wastewater on farms and in farm communities, better recommendations regarding crops and cultural practices most suitable for settings in which wastewater is the primary source of irrigation, and better methods for protecting farm workers and consumers from the potentially harmful pathogens and chemicals in wastewater (Sato et al. 2013). Finally, water crisis and wastewater problem are man-made problems and they must solved by man himself.

References

Abd El Lateef EM, Hall JE, Lawrence PC, Negm MS (2006) Cairo-East Bank effluent re-use study 3 – effect of field crop irrigation with secondary treated wastewater on biological and chemical properties of soil and groundwater. Biologia 61(19):S240–S245

Adin A, Sacks M (1991) Dripper-clogging factors in wastewater irrigation. J Irrig Drain Eng 117(6):813–826

Adrover M, Farrus E, Moya G, Vadell J (2012) Chemical properties and biological activity in soils of Mallorca following twenty years of treated wastewater irrigation. J Environ Manage 95:S188–S192

Afshar A, Marino M (1989) Optimization models for wastewater reuse in irrigation. J Irrig Drain Eng 115(2):185–202

Agrafioti E, Diamadopoulos E (2012) A strategic plan for reuse of treated municipal wastewater for crop irrigation on the Island of Crete. Agric Water Manag 105:57–64

Agunwamba JC (2001) Analysis of socioeconomic and environmental impacts of waste stabilization pond and unrestricted wastewater irrigation: interface with maintenance. Environ Manage 27(3):463–476

Aiello R, Cirelli GL, Consoli S (2007) Effects of reclaimed wastewater irrigation on soil and tomato fruits: a case study in Sicily (Italy). Agric Water Manag 93(1–2):65–72

Akber A, Mukhopadhyay A, Al-Senafy M, Al-Haddad A, Al-Awadi E, Al-Qallaf H (2008) Feasibility of long-term irrigation as a treatment method for municipal wastewater using natural soil in Kuwait. Agric Water Manag 95(3):233–242

Al-Hamaiedeh H, Bino M (2010) Effect of treated grey water reuse in irrigation on soil and plants. Desalination 256(1–3):115–119

Ali-Shtayeh MS, Jamous RMF, Abu-Ghdeib SI (1998) Ecology of cycloheximide-resistant fungi in field soils receiving raw city wastewater or normal irrigation water. Mycopathologia 144(1):39–55

Al-Juaidi AE, Kaluarachchi JJ, Kim U (2010) Multi-criteria decision analysis of treated wastewater use for agriculture in water deficit regions. JAWRA J Am Water Resour Assoc 46:395–411

Al-Lahham O, El Assi NM, Fayyad M (2003) Impact of treated wastewater irrigation on quality attributes and contamination of tomato fruit. Agric Water Manag 61(6):51–62

Al-Nakshabandi GA, Saqqar MM, Shatanawi MR, Fayyad M, Al-Horani H (1997) Some environmental problems associated with the use of treated wastewater for irrigation in Jordan. Agric Water Manag 34(1):81–94

Al-Shammiri M, Al-Saffar A, Bohamad S, Ahmed M (2005) Waste water quality and reuse in irrigation in Kuwait using microfiltration technology in treatment. Desalination 185(1–3):213–225

An Y-J, Yoon CG, Jung K-W, Ham J-H (2007) Estimating the microbial risk of *E. coli* in reclaimed wastewater irrigation on paddy field. Environ Monit Assess 129(1–3):53–60

Angelakis AN, Durham B (2008) Water recycling and reuse in EUREAU countries: trends and challenges. Desalination 218(1–3):3–12

Angelakis AN, Marecos Do Monte MHF, Bontoux L, Asano T (1999) The status of wastewater reuse practice in the Mediterranean basin: need for guidelines. Water Res 33(10):2201–2217

Axelrad G, Feinerman E (2009) Regional planning of wastewater reuse for irrigation and river rehabilitation. J Agric Econ 60:105–131

Baghapour MA, Nasseri S, Djahed B (2013) Evaluation of Shiraz wastewater treatment plant effluent quality for agricultural irrigation by Canadian Water Quality Index (CWQI). J Environ Sci Health 10:27

Bakopoulou S, Vasiloglou V, Kungolos A (2012) A multicriteria analysis application for evaluating the possibility of reusing wastewater for irrigation purposes in a Greek region, Desalin. Water Treat 39(1–3):262–270

Banon S, Miralles J, Ochoa J, Franco JA, Sanchez-Blanco MJ (2011) Effects of diluted and undiluted treated wastewater on the growth, physiological aspects and visual quality of potted lantana and polygala plants. Sci Hortic 129(4):869–876

Battilani A, Steiner M, Andersen M, Back SN, Lorenzen J, Schweitzer A, Dalsgaard A, Forslund A, Gola S, Klopmann W, Plauborg F, Andersen MN (2010) Decentralised water and wastewater treatment technologies to produce functional water for irrigation. Agric Water Manag 98(3):385–402

Bdour AN, Hamdi MR, Tarawneh Z (2009) Perspectives on sustainable wastewater treatment technologies and reuse options in the urban areas of the Mediterranean region. Desalination 237(1–3):162–174

Bedbabis S, Ferrara G, Ben Rouina B, Boukhris M (2010a) Effects of irrigation with treated wastewater on olive tree growth, yield and leaf mineral elements at short term. Sci Hortic 126(3):345–350

Bedbabis S, Ferrara G, Ben Rouina B, Boukhris M (2010b) The effect of waste water irrigation on the extra virgin olive oil quality from the Tunisian cultivar Chemlali. Sci Hortic 125(4):556–561

Bhamoriya V (2004) Wastewater irrigation in Vadodara. Economic Catalyst for Marginalised Communities, Gujarat

Bichai F, Polo-Lopez MI, Ibanez PF (2013) Solar disinfection of wastewater to reduce contamination of lettuce crops by Escherichia coli in reclaimed water irrigation. Water Res 46(18):6040–6050

Bixio D, Thoeye C, De Koning J, Joksimovic D, Savic D, Wintgens T, Melin T (2006) Wastewater reuse in Europe. Desalination 187(1–3):89–101

Bouri S, Abida H, Khanfir H (2008) Impacts of wastewater irrigation in arid and semi arid regions: case of Sidi Abid region. Tunis Environ Geol 53(7):1421–1432

Buechler SJ (2004) A sustainable livelihoods approach for action research on wastewater use in agriculture, International Water Management Institute (IWMI), India.

Candela L, Fabregat S, Josa A, Suriol J, Vigues N, Mas J (2007) Assessment of soil and groundwater impacts by treated urban wastewater reuse. A case study: application in a golf course (Girona, Spain). Sci Total Environ 374(1):26–35

Capra A, Scicolone B (2007) Recycling of poor quality urban wastewater by drip irrigation systems. J Clean Prod 15(16):1529–1534

Carr RM, Blumenthal UJ, Mara DD (2004) Health guidelines for use of wastewater in agriculture: developing realistic guidelines, International Water Management Institute (IWMI), India.

Carr G, Potter RB, Nortcliff S (2011) Water reuse for irrigation in Jordan: perceptions of water quality among farmers. Agric Water Manag 98(5):847–854

Chavez A, Rodas K, Prado B, Thompson R, Jimenez B (2012) An evaluation of the effects of changing wastewater irrigation regime for the production of alfalfa (Medicago sativa). Agric Water Manag 113:76–84

Chen J, Tang C, Yu J (2006) Use of ^{18}O, ^{2}H and ^{15}N to identify nitrate contamination of groundwater in a wastewater irrigated field near the city of Shijiazhuang, China. J Hydrol 326(1–4):367–378

Chiou R-J (2008) Risk assessment and loading capacity of reclaimed wastewater to be reused for agricultural irrigation. Environ Monit Assess 142(1–3):255–262

Chung NJ, Cho JY, Park SW, Park BJ, Hwang SA, Park TI (2008) Polycyclic aromatic hydrocarbons in soils and crops after irrigation of wastewater discharged from domestic sewage treatment plants. Bull Environ Contam Toxicol 81(2):124–127

Chung BY, Song CH, Park BJ, Cho JY (2011) Heavy metals in brown rice (Oryza sativa L.) and soil after long-term irrigation of wastewater discharged from domestic sewage treatment plants. Pedosphere 21(5):621–627

Cirelli GL, Consoli S, Licciardello F, Aiello R, Giuffrida F, Leonardi C (2012) Treated municipal wastewater reuse in vegetable production. Agric Water Manag 104:163–170

Coppola A, Santini A, Botti P, Vacca S, Comegna V, Severino G (2004) Methodological approach for evaluating the response of soil hydrological behavior to irrigation with treated municipal wastewater. J Hydrol 292(1–4):114–134

Cornish GA, Kielen NC (2004) Wastewater irrigation – hazard or lifeline? Empirical Results from Nairobi, Kenya and Kumasi, Ghana

de Oliveira Marinho LE, Tonetti AL, Stefanutti R, Filho BC (2013) Application of reclaimed wastewater in the irrigation of rosebushes. Water Air Soil Pollut 224:1669

de Paula AM, da Fonseca AF, Cardoso EJBN, Melfi AJ (2010) Microbial metabolic potential affected by surplus wastewater irrigation in tropical soil cultivated with Tifton 85 Bermuda grass (Cynodon dactylon Pers. X C. niemfuensis Vanderyst). Water Air Soil Pollut 205(1–4):161–171

Doll P, Hoffmann-Dobrev H, Portmann FT, Siebert S, Eicker A, Rodell M, Strassberg G, Scanlon BR (2012) Impact of water withdrawals from groundwater and surface water on continental water storage variations. J Geodyn 59–60:143–156

Dominguez F (2010) Water scarcity: can virtual water operators help? Util Policy 18(3):129–134

Egwu GN, Agbenin JO (2013) Lead enrichment, adsorption and speciation in urban garden soils under long-term wastewater irrigation in northern Nigeria. Environ Earth Sci 69(6):1861–1870

El-Gohary FA, Nasr FA, El-Hawaary S (1998) Performance assessment of a wastewater treatment plant producing effluent for irrigation in Egypt. Environmentalist 18(2):87–93

Elifantz H, Kautsky L, Mor-Yosef M, Tarchitzky J, Bar-Tal A, Chen Y, Minz D (2011) Microbial activity and organic matter dynamics during 4 years of irrigation with treated wastewater. Microb Ecol 62(4):973–981

Ensink JHJ, van der Hoek W, Amerasinghe FP (2006) Giardia duodenalis infection and wastewater irrigation in Pakistan. Trans R Soc Trop Med Hyg 100(6):538–542

Esteller M, Morell I, Almeida C (2001) Physico-chemical processes in a vadose zone during the infiltration of treated wastewater used for irrigation: application of the NETPATH model. Environ Geol 40(7):923–930

Evcimen S, Kerc A (2011) Application of UV disinfection in municipal wastewater treatment plants for agricultural use of reclaimed wastewater in Turkey. Desalin Water Treat 26(1–3):39–44

Evett SR, Zalesny RS Jr, Kandil NF, Stanturf JA, Soriano C (2011) Opportunities for woody crop production using treated wastewater in Egypt. II. Irrigation strategies. Int J Phytoremediat 13(Supp1):122–139

FAO (1992) Wastewater treatment and use in agriculture – FAO irrigation and drainage paper 47. Food and Agriculture Organization of the United Nations. Italy. ISBN 92-5-103135-5

FAO (2013) AQUASTAT database. http://fao.org

Fatta D, Salem Z, Mountadar M, Assobhei O, Loizidou M (2004) Urban wastewater treatment and reclamation for agricultural irrigation: the situation in Morocco and Palestine. Environmentalist 24(4):227–236

Fatta-Kassinos D, Kalavrouziotis IK, Koukoulakis PH, Vasquez MI (2011) The risks associated with wastewater reuse and xenobiotics in the agroecological environment. Sci Total Environ 409(19):3555–3563

Fattal B, Lampert Y, Shuval H (2004) A fresh look at microbial guidelines for wastewater irrigation in agriculture: a risk-assessment and cost-effectiveness approach, International Water Management Institute (IWMI), India.

Fischer G, Tubiello FN, van Velthuizen H, Wiberg DA (2007) Climate change impacts on irrigation water requirements: effects of mitigation, 1990–2080. Technol Forecast Soc Chang 74(7):1083–1107

Forslund A, Ensink JHJ, Battilani A, Kljujev I, Gola S, Raicevic V, Jovanovic Z, Stikic R, Sandei L, Fletcher T, Dalsgaard A (2010) Faecal contamination and hygiene aspect associated with the use of treated wastewater and canal water for irrigation of potatoes (Solanum tuberosum). Agric Water Manag 98(3):440–450

Gamri S, Soric A, Tomas S, Molle B, Roche N (2013) Biofilm development in micro-irrigation emitters for wastewater reuse. Irrig Sci. doi:10.1007/s00271-013-0414-0

Gatica J, Cytryn E (2013) Impact of treated wastewater irrigation on antibiotic resistance in the soil microbiome. Environ Sci Pollut Res 20:3529–3538

Green TR, Taniguchi M, Kooi H, Gurdak JJ, Allen DM, Hiscock KM, Treidel H, Aureli A (2011) Beneath the surface of global change: impacts of climate change on groundwater. J Hydrol 405(3–4):532–560

Gupta S, Satpati S, Nayek S, Garai D (2010) Effect of wastewater irrigation on vegetables in relation to bioaccumulation of heavy metals and biochemical changes. Environ Monit Assess 165(1–4):169–177

Hanjra MA, Blackwell J, Carr G, Zhang F, Jackson TM (2012) Wastewater irrigation and environmental health: implications for water governance and public policy. Int J Hyg Environ Health 215(3):255–269

Haruvy N, Offer R, Hadas A, Ravina I (1999) Wastewater irrigation-economic concerns regarding beneficiary and hazardous effects of nutrients. Water Resour Manag 13(5):303–314

Heidarian Z, Hafezi Moghadas N, Nedaie S (2011) Effect of Alghadie dam on quantity groundwater resources of Saveh plain. In: The 7th Iranian conference of engineering geology and the environment. Shahroud, Iran

Heidarpour M, Mostafazadeh-Fard B, Abedi Koupai J, Malekian R (2007) The effects of treated wastewater on soil chemical properties using subsurface and surface irrigation methods. Agric Water Manag 90(1–2):87–94

Hirich A, Choukr-Allah R, Jacobsen S-E (2013) The combined effect of deficit irrigation by treated wastewater and organic amendment on quinoa (Chenopodium quinoa Willd.) productivity. Desalin Water Treat. doi:10.1080/19443994.2013.777944

Hogg TJ, Tollefson LC, Weiterman G (1997) Effluent irrigation: the Saskatchewan perspective. Can Water Resour J 22(4):445–455

Howe J, Wagner MR (1996) The effect of papermill wastewater irrigation and gypsum soil amendments on sodium accumulation by cottonwood and soil. Agric Water Manag 31(3):295–306

Hseu Z-Y, Su S-W, Lai H-Y, Guo H-Y, Chen T-C, Chen Z-S (2010) Remediation techniques and heavy metal uptake by different rice varieties in metal-contaminated soils of Taiwan: new aspects for food safety regulation and sustainable agriculture. Soil Sci Plant Nutr 56(1):31–52

Huibers FP, Moscoso O, Duran A, van Lier JB (2004) The use of wastewater in Cochabamba. A Degrading Environment, Bolivia

Hunt PG, Stone KC, Matheny TA, Vanotti MB, Szogi AA, Busscher WJ (2011) Double-cropped soybean and wheat with subsurface drip irrigation supplemented by treated swine wastewater. Commun Soil Sci Plant 42(22):2778–2794

Hussain G, Al-Saati AJ (1999) Wastewater quality and its reuse in agriculture in Saudi Arabia. Desalination 123(2–3):241–251

Hussain I, Raschid L, Hanjra MA, Marikar F, Hoek W (2001) A framework for analysing socio-economic, health and environmental impacts of wastewater use in agriculture in developing countries. IWMI Working Paper, (26). International Water Management Institute. http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR26.pdf

Hussain I, Raschid-Sally L, Hanjra MA, Marikar F, Van Der Hoek W (2002) Wastewater use in agriculture: review of impacts and methodological issues in valuing impacts. International Water Management Institute, Colombo, IWMI Working Paper, no. 37. http://hdl.handle.net/10535/4846

Irenikatche Akponikpe PB, Wima K, Yacouba H, Mermoud A (2011) Reuse of domestic wastewater treated in macrophyte ponds to irrigate tomato and eggplant in semi-arid West-Africa: benefits and risks. Agric Water Manag 98(5):834–840

Jaber JO, Mohsen MS (2001) Evaluation of non-conventional water resources supply in Jordan. Desalination 136(1–3):83–92

Jalali M, Merikhpour H, Kaledhonkar MJ, Van Der Zee SEATM (2008) Effects of wastewater irrigation on soil sodicity and nutrient leaching in calcareous soils. Agric Water Manag 95(2):143–153

Jang T, Jung M, Lee E, Park S, Lee J, Jeong H (2013) Assessing environmental impacts of reclaimed wastewater irrigation in paddy fields using bioindicator. Irrig Sci 31(5):1225–1236

Jeison D, Chamy R, Salgado E (2003) Anaerobically treated wastewater in agricultural irrigation as an alternative for posttreatment in water-demanding zones. Appl Biochem Biotechnol 109(1–3):197–206

Jia Z, Evans R, Smith J (2006) Effect of controlled drainage and vegetative buffers on drainage water quality from wastewater irrigated fields. J Irrig Drain Eng 132(2):159–170

Jimenez B (2005) Treatment technology and standards for agricultural wastewater reuse: a case study in Mexico. Irrig Drain 54:S23–S33

Kass A, Gavrieli I, Yechieli Y, Vengosh A, Starinsky A (2005) The impact of freshwater and wastewater irrigation on the chemistry of shallow groundwater: a case study from the Israeli Coastal Aquifer. J Hydrol 300(1–4):314–331

Katzenelson E, Buium I, Shuval HI (1976) Risk of communicable disease infection associated with wastewater irrigation in agricultural settlements. Science 194(4268):944–946

Kayikcioglu HH (2012) Short-term effects of irrigation with treated domestic wastewater on microbiological activity of a Vertic xerofluvent soil under Mediterranean conditions. J Environ Manage 102:108–114

Keraita B, Konradsen F, Drechsel P, Abaidoo RC (2007a) Effect of low-cost irrigation methods on microbial contamination of lettuce irrigated with untreated wastewater. Trop Med Int Health 12:15–22

Keraita B, Konradsen F, Drechsel P, Abaidoo RC (2007b) Reducing microbial contamination on wastewater-irrigated lettuce by cessation of irrigation before harvesting. Trop Med Int Health 12:8–14

Keser G (2013) Effects of irrigation with wastewater on the physiological properties and heavy metal content in Lepidium sativum L. and Eruca sativa (Mill.). Environ Monit Assess 185(7):6209–6217

Keser G, Buyuk G (2012) Effects of wastewater irrigation on chemical and physical properties of Petroselinum crispum. Biol Trace Elem Res 146(3):369–375

Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG (2008) Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing. China Environ Pollut 152(3):686–692

Khan MU, Malik RN, Muhammad S (2013) Human health risk from heavy metal via food crops consumption with wastewater irrigation practices in Pakistan. Chemosphere. doi:10.1016/j.chemosphere.2013.07.067

Kivaisi AK (2001) The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review. Ecol Eng 16(4):545–560

Kiziloglu FM, Turan M, Sahin U, Angin I, Anapali O, Okuroglu M (2007) Effects of wastewater irrigation on soil and cabbage-plant (*brassica olerecea* var. capitate cv. yalova-1) chemical properties. Z Pflanzenernaehr Bodenkd 170:166–172

Kiziloglu FM, Turan M, Sahin U, Kuslu Y, Dursun A (2008) Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (Brassica olerecea L. var. botrytis) and red cabbage (Brassica olerecea L. var. rubra) grown on calcareous soil in Turkey. Agric Water Manag 95(6):716–724

Klay S, Charef A, Ayed L, Houman B, Rezgui F (2010) Effect of irrigation with treated wastewater on geochemical properties (saltiness, C, N and heavy metals) of isohumic soils (Zaouit Sousse perimeter, Oriental Tunisia). Desalination 253(1–3):180–187

Lado M, Ben-Hur M (2009) Treated domestic sewage irrigation effects on soil hydraulic properties in arid and semiarid zones: a review. Soil Tillage Res 106(1):152–163

Laposata MM, Dunson WA (2000) Effects of treated wastewater effluent irrigation on terrestrial salamanders. Water Air Soil Pollut 119(1–4):45–57

Laurenson S, Bolan NS, Smith E, McCarthy M (2012) Review: use of recycled wastewater for irrigating grapevines. Aust J Grape Wine R 18:1–10

Li F, Wichmann K, Otterpohl R (2009) Review of the technological approaches for grey water treatment and reuses. Sci Total Environ 407(11):3439–3449

Li YK, Liu YZ, Li GB, Xu TW, Liu HS, Ren SM, Yan DZ, Yang PL (2012) Surface topographic characteristics of suspended particulates in reclaimed wastewater and effects on clogging in labyrinth drip irrigation emitters. Irrig Sci 30(1):43–56

Liberti L, Notarnicola M, Petruzzelli D (2002) Advanced treatment for municipal wastewater reuse in agriculture. UV disinfection: parasite removal and by-product formation. Desalination 152(1–3):315–324

Liu H, Huang G (2009) Laboratory experiment on drip emitter clogging with fresh water and treated sewage effluent. Agric Water Manag 96(5):745–756

Lopez A, Vurro M (2008) Planning agricultural wastewater reuse in southern Italy: the case of Apulia region. Desalination 218(1–3):164–169

Lopez A, Pollice A, Lonigro A, Masi S, Palese AM, Cirelli GL, Toscano A, Passino R (2006) Agricultural wastewater reuse in southern Italy. Desalination 187(1–3):323–334

Loutfy N, Mosleh Y, Ahmed MT (2010) Dioxin, Dioxin–like PCBs and indicator PCBs in some medicinal plants irrigated with wastewater in Ismailia. Egypt Polycycl Aromat Compd 30(1):9–26

Lubello C, Gori R, Nicese FP, Ferrini F (2004) Municipal-treated wastewater reuse for plant nurseries irrigation. Water Res 38(12):2939–2947

Mahdizadeh Khasraghi M, Gholami Sefidkouhi MA, Valipour M (2015) Simulation of open- and closed-end border irrigation systems using SIRMOD. Arch Agron Soil Sci 61(7):929–941

Martijn E-J, Redwood M (2005) Wastewater irrigation in developing countries—limitations for farmers to adopt appropriate practices. Irrig Drain 54:S63–S70

McNeill LS, Almasri MN, Mizyed N (2009) A sustainable approach for reusing treated wastewater in agricultural irrigation in the West Bank – Palestine. Desalination 248(1–3):315–321

Mojid MA, Wyseure GCL (2013) Implications of municipal wastewater irrigation on soil health from a study in Bangladesh. Soil Use Manag 29:384–396

Mojid MA, Wyseure GCL, Biswas SK, Hossain ABMZ (2010) Farmers' perceptions and knowledge in using wastewater for irrigation at twelve peri-urban areas and two sugar mill areas in Bangladesh. Agric Water Manag 98(1):79–86

Mojid MA, Biswas SK, Wyseure GCL (2012) Interaction effects of irrigation by municipal wastewater and inorganic fertilisers on wheat cultivation in Bangladesh. Field Crop Res 134:200–207

Molle B, Brelle F, Bessy J, Gatel D (2012) Which water quality for which uses? Overcoming overzealous use of the precautionary principle to reclaim wastewater for appropriate irrigation uses. Irrig Drain 61:87–94

Mooers HD, Alexander EC Jr (1994) Contribution of spray irrigation of wastewater to groundwater contamination in the karst of southeastern Minnesota. USA Appl Hydrogeol 2(1):34–44

Moradmand M, Beigi Harchegani H (2011) Treated municipal wastewater irrigation effect on lead content and health risks of nickel in soil and pepper in Shahrekord. Iran Desalin Water Treat 28(1–3):42–45

Moraetis D, Stamati FE, Nikolaidis NP, Kalogerakis N (2011) Olive mill wastewater irrigation of maize: impacts on soil and groundwater. Agric Water Manag 7(15):1125–1132

Morari F, Giardini L (2009) Municipal wastewater treatment with vertical flow constructed wetlands for irrigation reuse. Ecol Eng 35(5):643–653

Morugan-Coronado A, Garcia-Orenes F, Mataix-Solera J, Arcenegui V, Mataix-Beneyto J (2011) Short-term effects of treated wastewater irrigation on Mediterranean calcareous soil. Soil Tillage Res 112(1):18–26

Murillo JM, Lopez R, Fernandez JE, Cabrera F (2000) Olive tree response to irrigation with wastewater from the table olive industry. Irrig Sci 19(4):175–180

Murray A, Ray I (2010) Wastewater for agriculture: a reuse-oriented planning model and its application in peri-urban China. Water Res 44(5):1667–1679

Mutengu S, Hoko Z, Makoni FS (2007) An assessment of the public health hazard potential of wastewater reuse for crop production. A case of Bulawayo city. Zimb Phys Chem Earth 32(15–18):1195–1203

Muyen Z, Moore GA, Wrigley RJ (2011) Soil salinity and sodicity effects of wastewater irrigation in South East Australia. Agric Water Manag 99(1):33–41

Nadav I, Tarchitzky J, Chen Y (2013) Induction of soil water repellency following irrigation with treated wastewater: effects of irrigation water quality and soil texture. Irrig Sci 31(3):385–394

Norton-Brandao D, Scherrenberg SM, van Lier JB (2013) Reclamation of used urban waters for irrigation purposes – a review of treatment technologies. J Environ Manage 122:85–98

Oron G, DeMalach Y (1987) Response of cotton to treated domestic wastewater applied through trickle irrigation. Irrig Sci 8(4):291–300

Owusu V, Andivi Bakang J-E, Abaidoo RC, Kinane ML (2012) Perception on untreated wastewater irrigation for vegetable production in Ghana. Environ Dev Sustain 14(1):135–150

Palese AM, Pasquale V, Celano G, Figliuolo G, Masi S, Xiloyannis C (2009) Irrigation of olive groves in Southern Italy with treated municipal wastewater: effects on microbiological quality of soil and fruits. Agr Ecosyst Environ 129(1–3):43–51

Pedrero F, Alarcon JJ (2009) Effects of treated wastewater irrigation on lemon trees. Desalination 246(1–3):631–639

Pedrero F, Kalavrouziotis I, Alarcon JJ, Koukoulakis P, Asano T (2010) Use of treated municipal wastewater in irrigated agriculture—review of some practices in Spain and Greece. Agric Water Manag 97(9):1233–1241

Pereira BFF, He ZL, Stoffella PJ, Melfi AJ (2011) Reclaimed wastewater: effects on citrus nutrition. Agric Water Manag 98(12):1828–1833

Puig-Bargues J, Arbat G, Elbana M, Duran-Ros M, Barragan J, de Cartagena FR, Lamm FR (2010) Effect of flushing frequency on emitter clogging in microirrigation with effluents. Agric Water Manag 97(6):883–891

Qadir M, Sharma BR, Bruggeman A, Choukr-Allah R, Karajeh F (2007) Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries. Agric Water Manag 87(1):2–22

Qadir M, Wichelns D, Raschid-Sally L, McCornick PG, Drechsel P, Bahri A, Minhas PS (2010) The challenges of wastewater irrigation in developing countries. Agric Water Manag 97(4):561–568

Qishlaqi A, Moore F (2006) Impacts of wastewater irrigation on soils and crops in suburban area of Shiraz, Iran. Chin J Geochem 25(1):214

Raschid-Sally L, Jayakody P (2008) Drivers and characteristics of wastewater agriculture in developing countries: results from a global assessment. International Water Management Institute, Colombo. 35p. (IWMI Research Report 127)

Rebhun M (2004) Desalination of reclaimed wastewater to prevent salinization of soils and groundwater. Desalination 160(2):143–149

Redondo JA, Lomax I (1997) Experiences with the pretreatment of raw water with high fouling potential for reverse osmosis plant using FILMTEC membranes. Desalination 110(1–2):167–182

Rezapour S, Samadi A (2011) Soil quality response to long-term wastewater irrigation in Inceptisols from a semi-arid environment. Nutr Cycl Agroecosyst 91(3):269–280

Rezapour S, Samadi A, Khodaverdiloo H (2011) An investigation of the soil property changes and heavy metal accumulation in relation to long-term wastewater irrigation in the semi-arid region of Iran. Soil Sediment Contam 20(7):841–856

Rezapour S, Samadi A, Khodaverdiloo H (2012) Impact of long-term wastewater irrigation on variability of soil attributes along a landscape in semi-arid region of Iran. Environ Earth Sci 67(6):1713–1723

Rijsberman FR (2006) Water scarcity: fact or fiction? Agric Water Manag 80(1–3):5–22

Ringler C, Rosegrant MW, Paisner, Michael S (2000) Irrigation and water resources in Latin America and the Caribbean: challenges and strategies. Environment and Production Technology Division. International Food Policy Research Institute, Washington, DC

Rojas-Valencia MN, Orta de Velasquez MT, Franco V (2011) Urban agriculture, using sustainable practices that involve the reuse of wastewater and solid waste. Agric Water Manag 98(9):1388–1394

Rosenqvist H, Dawson M (2005) Economics of using wastewater irrigation of willow in Northern Ireland. Biomass Bioenerg 29(2):83–92

Rosenqvist H, Aronsson P, Hasselgren K, Perttu K (1997) Economics of using municipal wastewater irrigation of willow coppice crops. Biomass Bioenerg 12(1):1–8

Rusan MJM, Hinnawi S, Rousan L (2007) Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. Desalination 215(1–3):143–152

Rutkowski T, Raschid-Sally L, Buechler S (2007) Wastewater irrigation in the developing world—two case studies from the Kathmandu Valley in Nepal. Agric Water Manag 88(1–3):83–91

Samia K, Abdelkarim C, Yassin H, Teruo H (2012) The effect of long-term soil irrigation by wastewater on organic matter, polycyclic aromatic hydrocarbons, and heavy metals evolution: case study of Zaouit Sousse (Tunisia). Arab J Geosci. doi:10.1007/s12517-012-0666-7

Sato T, Qadir M, Yamamoto S, Endo T, Zahoor A (2013) Global, regional, and country level need for data on wastewater generation, treatment, and use. Agric Water Manag 130:1–13

Sayed WF (2003) Effects of land irrigation with partially-treated wastewater on Frankia survival and infectivity. Plant Soil 254(1):19–25

Scheierling SM, Bartone CR, Mara DD, Drechsel P (2011) Towards an agenda for improving wastewater use in agriculture. Water Int 36(4):420–440

Scott CA, Faruqui NI, Raschid-Sally L (2004) Wastewater use in irrigated agriculture: management challenges in developing countries, International Water Management Institute (IWMI), India.

Scott CA, Drechsel P, Raschid-Sally L, Bahri A, Mara D, Redwood M, Jimenez B (2010) Wastewater irrigation and health: challenges and outlook for mitigating risks in low-income countries, International Water Management Institute (IWMI), India.

Segarra E, Darwish MR, Ethridge DE (1996) Returns to municipalities from integrating crop production with wastewater disposal. Resour Conserv Recycl 17(2):97–107

Shahalam A, Abu Zahra BM, Jaradat A (1998) Wastewater irrigation effect on soil, crop and environment: a pilot scale study at Irbid, Jordan. Water Air Soil Pollut 106(3–4):425–445

Shetty S (2004) Treated wastewater use in Tunisia: lessons learned and the road ahead, International Water Management Institute (IWMI), India.

Shi Y, Gao L, Li W, Liu J, Cai Y (2012) Investigation of fluoroquinolones, sulfonamides and macrolides in long-term wastewater irrigation soil in Tianjin. China B Environ Contam Toxicol 89(4):857–861

Siebert S, Burke J, Faures JM, Frenken K, Hoogeveen J, Doll P, Portmann FT (2010) Groundwater use for irrigation – a global inventory. Hydrol Earth Syst Sci 7:3977–4021

Singh PK, Deshbhratar PB, Ramteke DS (2012) Effects of sewage wastewater irrigation on soil properties, crop yield and environment. Agric Water Manag 103:100–104

Siracusa G, La Rosa AD (2006) Design of a constructed wetland for wastewater treatment in a Sicilian town and environmental evaluation using the energy analysis. Ecol Model 197(3–4):490–497

Stockholm Environment Institute (2005) Sustainable pathways to attain the millennium development goals – assessing the key role of water, energy and sanitation, Stockholm Environment Institute, Sweden.

Stumpe B, Marschner B (2007) Long-term sewage sludge application and wastewater irrigation on the mineralization and sorption of 17β-estradiol and testosterone in soils. Sci Total Environ 374(2–3):282–291

Tarchouna LG, Merdy P, Raynaud M, Pfeifer H-R, Lucas Y (2010) Effects of long-term irrigation with treated wastewater. Part I: Evolution of soil physico-chemical properties. Appl Geochem 25(11):1703–1710

Tassoula A (2011) An assessment of microbiological quality criteria for reuse of treated wastewater in agricultural irrigation. Desalin Water Treat 33(1–3):164–171

Toze S (2006) Reuse of effluent water—benefits and risks. Agric Water Manag 80(1–3):147–159

Trinh LT, Duong CC, Van Der Steen P, Lens PNL (2013) Exploring the potential for wastewater reuse in agriculture as a climate change adaptation measure for Can Tho City. Vietnam Agric Water Manag 128:43–54

Valipour M (2012a) Sprinkle and trickle irrigation system design using tapered pipes for pressure loss adjusting. J Agric Sci 4(12):125–133

Valipour M (2012b) Comparison of surface irrigation simulation models: full hydrodynamic, zero inertia, kinematic wave. J Agric Sci 4(12):68–74

Valipour M (2012c) Critical areas of Iran for agriculture water management according to the annual rainfall. Eur J Sci Res 84(4):600–608

Valipour M (2014a) Future of the area equipped for irrigation. Arch Agron Soil Sci 60:1641–1660

Valipour M (2014b) Drainage, waterlogging, salinity. Arch Agron Soil Sci 60:1625–1640

Valipour M (2014c) Use of average data of 181 synoptic stations for estimation of reference crop evapotranspiration by temperature-based methods. Water Resour Manag 28(12):4237–4255

Valipour M (2015a) Investigation of Valiantzas' evapotranspiration equation in Iran. Theor Appl Climatol 121(1–2):267–278
Valipour M (2015b) Comparative evaluation of radiation-based methods for estimation of potential evapotranspiration. J Hydrol Eng 20(5):04014068
Valipour M (2015c) Long-term runoff study using SARIMA and ARIMA models in the United States. Meteorol Appl 22(3):592–598
Valipour M (2015d) Temperature analysis of reference evapotranspiration models. Meteorol Appl 22(3):385–394
Valipour M (2015e) Evaluation of radiation methods to study potential evapotranspiration of 31 provinces. Meteorol Atmos Phys 127(3):289–303
Valipour M (2015f) Study of different climatic conditions to assess the role of solar radiation in reference crop evapotranspiration equations. Arch Agron Soil Sci 61(5):679–694
Valipour M (2015g) Importance of solar radiation, temperature, relative humidity, and wind speed for calculation of reference evapotranspiration. Arch Agron Soil Sci 61(2):239–255
Valipour M (2015h) A comprehensive study on irrigation management in Asia and Oceania. Arch Agron Soil Sci 61(9):1247–1271
Valipour M (2015i) Future of agricultural water management in Africa. Arch Agron Soil Sci 61(7):907–927
Valipour M (2016a) Optimization of neural networks for precipitation analysis in a humid region to detect drought and wet year alarms. Meteorol Appl 23(1):91–100
Valipour M (2016b) Variations of land use and irrigation in Americas for next decades under different scenarios. Irriga (In Press)
Valipour M, Banihabib ME, Behbahani SMR (2012) Parameters estimate of autoregressive moving average and autoregressive integrated moving average models and compare their ability for inflow forecasting. J Math Stat 8(3):330–338
Valipour M, Banihabib ME, Behbahani SMR (2013) Comparison of the ARMA, ARIMA, and the autoregressive artificial neural network models in forecasting the monthly inflow of Dez dam reservoir. J Hydrol 476:433–441
Valipour M, Eslamian S (2014) Analysis of potential evapotranspiration using 11 modified temperature-based models. Int J Hydrol Sci Technol 4(3):192–207
Valipour M, Gholami Sefidkouhi MA, Eslamian S (2015) Surface irrigation simulation models: a review. Int J Hydrol Sci Technol 5(1):51–70
van der Hoek W (2004) A framework for a global assessment of the extent of wastewater irrigation: the need for common wastewater typology, International Water Management Institute (IWMI), India.
Van Ginneken M, Oron G (2000) Risk assessment of consuming agricultural products irrigated with reclaimed wastewater: an exposure model. Water Resour Res 36(9):2691–2699
van Opstal JD, Huibers FP, Cresswell RG (2012) A participatory modelling approach to define farm-scale effects of reclaimed wastewater irrigation in the Lockyer Valley, Australia. Water Int 37(7):843–858
Verhoeven JTA, Meuleman AFM (1999) Wetlands for wastewater treatment: opportunities and limitations. Ecol Eng 12(1–2):5–12
Viviani G, Iovino M (2004) Wastewater reuse effects on soil hydraulic conductivity. J Irrig Drain Eng 130(6):476–484
Walker C, Lin HS (2008) Soil property changes after four decades of wastewater irrigation: a landscape perspective. CATENA 73(1):63–74
Wallace JS (2000) Increasing agricultural water efficiency to meet future food production. Agric Ecosyst Environ 82:105–119
Wang J-f, Wang G-x, Wanyan H (2007) Treated wastewater irrigation effect on soil, crop and environment: wastewater recycling in the loess area of China. J Environ Sci 19(9):1093–1099
Weber S, Khan S, Hollender J (2006) Human risk assessment of organic contaminants in reclaimed wastewater used for irrigation. Desalination 187(1–3):53–64

Wichelns D, Drechsel P (2011) Meeting the challenge of wastewater irrigation: economics, finance, business opportunities and methodological constraints. Water Int 36(4):415–419

Wichelns D, Owaygen M, Redwood M (2011) Developing country farmers need more than financial incentives to reduce the risks of wastewater irrigation. Water Int 36(4):467–475

World Health Organization (WHO) (1989) Health guidelines for the use of wastewater in agriculture and aquaculture. Report of WHO Scientific Group, WHO technical report series, 778. WHO, Geneva

World Health Organization (WHO) (2006) WHO guidelines for the safe use of wastewater, excreta and greywater, 4 volumes. World Health Organization Press, Geneva

Wu G-H, Cao S-S (2010) Mercury and cadmium contamination of irrigation water, sediment, soil and shallow groundwater in a wastewater-irrigated field in Tianjin. China B Environ Contam Toxicol 84(3):336–341

Xu J, Wu L, Chang AC, Zhang Y (2010) Impact of long-term reclaimed wastewater irrigation on agricultural soils: a preliminary assessment. J Hazard Mater 183(1–3):780–786

Yan D, Bai Z, Rowan M, Gu L, Shumei R, Yang P (2009) Biofilm structure and its influence on clogging in drip irrigation emitters distributing reclaimed wastewater. J Environ Sci 21(6):834–841

Yannopoulos SI, Lyberatos G, Theodossiou N, Li W, Valipour M, Tamburrino A, Angelakis AN (2015) Evolution of water lifting devices (pumps) over the centuries worldwide. Water 7(9):5031–5060

You L, Ringler C, Wood-Sichra U, Robertson R, Wood S, Zhu T, Nelson G, Guo Z, Sun Y (2011) What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. Food Policy 36(6):770–782

Zema DA, Bombino G, Andiloro S, Zimbone SM (2012) Irrigation of energy crops with urban wastewater: effects on biomass yields, soils and heating values. Agric Water Manag 115:55–65

Zhang Y, Zhang H-W, Su Z-C, Zhang C-G (2008) Soil microbial characteristics under long-term heavy metal stress: a case study in Zhangshi wastewater irrigation area, Shenyang. Pedosphere 18(1):1–10

Zhang C, Liao X, Li J, Xu L, Liu M, Du B, Wang Y (2013) Influence of long-term sewage irrigation on the distribution of organochlorine pesticides in soil–groundwater systems. Chemosphere 92(4):337–343

Chapter 19
Impacts of Wastewater Reuse on Peri-Urban Agriculture: Case Study in Udaipur City, India

K.K. Yadav, P.K. Singh, and R.C. Purohit

Abstract The present study was undertaken to determine the effect of reuse of wastewater in the peri-urban area of Udaipur city on the quality of soil, vegetable crops and groundwater in reference to heavy metal contamination. For this study four sites were selected for soil, water and vegetable sampling. Three samples each of soil, irrigation water and selected vegetable crops were collected. These samples were analysed for iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cadmium (Cd) and nickel (Ni) with the help of an Atomic Absorption Spectrophotometer (AAS) model EC 4141-8. The heavy metal accumulation in groundwater irrigated vegetables was found to increase with the increasing contamination of these metals in the groundwater at different locations. However, the metallic accumulation in all the selected vegetable crops (cauliflower, cabbage, brinjal, spinach, tomato and radish) irrigated by groundwater at all the selected locations were found to be within the maximum permissible limits as prescribed by World Health Organization (WHO). In the case of wastewater irrigation, accumulation of Fe, Zn and Cd in spinach, tomato and radish crossed the maximum permissible limits at site 3 (Kanpur – Madri Villave). Urban wastewater irrigated spinach was found to have accumulated Fe, Zn and Cd to a great extent (more than the maximum permissible limits) at all three selected locations and is most unsafe for human consumption.

Keywords Wastewater • Irrigation water • Reuse • Vegetable crops • Metalic accumulation

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19.1 Introduction

The reuse of urban wastewater is one method of disposal and recycling the plant nutrient elements contained in the wastewater. The demand on fresh water is overstressed and the use of wastewater in the agricultural sector has increased to a great extent in many parts of the world (Scott et al. 2004; Yadav 2008). There are increasing concerns about water and food security in urban areas. For cities to be liveable and sustainable into the future there is a need to maintain the natural resource base and the ecosystem services in the peri-urban areas surrounding cities. The peri-urban agriculture is endorsed as a means to reduce poverty, improve food security and enhance the urban environment through the creation of green spaces (Ensink et al. 2007). Recently vegetable cultivation in peri-urban areas has become a profitable occupation because of the proximity to urban markets which reduces transport, handling and production costs and makes food products readily available to the urban poor. In many developing countries, as a result of rapid urbanisation and the absence of wastewater treatment facilities, peri-urban farmers often use wastewater either directly from sewage drains or indirectly through wastewater-polluted irrigation water which can pose a significant occupational and public health risk (Blumenthal and Peasey 2002). One of the major constraints with wastewater irrigation is the possible contamination of the human food chain with toxic substances, such as heavy metals, when food crops are grown on soils irrigated with wastewater or contaminated groundwater (Arora et al. 2008). Keeping in view the above facts, the present investigation was undertaken to study the extent of pollutants accumulation (heavy metals viz. Fe, Mn, Cu, Zn, Cd and Ni) in six important vegetables viz. cauliflower, cabbage, brinjal, spinach, tomato and radish grown in peri-urban areas of Udaipur City, India, irrigated with urban wastewater and polluted groundwater.

19.2 Experiment

19.2.1 Study Area

Udaipur city is a historical city (more than 460 years old) having a saucer shape surrounded by hillocks. Presently it is the divisional head quarter of Rajasthan, a state of India which is located at 24.52° N latitude and 73.68° E longitude with an average elevation of 598 m above mean sea level. Udaipur city has a population of 608426 (census, 2011) which is spread over 64 km^2 area. Udaipur city has no wastewater treatment plant and sewerage lines. Most of the wastewater of the city is being discharged through different channels to the Ahar River which is a seasonal river that runs diagonally (northwest to southeast) through the eastern suburbs of Udaipur (Fig. 19.1).

Fig. 19.1 Urban wastewater in Ahar River

19.2.2 Agricultural Practices

The farms of the peri-urban areas especially the middle and lower reaches of the Ahar River are growing vegetables, flowers and fodder crops with wastewater irrigation. Among the vegetables cauliflower, cabbage, brinjal, spinach, tomato and radish are grown commonly and prominently with wastewater.

19.2.3 Sampling Sites

A total of four sites were selected for soil, groundwater and vegetable samples (Figs. 19.2 and 19.3). Site 1 is the Horticulture Farm of the university which is situated 3 km away from the Ahar River where land is irrigated only with good quality groundwater. The data of site 1 were used to compare the results. Site 2 is the Manva Kheda village which is located in the middle reach of the Ahar River where the lands are irrigated with domestic wastewater and polluted groundwater and site 3 is Kanpur-Madri village which is also located in the middle reach of the Ahar River where the lands are irrigated with a muddle of domestic+industrial wastewater and polluted groundwater. Site 4 is Matoon village which is situated in the lower reach

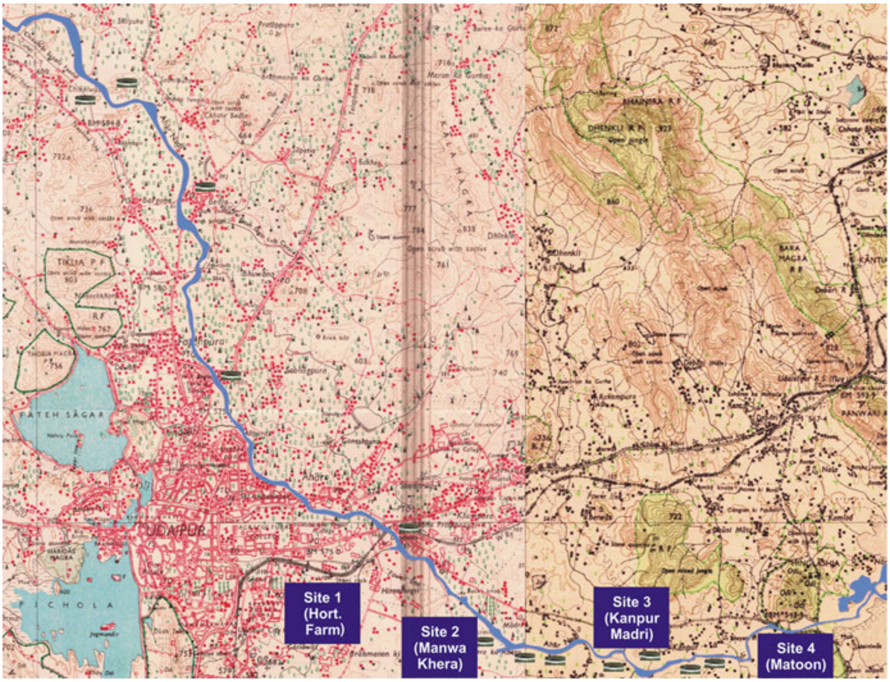

Fig. 19.2 Location of sampling sites

of the Ahar River near Lake Udaisagar and the lands are irrigated with well aerated-mixed wastewater and polluted groundwater.

19.2.4 Collection of Samples

Three samples each of soil, groundwater and selected vegetable crops were collected from the Horticulture Farm as a control to compare with the samples collected from sites irrigated with polluted groundwater and wastewater. Soil, groundwater, wastewater and vegetable samples were collected from selected sites in the middle and lower reaches of the Ahar River, viz. Manva Kheda, Kanpur-Madri and Matoon villages.

19.2.5 Analysis

These samples were analysed for iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cadmium (Cd) and nickel (Ni) content with the help of an Atomic Absorption Spectrophotometer (AAS) model EC 4141-8 following standard procedures.

Fig. 19.3 Drying of vegetable samples

19.3 Results and Discussion

19.3.1 Heavy Metal Accumulation in Soil

The continuous application of wastewater generally leads to undesirable changes in the soil and consequently an accumulation of contaminants. The results of 3 years of investigation regarding heavy metal accumulation in soil (Table 19.1) revealed that the mean values of the available heavy metals (Fe, Mn, Cu, Zn, Cd and Ni) at sites 2, 3 and 4 which are irrigated with wastewater increased to a large extent when compared to the control site (site 1: Horticulture Farm) which is never irrigated with wastewater. The highest metal accumulation was observed at site 3 (Kanpur-Madri Village) which is irrigated with the muddles of domestic+industrial wastewater. The

Table 19.1 Heavy metal content in soil (available form) at different locations (mean of 3 years)

Site	Heavy metal content in soil (mg/kg)					
	Fe	Mn	Cu	Zn	Cd	Ni
Site 1	1.081	1.236	0.970	0.953	0.017	0.003
Site 2	2.808	4.537	2.054	3.855	0.067	0.203
Site 3	4.650	6.842	2.372	4.817	0.104	0.267
Site 4	3.842	5.972	2.270	4.026	0.089	0.217

Table 19.2 Heavy metal contamination in groundwater at different locations (mean of 3 years)

Site	Heavy metal content in groundwater (mg/kg)					
	Fe	Mn	Cu	Zn	Cd	Ni
Site 1	0.031	0.019	0.000	0.000	0.000	0.000
Site 2	0.180	0.025	0.035	0.015	0.012	0.083
Site 3	0.183	0.032	0.037	0.021	0.014	0.084
Site 4	0.165	0.035	0.030	0.022	0.012	0.049

available metal (Fe, Mn, Cu, Zn, Cd and Ni) concentration at site 3 was observed at 4.3, 5.5, 2.4, 5.1, 6.1 and 89.0 times higher, respectively, when compared to the control site. Although the concentrations of the available heavy metals were far below the toxic levels because these soils were brought under wastewater irrigation only 10 years ago, the rate of increase is very high which may be a threat in the near future.

19.3.2 Heavy Metal Contamination of Groundwater

The data in Table 19.2 show that the groundwater was polluted with heavy metals to an enormous degree at site 2, 3 and 4 as compared to site 1. The highest contamination of these metals was found at sites 3 and 4, which are situated in the middle and lower reaches of the Ahar River. The mean values of Fe and Mn in groundwater at site 3 was found to be 5.9 and 1.7 times higher, respectively, when compared to the control site. The Cu, Zn, Cd and Ni in groundwater was also found in an appreciable amount at sites 2, 3 and 4. Cadmium (Cd) crossed the maximum permissible limit (0.01 mg/kg) at all three selected sites irrigated with wastewater.

19.3.3 Heavy Metal Concentration in Wastewater

The wastewater at site 3 is highly polluted with the metallic cations compared to the two other sites. This may be due to the addition of wastewaters from different industries having higher metals from the Madri Industrial Area (MAI). Further, the

Table 19.3 Heavy metal concentration in wastewater (mean of 3 years)

Site	Heavy metal content in wastewater (mg/kg)					
	Fe	Mn	Cu	Zn	Cd	Ni
Site 2	0.188	0.195	0.110	0.191	0.156	0.189
Site 3	0.197	0.207	0.112	0.208	0.168	0.199
Site 4	0.188	0.193	0.106	0.183	0.139	0.193

metallic contamination in wastewater was found to be reduced at site 4 (Table 19.3). This may be due to natural chemical fixation of such metals during flow for a long distance or some absorption by trees and grasses grown in between these two sites.

19.3.4 Heavy Metal Accumulation in Vegetables Through Polluted Groundwater Irrigation

The perusal of data in Table 19.4 revealed that the vegetables under irrigation with groundwater at different sites have a large variation in metal concentration. At the control site the groundwater irrigated vegetables have normal contents of the metals but at the other sites where groundwater is polluted (highly contaminated with heavy metals), the contents of these metals was found to be very high. The highest metal accumulation in cauliflowers was observed at site 3. The Fe, Mn, Cu and Zn content in groundwater irrigated cauliflowers at site 3 was found to be 1.2, 1.4, 2.1 and 2.0 times higher when compared to site 1 (unpolluted groundwater). The Cd and Ni contents in cauliflowers at site 1 were Not Detectable (ND), whereas these two metals were found in a noticeable amount in cauliflowers at sites 2, 3 and 4 which were irrigated by polluted groundwater. Similarly in cabbages the highest metal accumulation was observed at site 3. The Fe, Mn, Cu and Zn content in groundwater irrigated cabbages at site 3 was found to be 1.5, 1.6, 2.3 and 2.4 times higher when compared to site 1 (unpolluted groundwater). Cd and Ni were not detected at all in cabbages at site 1 but at site 3 the mean values of Cd and Ni reached up to 0.06 and 0.69 ppm, respectively. It may be due to higher contamination of groundwater by these metals at this site. In the case of brinjal, the highest accumulation of Fe, Zn and Cd was observed at site 2 and Mn and Ni at site 3. The Cd contents in brinjal at all the sites were found very low but the Ni contents were markedly higher at the polluted groundwater irrigated sites (sites 2, 3 and 4).

Similar to the other vegetables, polluted groundwater irrigated spinach was also found to accumulate much higher heavy metals as compared to the control site. The extent of accumulation of Fe, Mn, Cu and Zn in spinach at site 3 was observed at 2.4, 2.0, 2.5 and 2.6 times more than at site 1. The Cd and Ni also accumulated to a great extent in spinach irrigated with polluted groundwater at sites 2, 3 and 4. The highest contents of Cd and Ni were found in spinach at site 3. The mean values of Cd and Ni content increased from 0.01–0.07 ppm and 0.01–0.72 ppm, respectively.

Table 19.4 Heavy metal content in vegetables (mg/kg) through different quality groundwater (mean of 3 years)

Site	Fe	Mn	Cu	Zn	Cd	Ni
Cauliflower						
Site 1	30.75	52.02	3.85	21.64	0.00	0.00
Site 2	34.55	67.65	6.78	38.71	0.02	0.39
Site 3	37.33	72.69	8.10	43.04	0.04	0.45
Site 4	33.43	59.90	6.05	34.53	0.03	0.38
Cabbage						
Site 1	39.62	60.27	4.32	21.06	0.00	0.00
Site 2	48.17	83.60	8.71	42.95	0.04	0.57
Site 3	58.65	98.89	10.09	49.90	0.06	0.69
Site 4	49.63	79.33	8.72	41.58	0.05	0.60
Brinjal						
Site 1	47.97	50.22	2.18	12.54	0.00	0.00
Site 2	64.93	80.44	4.22	18.11	0.02	0.27
Site 3	62.23	92.20	4.60	13.17	0.01	0.33
Site 4	62.38	84.91	4.86	13.15	0.00	0.27
Spinach						
Site 1	161.07	47.41	4.10	30.02	0.01	0.01
Site 2	312.50	80.41	8.48	75.00	0.04	0.63
Site 3	387.81	96.37	10.23	79.32	0.07	0.72
Site 4	300.23	83.90	7.73	59.45	0.04	0.61
Tomato						
Site 1	119.31	82.08	6.45	22.04	0.00	0.00
Site 2	208.24	156.45	7.81	54.83	0.04	0.54
Site 3	239.91	160.40	8.49	69.87	0.07	0.63
Site 4	206.57	149.35	7.84	52.97	0.05	0.61
Radish						
Site 1	139.10	71.52	7.09	29.32	0.01	0.02
Site 2	252.17	122.81	9.50	55.47	0.06	0.91
Site 3	266.27	136.31	10.27	81.37	0.07	0.90
Site 4	248.93	127.13	8.75	75.05	0.07	0.85

Furthermore, the data in Table 19.4 show that at the control site Cd and Ni contents in tomato were Not Detectable (ND) but at sites 2, 3 and 4 considerable amounts of Cd and Ni were accumulated and the highest mean values of Cd and Ni were observed at site 3 i.e. 0.07 and 0.63 ppm, respectively. Accumulation of Fe, Mn, Cu and Zn at site 3 were 2.0, 2.0, 1.3 and 3.2 times more than the control site. In the case of radish the highest accumulations of Fe, Mn, Cu, Zn and Cd were observed at site 3, whereas the highest mean accumulation of Ni (0.91 ppm) was observed at site 2. The Fe, Mn, Cu and Zn concentrations in radishes at site 3 were 1.9, 1.9, 1.4 and 2.8 times higher than the control site.

19.3.5 Heavy Metal Accumulation in Wastewater Irrigated Vegetables

The data in Table 19.5 clearly revealed that highest metallic accumulation in wastewater irrigated vegetables selected for this study was observed at site 3 (Kanpur – Madir village) which also had the highest metallic concentration in the wastewater. At site 3 cauliflowers accumulated Fe, Mn, Cu and Zn at rates of 2.34, 2.63, 4.20 and 3.97 higher, respectively, than the normal concentration of these metals (site 1, Table 19.4). Cadmium and nickel were Not Detectable (ND) in cauliflowers at site 1 (Table 19.4) but considerable amounts (0.06 and 1.05 ppm) of these metals were found in wastewater irrigated cauliflowers. In the case of cabbages Fe, Mn, Cu and Zn accumulation were found to be 2.31, 2.85, 4.22 and 3.57 times higher in that order. These results are in close conformity with the findings of Yadav et al. (2012).

Under the most polluted site (site 3) the wastewater irrigated brinjal accumulated Fe, Mn, Cu and Zn at rates of 2.96, 2.89, 7.44 and 2.86 higher, respectively, than normal ranges at the control site given in Table 19.4. Spinach was found to contain Fe, Mn, Cu and Zn 3.24, 3.45, 4.39 and 4.25, respectively, higher than their normal ranges. At site 3, wastewater irrigated tomato was found to have the highest accumulation of Fe, Mn and Zn amongst the all selected vegetable crops. The Fe, Mn, Cu and Zn were found 4.03, 4.10, 2.50 and 5.75 times higher in that order in wastewater irrigated tomato as compared to the normal ranges. The wastewater irrigated radish was found to contain Fe, Mn, Cu and Zn at 3.78, 3.73, 2.41 and 4.36 times, respectively, higher than the control. The data in Table 19.5 revealed that the iron and zinc concentrations in spinach grown with wastewater irrigation at all three sites crossed the maximum permitted levels (425 ppm for Fe and 100 ppm for Zn) as prescribed by WHO. At site 2 the Cd concentration in spinach is on the MPL (Maximum Permitted Level) whereas at site 3 and 4, the Cd concentration crossed the MPL.

The critical observation of the data in Table 19.5 elucidated that tomato irrigated with wastewater at site 3 accumulated Fe at more than the maximum permitted level, whereas Zn accumulation crossed the maximum permissible limit (100 ppm) at site 2 and site 3. The cadmium accumulation also increased to an alarming level at site 2, whereas it crossed the maximum permissible limits at sites 3 and 4.

In the case of radish grown under irrigation with wastewater, Fe and Cd crossed the maximum permissible level at all three sites, whereas the Zn accumulation was found near the maximum permissible limits in the radish grown at site 2 and it crossed the limits at sites 3 and 4.

Table 19.5 Heavy metal accumulation in vegetables (mg/kg) through wastewater irrigation (mean of 3 years)

Site	Fe	Mn	Cu	Zn	Cd	Ni
Cauliflower						
Site 2	62.53	122.63	14.32	80.20	0.05	1.03
Site 3	71.99	136.60	16.17	85.82	0.06	1.05
Site 4	59.59	107.64	15.30	67.77	0.03	0.89
Cabbage						
Site 2	80.78	154.35	14.68	74.60	0.07	1.10
Site 3	91.58	171.78	18.21	75.27	0.06	1.04
Site 4	81.35	154.38	16.16	68.74	0.06	0.92
Brinjal						
Site 2	125.45	132.96	10.94	31.50	0.05	0.88
Site 3	142.04	145.20	16.21	35.88	0.06	0.96
Site 4	133.83	141.95	16.31	31.87	0.05	0.84
Spinach						
Site 2	487.98	136.13	17.49	111.69	0.10	1.22
Site 3	522.54	163.77	17.99	127.45	0.14	1.45
Site 4	451.06	157.30	14.13	107.41	0.13	1.03
Tomato						
Site 2	409.84	274.01	14.12	103.73	0.09	0.98
Site 3	480.93	336.68	16.11	126.73	0.12	1.36
Site 4	411.08	325.38	15.84	97.79	0.11	0.97
Radish						
Site 2	474.88	244.77	15.88	91.25	0.12	1.40
Site 3	526.25	267.08	17.09	127.89	0.13	1.57
Site 4	500.11	270.82	15.56	107.37	0.13	1.17

19.4 Conclusion

The heavy metal accumulation in groundwater irrigated vegetables was found to increase with increasing contamination of these metals in groundwater at different locations but the metallic accumulation in all the selected vegetable crops (cauliflower, cabbage, brinjal, spinach, tomato and radish) irrigated by groundwater at all the selected locations were found to be within the maximum permissible limits as prescribed by WHO. In the case of wastewater irrigated spinach, tomato and radish the maximum permissible limits of Fe, Zn and Cd accumulation in edible parts were crossed at site 3 (Kanpur – Madri Village) which is irrigated with a muddle of domestic+industrial wastewater. Spinach is the most common and popularly grown leafy vegetable that with wastewater irrigation was found to accumulate Fe, Zn and Cd to a great extent (more than the maximum permissible limit) at all three selected locations. Hence, it can be inferred that vegetable crops mainly tomato, radish and spinach grown with untreated wastewater irrigation are unsafe for human consumption.

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References

Arora M, Kiran B, Rani S, Rani A, Kaur B, Mittal N (2008) Heavy metal accumulation in vegetables irrigated with water from different sources. Food Chem 111:811–815

Blumenthal U, Peasey A (2002) Critical review of epidemiological evidence of the health effects of wastewater and excreta use in agriculture. Unpublished document prepared for WHO (available on request), Geneva

Ensink JHJ, Mahmood T, Dalsgaard A (2007) Wastewater-irrigated vegetables: market handling versus irrigation water quality. Trop Med Int Health 12(2):2–7

Scott CA, Faruqui NI, Raschid-Sally L (2004) Wastewater use in irrigated agriculture: confronting the livelihood and environmental realities. CABI, Wallingford

Yadav KK (2008) Soil fertility improvement of lower reaches of Ahar river (Udaipur) through long-term sewage irrigation. Indian Farm 11:16–18

Yadav KK, Chandra S, Sharma M, Singh PK, Lakhawat SS (2012) Effect of cyclic use of sewage water on growth, yield and heavy metal accumulation in cabbage. Ecol Environ Conserv 18(1):95–100

Part VII
Urban Agriculture and Food Security

Chapter 20
Urban Agriculture in Cuba: Alternative Legal Structures, Crisis and Change

Liesel Spencer

Abstract The dominant mode of feeding Australian cities is the industrial food system, including industrial agriculture. This food system has produced crises in public health in the form of rising incidence of non-communicable disease linked to diet; and crises in environmental health flowing from industrial agriculture and the food processing and distribution network. This chapter discusses the urban agriculture program implemented in Cuba in the mid-1990s 'Special Period' in response to a food security crisis, as an example of legal change in response to food system failure. The Cuban experience is analysed by drawing on Blomley's work on legal geography methodological tools of performativity, and pragmatism (specifically Dewey's writings on 'habit'). It is concluded that changes to the law and policy underpinning Australia's dysfunctional urban food system might be catalysed by framing and communicating the health and ecological problems in the language of crisis, and by responding to this food system crisis by experimenting with alternatives such as urban agriculture.

Keywords Urban agriculture • Legal structures • Industrial food systems • Environmental health • Policy

20.1 Introduction

This chapter is about a research project situated within a broader research agenda investigating law and alternative urban food systems, and specifically the alternative of supplementing Australia's urban food system with urban agriculture in the form of a locally-adapted agrarian (or 'agroecological') food production network (Orr 2001). The complicated relationship of cities and urban society to food supply is not a new governance problem, being inherent in the formation of even the first cities (Standage 2010). The particular aspect of this old problem which is of interest

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here is the interdisciplinary question, as to what laws and policies could catalyse and sustain urban agriculture in Australian cities. It should be noted at the outset that this is not a Utopian aspiration to urban self-sufficiency, but a proposed supplement and (partial) alternative to existing food provisioning practice.

The impetus for a research agenda exploring alternative urban food systems, is the dysfunctional and precarious nature of the system we have. The dominant mode of feeding Australian cities is the industrial food system, including industrial agriculture. The material ill-effects of this food system impact on human bodies and on broader ecological systems. Compounding this situation is the intensity of Australia's urbanisation as one of the most urbanised nations in the world (Australian Bureau of Statistics 2013); and the consequent invisibility of many food system processes which occur outside the cities (Robin 2007; Steel 2013). Problems specific to urban places are magnified in Australia.

In common with other wealthy countries (Raubenheimer et al. 2015), Australia has experienced a dramatic increase in the public health disease burden of non-communicable, 'lifestyle' diseases associated with the food system (World Health Organisation 2013). Obesity, for example, has been described as a (non-traditional) pandemic (Krebs 2013). The main contributors to the increase in non-communicable disease are diet and activity levels (Egger and Swinburn 2010); this research focuses on diet. Intake of fresh fruit and vegetables strongly correlates to health status (Australian Bureau of Statistics 2012). This dietary intake of fresh produce is the central determinant of health with which the public health aspect of this research project is concerned. Fresh produce intake is considered within a theoretical framework of 'ecological public health', a relatively recent iteration of public health theory which places health in the context of the 'material, biological, social and cultural dimensions of existence' (Rayner and Lang 2012).

Environmental damage flowing from industrial food and industrial agriculture is well-documented (Burdon 2010; Woodhouse 2010; Weis 2010; Muir 2014). Specific consequences include desertification and salinity in agricultural land (Muir 2010), global warming 'associated with land use changes, mostly from the food system' (Stern 2007) deforestation, water consumption and contamination, land degradation, and loss of biodiversity (Singer 2006). In the Australian landscape these consequences are exaggerated by place-specific physical geography such as fragile topsoil and droughts, to which European-style agricultural production is unsuited, or 'maladapted' (Graham 2011). Environmental fallout continues beyond sites of agricultural production, caused by food transport, storage, processing, packaging and retailing and by the management of the wastes of these processes (Spencer 2014).

20.2 Governance at Different Scales

Under the present legislative arrangements, primary responsibility for law and policy relating to urban agriculture rests with local government. On the one hand this is appropriate, as local government is best placed to implement regionally appropriate and adapted practice suited to the physical and cultural geography of particular regions. On the other hand, local councils in New South Wales are constrained by very limited resources, and a plethora of other legislative priorities and responsibilities: what Valverde refers to as 'the political effects of scale', expressed via jurisdiction, which impacts how we are governed (Valverde 2009).

The statutory responsibilities of local government in New South Wales (NSW) include onerous and extensive planning and reporting under the Integrated Planning and Reporting Framework (IPR) mandated by Chapter 13 of the *Local Government Act 1993* (NSW); councils further have regulatory and statutory planning responsibilities under the *Environmental Planning and Assessment Act 1979* (NSW). These statutory responsibilities encompass both public health and environmental health. Urban agriculture, (including peri-urban agriculture) is here proposed as one means by which local government can address itself to statutory obligations regarding public health and environmental health. Extrapolating from the emerging theory of 'cobenefits' (Capon and Russell 2010) suggests that local councils can better reconcile priorities within resource constraints, by exercising functions in ways that acknowledge the interdependency of human health and ecological health.

As will be evident from the case study of Cuba below, however, it may be argued that urban agriculture practice is better served by not confining governance responsibility for urban food systems and urban agricultural production to the scale of the local. By way of example, the template Local Environmental Plan (LEP) for local councils in NSW is imposed by State government, and does not incorporate considerations of urban agriculture. Government at the State scale is dominant over government at the local scale; and therefore local councils are somewhat bound if urban agriculture initiatives would clash with the State LEP template. Although councils can add objectives to particular zones under the LEP, these objectives cannot conflict with those in the template. A comprehensive plan for urban agriculture across all three tiers of government is arguably therefore a better arrangement.

20.3 Comparative Legal Geography

Devising an appropriate methodology for interdisciplinary legal research requires more than the traditional legal research doctrinal methodology. As this research project is a comparative study, comparative law methodology is a relevant inclusion (Zweigert and Kotz 1998). It is, however, a necessary but not sufficient condition in this instance. 'Legal transplants', or borrowing from the experience of foreign jurisdictions, are a long-established method of law reform (Watson 1991, 1993). Legal transplants, (and comparative law methodology more generally) have been criticised as not paying sufficient heed to the place-specific context of the transplantor and transplantee jurisdictions (Kedar 2014; Legrand 1997; Kahn-Freund 1974).

To address this shortfall in comparative law methodology, a novel hybrid methodology has been used for this research: comparative legal geography. Legal geography, the study of the mutually constitutive relationships between law, land and people, takes a place-specific approach to the analysis of law and legal policy (Valverde 2011; Hinchcliffe and Whatmore 2006). Incorporating legal geography into a hybrid comparative legal geography methodology (Kedar 2014) facilitates analysis of the interactions between law, land and people specific to the practice of urban agriculture in the jurisdictions being compared.

The comparative study in this chapter utilises two specific tools within legal geography methodology, drawing on the work of Blomley on performativity (2013) and pragmatism (2014). Performativity theory is a tool in this instance to analyse why 'certain conceptions of property are dominant' and endure despite being 'flawed', because of their 'citational' and 'reiterative' qualities; and how 'counter-performance[s] of property' might be made 'less marginal' by responding to a situation of crisis: 'where truth fails, there are possibilities for political learning and experimentation' (Blomley 2013).

Property is performed by the industrial food system as a hegemonic mode of land use and market control, of food production and supply to urban populations. This successful claim on the urban food system is flawed or not truthful in the sense of the dysfunctions discussed above. This success is in part attributable to a performance of property which uses language to enact reality (for example the narrative of supermarkets as self-described 'fresh food people' and of food labels with fictitious depictions of farm animals grazing in idealised paddocks). Success is also here a function of citational and reiterative performances of property – urban food consumption behaviour is influenced by the 'citational ability to reference innumerable other such manifestations' (Blomley 2013) such that past food practice becomes the prevailing norm and predicts future practice. This is manifested for example in the supermarket duopoly in Australia, which rests on an illusion of 'resolution, simplicity, order, certainty and security' (Blomley 2013). Blomley describes this entrenchment of dominant performances of property as a form of frozen politics, but notes that such entrenched practices are only 'human projects, rather than a static distillation of timeless, pre-political realities' (2013). The food system we have is not as inevitable and intractable as it may appear. What is needed to make alternatives less marginal, or to create space for viable food system alternatives such as urban agriculture? Crisis or failure in the dominant model is an instance of 'where truth fails' and accordingly makes space for 'possibilities for political learning and experimentation' (Blomley 2013). The Cuban experience involved radical and relatively swift changes to the food system of an entire country, precipitated by an acute food security crisis. This chapter considers what might be learned from that experience and applied to the Australian context.

Blomley's work on the usefulness of insights from pragmatism (2014) is the other specific tool of legal geography methodology employed in this research. Expanding on Dewey's writings on pragmatism (1922–1930), Blomley considers the power of habit, drawing from 'pragmatism's primary emphasis on experience' with habit predisposing us to certain forms of action; and 'certain habits become[ing] more collectively engrained or congealed in what Dewey terms *custom*' (2014). The power of habit might be seen as linked to the normative effect of citational and reiterative performances of property. Habits, despite having the force of stability, can change, being 'adaptable and diverse [to the] experimental and contingent'; customs 'persist because individuals form their habits under conditions set by prior custom' (Blomley 2014). Habit and custom are potentially a lever to implement change in the food system, utilising 'the value of forms of experimental inquiry or intelligence, essential for the learning through experience that, ideally, opens up future possibilities for learning' (Blomley 2014).

In summary, then, the methodological tools of legal geography, performativity and pragmatism, are useful in explaining how Cuba's food system underwent a swift and radical change in the mid-1990s; and further this might point to a 'new place to begin' (Blomley 2014) in experimenting with alternatives to Australia's urban food system. Such an approach does not fall into the comparative law trap of cut-and-pasting foreign legal structures into a new context, but rather points to that which is true in a particular context (Cuba) and invites experimentation with place-specific alternatives: 'there are no predetermined outcomes that can be derived from law's geographies … such geographies should be thought of as experimental and contingent … [citing Allen] "What works best in any given situation cannot be known in advance, only *in practice*"' (Blomley 2014).

20.4 Urban Agriculture in Cuba and Food Crisis

Urban agriculture in Cuba is practised along agrarian/agroecological rather than industrial/mechanised lines, with minimal artificial pesticides, fertilisers, or petrol-dependent technology (Diaz and Harris 2005; Manzano 2007), and with produce retailed directly to local food consumers (Premat 2012). The Cuban program was implemented in response to an acute food security crisis during the Special Period following the withdrawal of Soviet oil supplies in the early 1990s (Clouse 2014; Wright 2009). A significant proportion of Cuban food production was shifted to urban land to bring sites of production closer to sites of consumption, as fossil fuel transport was limited by oil shortages (Wright 2009). Further, the shift to agroecological farming methods was driven by shortages of oil-based pesticides and fertilisers, and shortages of oil to drive farm machinery (Deere et al. 1994). Urban agriculture was not a deliberate governmental strategy to improve public and environmental health. There were, however, side-effects of the Cuban agricultural reforms which are anomalous in the developed world and which therefore merit the attention of Australian law and policy makers. Cuba is the only nation in the world to meet the World Wildlife Foundation's definition of sustainable development, having both an acceptable ecological footprint per capita and an acceptable Human Development Index rating (World Wildlife Foundation 2006). Cuba's low ecological footprint per person, low infant mortality and high life expectancy in the wake of the Special Period are an anomalous combination in the developed world. Immediately following the changes to Cuba's food system in the early 1990s, there was a 'rapid decline in death rates from diabetes and heart disease' (Franco et al. 2013). Cuba is not here held up as a paragon or perfect model, and the Cuban system has past and ongoing problems (Hagelberg 2010; Alvarez 2001). The significance of the Cuban data for Australian law and policy on urban food systems is that, whilst imperfect, the Cuban program met with notable (if unintended) successes in public and environmental health.

Prior to the Special Period of crisis and disruption in the Cuban food system, Cuban dietary habits were poor with high consumption of sugar, animal fats, and rice, and low consumption of a very limited range of fruits and vegetables (Wright 2009). Environmental and public health impacts from the industrial agricultural system included chemical pesticide and fertiliser residue and increased mortality rates (Wright 2009). The food system was flawed, and the Cuban government acknowledged the flaws. It took the Special Period oil crisis, however, to move from knowledge to change. If pragmatism advocates for learning via experimentation and experience of what works, it is apparent from what occurred in Cuba that this knowledge alone is unlikely to be enough to instigate change. Blomley's discussion of performativity theory (2013) points to failure and crisis in the (flawed) dominant model as an entry point for alternatives.

The post-Special Period food system reforms in Cuba involved extensive revisions of property rights. (This should be read, of course, from the perspective that Cuba is a socialist state with a fundamentally different political system than that of Australia.) At a rural level, the most significant reform was the breakup of large state farms into *unidades basicas de produccion cooperativas* (UBPCs), small farming cooperatives located on the peri-urban fringe and run autonomously by groups of farmers (Gropas 2006). Under this scheme worker collectives were granted leases, rent-free, over state farm lands in permanent usufruct together with ownership of the goods produced (Deere et al. 1994).

Within the cities, two key features of the Cuban program are the *organoponicos* and the *mercados agropecuarios*. The *organoponicos* are raised-bed intensive-production gardens located on public land (Viljoen and Howe 2005). The produce from the *organoponicos* and other sources is retailed directly to consumers via the *mercados agropecuarios*, local farmers' markets in the city (Premat 2009).

The Cuban program has separately promoted urban and peri-urban agriculture. The *Agricultura Urbana* program initiated in the 1990s concentrated on 'patios (domestic gardens), plots (empty lots planted to vegetables) and… *organoponicos* – low-walled beds filled with soil and organic matter, with or without drip irrigation' (Hagelberg 2010). Plots, or *parcelas*, were located on a variety of available land types, including 'parks, open baseball fields, and, more commonly, demolition sites' (Premat 2009) with this land being granted in rent-free usufruct (Premat 2012). Cubans were encouraged to use every possible urban space for food production. Private gardens and rooftops (*patios*) were transformed into spaces for chicken coops, pig sties, goat sheds, and vegetable gardens (Premat 2009).

A separate and distinct program, *Agricultura Suburbana*, was implemented in peri-urban regions, on *fincas* (small farms) in 'an eight-kilometre-deep ring between two and ten kilometres from urban centers' (Hagelberg 2010). These programs were implemented in great haste in response to the acute food security crisis. Urban planners responsible for the capital Havana were consequently frustrated by the lack of overall design and planning in implementing the Finca Program, as in the rush to rapidly increase food production other city planning work such as transport and water supply were disregarded (Premat 2012). Legal geography's understandings of the mutually constitutive nature of law and place are a means of interpreting this upending of law in response to the material demand for food security. This exposes the myth of law's instrumentality – zoning as a top-down legal instrument interacts in reality with place, exposing: '… the myth that zoning is an instrument of rational, disinterested planning … [there are] myriad instances of … particularistic and reactive land use control.' (Valverde 2011).

20.5 Lessons from the Cuban Experience

As a social experiment, the Cuban food security crisis and the law and policy response are the sort of thing that would never gain approval from a university ethics committee. Viewed from the perspective of pragmatism, however, the Cuban experience does yield knowledge about place-specific alternatives to the industrial food system. The state-sanctioned national urban agriculture program in Cuba provides an evidence base from which planning lawyers and policy makers of Australian cities could extrapolate possibilities for implementing an alternative, urban-agrarian food system. (In the Australian context, and given our demographic distribution and city forms, 'suburban agrarianism' might be more accurate.) The evidence from Cuba points to the potential of urban agrarianism, or 'urban agroecology' as a mode of supplementary food production for cities which optimally promotes public health and environmental health.

Usufruct legal arrangements are a key feature of Cuba's agricultural reforms implemented in response to the 1990s crisis. Usufruct leases, (rent-free long term tenancy over land with ownership of crops produced) did overcome one barrier to urban agriculture: access to land. The granting of land in permanent, rent-free usufruct for agriculture is acknowledged by the Cuban government as one of the more successful initiatives of the post-Special Period agricultural reforms. The data from Cuba on agricultural productivity in this period is not as statistically reliable as might be hoped (Campbell 2008; Mesa-Lago 1998), however there is consensus that private farmers outperformed state owned farms and large cooperatives and collectives (Deininger 1995), and that production of vegetables exceeded FAO guidelines for minimum consumption (Koont 2008). Small scale, privately run urban operations have been notably productive (Campbell 2008) especially in vegetables. Excessive governmental interference with cooperatives, such as monopolies on procurement and distribution, have been blamed for relatively lower productivity (Deere and Meurs 1992) when compared with private farming operations.

The relative success in productivity terms of smaller private farming operations led to further law reform under Raul Castro in 2008. Decree-Law No 259 of 2008 legislated for the 'mass grant in usufruct of idle state land, mainly to small farmers and landless persons' (Hagelberg 2010). This program was so popular that demand far exceeded supply (Carrobello and Terrero 2009).

Access to land is a prerequisite of agriculture. One could split hairs and argue that proponents of vertical farming and rooftop gardens have circumvented this requirement; these modes of urban agriculture are, however, the exception rather than the rule. Land in the sense of space in which to grow food is still a requirement, even where the earth or hydroponic system is suspended in containers over the land on rooftops or in vertical gardens. Urban land is fragmented, small scale and not suited to industrial/mechanised farming (vacant city blocks do not comfortably accommodate combine harvesters). Urban land is also more valuable a commodity than rural land, and its possession and use are more hotly contested.

In proposing a widespread program of urban agriculture in Australian cities, a critical consideration is finding available land which can be put to use growing food. Cuba's urban agriculture is largely located on abandoned, disused land in cities. This is a possibility in Australian cities, but to a lesser extent than is possible in Cuban cities. Following the Special Period, much of Cuba's urban space fell into disuse and abandonment, leaving a comparatively large quantity of land available to be put to use in growing food. The economic recovery of, for example, the capital Havana has led to urban agriculture sites being subject to challenge for competing uses by developers (Premat 2012).

Finding available land, then, is the complicated first step in developing a city-wide program of urban food production. Public land within control of local councils is a potential resource for urban agriculture. Usufruct legal arrangements over public land are one possible law and policy structure to make land available for urban agriculture. In the Australian context, suburban and peri-urban land represents the most significant source of available land, particularly given Australia's urban sprawl and the creep of suburban development into the peri-urban fringe (Webb and King 2007).

It is not economically viable for urban farmers to buy or rent valuable urban land and use it for food production. One means of making urban food production economically viable is to provide rent-free usufruct tenure over public land, on condition that it be used for growing food, and that this food be made available for local consumers. In the Cuban model public land is leased rent-free to individual farmers or farming collectives, and the produce is retailed directly to the public via local farmers' markets (*mercados agropecuarios*). The benefits of usufruct legal arrangements for urban agriculture extend beyond affordability considerations. Long-term, stable usufruct over land (the Cuban model gave renewable rent-free leases of 10–25 years) gives stable tenure over land. The flow-on effects of long-term stable tenure are connected to a sense of ownership. Short-term and/or unreliable land tenure can lead to exploitation of land to obtain a yield and profits without regard to the future health and productivity of the land. Long-term stable tenure fosters a land care ethic.

Long-term land tenure allows for a diversity of produce, including longer-term investment crops such as fruit trees. Long-term tenure also provides urban farmers with relatively steady and reliable income, and a long-term right livelihood. The Cuban experience also indicates sustainable urban economic activity as a by-product of implementing a widespread program of urban agriculture – 350,000 'well-paid urban jobs' having been created by 2006 (Koont 2008).

The capacity already exists in New South Wales legislation for local councils to grant parcels of public land in rent-free usufruct to urban farmers, on the condition that the land be used for food production. The *Local Government Act 1993* (NSW) authorises local councils to deal with public land for various purposes. Public land categorised as 'community land' under section 26, and subcategorised as 'general community use' under section 36(4)(3) can be leased, licenced or sublet (section 36(3A)(b)(ii)), and it is within the discretion afforded to councils under the legislation to do so on a usufruct basis and for the purposes of food production (Spencer 2012).

Aside from the specific issue of overcoming the obstacle of access to land for food production, other obstacles should be taken into consideration by any local council considering a program of urban agriculture. The Cuban experience indicates that barriers to the success of urban, suburban and peri-urban agriculture include the inexperience of novice farmers, and lack of finance, tools and equipment. Urban farmers also need access to consumers to sell farm produce. A critique of the Cuban agricultural reforms post-Special Period concerns the level of skill and knowledge amongst novice farmers who took up the government offer of usufruct land (Duenas et al. 2009). Much of the available land was infested with weeds, and the new farmers often lacked hand tools, fencing wire, machinery, fuel, and access to finance, in addition to struggling with uncertainty about what activity was permitted, and bureaucratic oversight and compliance burdens (Hagelberg 2010). The micro-management interventions of the Cuban state have been coupled with often unreliable state support, such as procurement trucks that do not arrive to collect perishable goods (Deere et al. 1994).

A detailed consideration of these issues is beyond the scope of this chapter and is part of the broader research agenda of which it forms part. In brief, however, possible solutions might include tool lending libraries, linking local seed-savers groups to new farmers to provide locally-adapted plant strains, Federal Assistance Grants for start-up lending, and mentoring and apprenticeship programs to impart food growing skills and knowledge. Councils also have the capacity to provide a forum for direct sales of farm produce to local consumers, by establishing and maintaining local farmers' and produce markets.

20.6 Conclusions

The way Australian cities are currently provisioned with food is via a dysfunctional food system which has damaging consequences for public health and environmental health. However, the power of habit and custom, or 'business as usual', is strong. Knowledge that the food system is flawed is not enough to propel change. Perhaps our understanding of what constitutes a crisis is a leverage point to enable alternatives to emerge and gain a foothold. Public health literature variously describes the rising instance of non-communicable diseases linked to diet as pandemics, or epidemics. The ecological damage from industrial agriculture and the wider industrial food system is also well-documented. Our food system is indeed in a state of crisis, albeit not a crisis as recognisable as the acute food security crisis in Cuba during the Special Period. This crisis must be properly communicated as a counter to the dominant narrative of the food industry, in order to provoke changes in habit and custom and allow space for experimentation with alternatives. An alternative/supplementary urban food supply based on urban, suburban and peri-urban agriculture is part of the solution to these problems. The Cuban model of urban agriculture has proven to be relatively successful and productive. The legal and policy structures underpinning the Cuban program are worth considering, in adapted format, for implementation in Australia.

References

Alvarez J (2001) Rationed products and something else: food availability and distribution in Cuba. Cuba Transit ASCE 2001:305–322

Australian Bureau of Statistics (2012) 1301.0 - Year Book Australia, 2012 Fruit and Vegetable Consumption in Australia. http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/1301.0Main+Features2362012

Australian Bureau of Statistics (2013) http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features30April+2013

Blomley N (2013) Performing property, making the world. Can J Law Jurisprud 26:23–48

Blomley N (2014) Learning from Larry: pragmatism and the habits of legal space. In: Braverman I et al (eds) The expanding spaces of law: a timely legal geography. Stanford Law Books, Stanford, pp 77–94

Burdon P (2010) What is good land use? From rights to relationship. Melb Univ Law Rev 34:708–735

Campbell A (2008) The Cuban economy: where it stands today. Rev Radic Polit Econ 40(3):276–284

Capon A, Russell C (eds) (2010) Chronic disease and climate change: understanding co-benefits and their policy implications. NSW Public Health Bull 21(5–6):109–113

Carrobello C, Terrero A (2009) Contra la peor de las plagas posibles. Bohemia. (Cited in Hagelberg, 2010)

Clouse C (2014) Farming Cuba: urban agriculture from the ground up. Princeton Architectural Press, New York, 191 p

Deere C, Meurs M (1992) Markets, markets everywhere? Understanding the Cuban anomaly. World Dev 20(6):825–839

Deere C, Perez N, Gonzales E (1994) The view from below: Cuban agriculture in the "Special Period in Peacetime". J Peasant Stud 21(2):194–234

Deininger K (1995) Collective agricultural production: a solution for transition economies? World Dev 23(8):1317–1334
Diaz J, Harris P (2005) Urban agriculture in Havana: opportunities for the future. In: Viljoen A et al (eds) CPULs: continuous productive urban landscapes. Routledge, New York, pp 135–145
Duenas F et al (2009) Cuba's success story, further developed. Leisa India. pp 27–29. http://leisa-india.org/wp-content/uploads/2010/06/pages-1-40.pdf
Egger G, Swinburn B (2010) Planet obesity: how we're eating ourselves and the planet to death. Allen & Unwin, Crows Nest, 139 p
Franco M et al (2013) Population-wide weight loss and regain in relation to diabetes burden and cardiovascular mortality in Cuba 1980–2010: repeated cross sectional surveys and ecological comparison of secular trends. Br Med J 346: 1–9. doi:http://dx.doi.org/10.1136/bmj.f1515
Graham N (2011) Lawscape: property, environment, law. Routledge, London, 226 p
Gropas M (2006) Landscape, revolution and property regimes in rural Havana. J Peasant Stud 33(2):248–277
Hagelberg G (2010) If it were just the marabu… Cuba's agriculture 2009–10. Cuba Transit ASCE 2010:32–46
Hinchcliffe S, Whatmore S (2006) Living cities: towards a politics of conviviality. Sci Cult 15:123–138
Kahn-Freund O (1974) On uses and misuses of comparative law. Mod Law Rev 37:1–27
Kedar A (2014) Expanding legal geographies: a call for a critical comparative approach. In: Braverman I et al (eds) The expanding spaces of law: a timely legal geography. Stanford University Press, Stanford, pp 95–119
Koont S (2008) A Cuban success story: urban agriculture. Rev Radic Polit Econ 40(3):285–291
Krebs J (2013) Food: a very short introduction. Oxford University Press, Oxford, 130 p
Legrand P (1997) The impossibility of "legal transplants". Maastricht J Eur Comp Law 4:111–124
Manzano A (2007) The socialization of science and technology: the urban agriculture program in Cuba. Tailoring Biotechnol 3(2):49–68
Mesa-Lago C (1998) Assessing economic and social performance in the Cuban transition of the 1990s. World Dev 26(5):857–876
Muir C (2010) Feeding the world. Griffith Rev 27:59–73
Muir C (2014) The broken promise of agricultural progress. Routledge, London, 211 p
Orr D (2001) The urban-agrarian mind. In: Freyfogle E (ed) The new agrarianism: land, culture, and the community of life. Island Press, London, pp 93–107
Premat A (2009) State power, private plots and the greening of Havana's urban agriculture movement. City Soc 21(1):28–57
Premat A (2012) Sowing change: the making of Havana's urban agriculture. Vanderbilt, Nashville, 216 p
Raubenheimer D, Machovsky-Capuska G, Gosby A, Simpson S (2015) Nutritional ecology of obesity: from humans to companion animals. Br J Nutr 113:26–39
Rayner G, Lang T (2012) Ecological public health: reshaping the conditions for good health. Routledge, London, 432 p
Robin L (2007) How a continent created a nation. University of New South Wales Press, Sydney, 259 p
Singer P (2006) The ethics of what we eat. Rodale, New York, 328 p
Spencer L (2012) Integrating food security into local government law, policy and planning: using local government legal structures to build community resilience to food insecurity. Food Stud Int J 2(1):1–15
Spencer L (2014) Farming the city: urban agriculture, planning law and food consumption choices. Altern Law J 39:120–124
Standage T (2010) An edible history of humanity. Atlantic, London, 274 p
Steel C (2013) Hungry city: how food shapes our lives. Vintage, London, 386X p

Stern N (2007) The economics of climate change: the Stern Review. Cambridge University Press. http://webarchive.nationalarchives.gov.uk/20100407172811/http://www.hm-treasury.gov.uk/stern_review_report.htm

Valverde M (2009) Jurisdiction and scale: legal technicalities as resources for theory. Soc Leg Stud 18(2):139–157

Valverde M (2011) Seeing like a city: the dialectic of modern and premodern ways of seeing in urban governance. Law Soc Rev 45:277–312

Viljoen A, Howe J (2005) Cuba: laboratory for urban agriculture. In: Viljoen A et al (eds) CPULs: continuous productive urban landscapes. Routledge, New York, pp 146–191

Watson A (1991) Legal origins and legal change. Hambledon Press, London, 321 p

Watson A (1993) Legal transplants: an approach to comparative law. University of Georgia Press, Athens

Webb K, King L (2007) Food, nutrition and the built environment. Public Health Bulletin 4(1):12–14

Weis T (2010) The accelerating biophysical contradictions of industrial capitalist agriculture. J Agrar Chang 10(3):315–341

Woodhouse P (2010) Beyond industrial agriculture? Some questions about farm size, productivity and sustainability. J Agrar Chang 10(3):437–453

World Health Organisation (2013) Health Profile: Australia, http://www.who.int/countries/aus/en/. Accessed 20 July 2015

World Wildlife Foundation (2006) Living planet report. http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/living_planet_report_timeline/lp_2006/

Wright J (2009) Sustainable agriculture and food security in an era of oil scarcity: lessons from Cuba. Earthscan, London, 261 p

Zweigert K, Kotz H (1998) Introduction to comparative law. Oxford University Press, Oxford, 744 p

Chapter 21
High Quality Agricultural Land in Western Australia: A New Decision Tool for Planning

Dennis van Gool, Angela Stuart-Street, and Peter Tille

Abstract The Department of Agriculture and Food, Western Australia, has worked closely with state and local planners and agricultural practitioners over the last 4 years to develop a new way to identify high quality agricultural land (HQAL). This methodology combines land capability or suitability for horticulture and dry land cropping and grazing with irrigation supplies, rainfall and yield information. It then ranks large tracts of "similar" land according to its versatility for a range of agricultural land uses. This information, developed in a pilot project in the mid west region of Western Australia (WA) has been designed to suit formal land use planning. The HQAL methodology is being extended to other parts of Western Australia (WA) and has value for local planning. To use this information effectively more work is required state-wide and nationally to establish the relative importance of HQAL in many locations, including those near cities and towns.

Keywords Decision tool • High quality agricultural land • Dry land cropping • Agricultural land use • State planning • Planning Commission

21.1 Introduction

In Australia, planning for agricultural land uses is managed primarily by the states, with different approaches adopted throughout the country. In Western Australia, planning for important agricultural land is guided by the Western Australian Planning Commission (WAPC) and its State Planning Policy 2.5 *Land Use Planning in Rural Areas* (WAPC 2012). Identification of important areas of agricultural land has been supported by the Department of Agriculture and Food, Western Australia (DAFWA) for many decades. DAFWA previously prepared 'blobby' (broadly defined) regional scale maps which highlighted Agricultural Priority Management Areas for the former State Planning Policy (WAPC 2002). Detailed land capability

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mapping has been published online since 2008 (SLIP NRM 2014), and before then in technical reports and maps (Land capability, as used in Western Australia, is analogous to "land resource suitability" used elsewhere.)

Despite this information having been available for many years, it has not always been well adopted or understood. Planning for agriculture has largely remained piecemeal with decisions favouring traditional urban developments in a business-as-usual approach.

The implications for the long-term sustainability of food production are that agricultural industries and community demands for fresh food are not factored into the continuous cycle of agricultural displacement and relocation. Areas with good quality land and water to which agriculture could relocate to are limited, pushing agriculture onto less productive and more fragile areas with more variable climate.

The Planning Institute of Australia has recognised this continual pressure and the resultant conflicts as a significant problem. They state that "…*there has not been much attention to planning for the protection of land that grows food*," (PIA 2011, p. 3). They add that "…*the production of food from land is an ongoing use and paving over of it for urban development*, *potentially restricting it by rural residential development*, *or extracting the resources and interfering with the landscape*, *does not allow the land to continually produce food*."

The requirement for agricultural land use information is now embedded in the WAPC State Planning Policy 2.5 Land Use Planning in Rural Areas (2012) and Rural Planning Guidelines (2014). DAFWA provides interpreted base data about the agricultural land quality such as HQAL and the planning system considers other land requirements and consults with local communities to identify Priority Agricultural Land.

21.2 Identification of High Quality Agricultural Land in the Geraldton Planning Region

In the Geraldton area in the mid-west region (Fig. 21.1), DAFWA worked closely with local and state level planners to learn what would be most useful for them to more effectively plan for agricultural land. Using these insights, the project team brought together a range of analyses in a format that contributes information about agricultural land quality and potential value into local and regional planning outcomes. This pilot project produced information at a regional and local scale for the Geraldton Planning Region (Tille et al. 2013).

The need for concise agricultural information for planners was identified at a variety of levels to support the decision making process. This information needs to:

- identify land and water resources of greatest priority for agriculture;
- be relatively easy to incorporate into the planning system;
- provide justification for the allocation of resources to agriculture; and

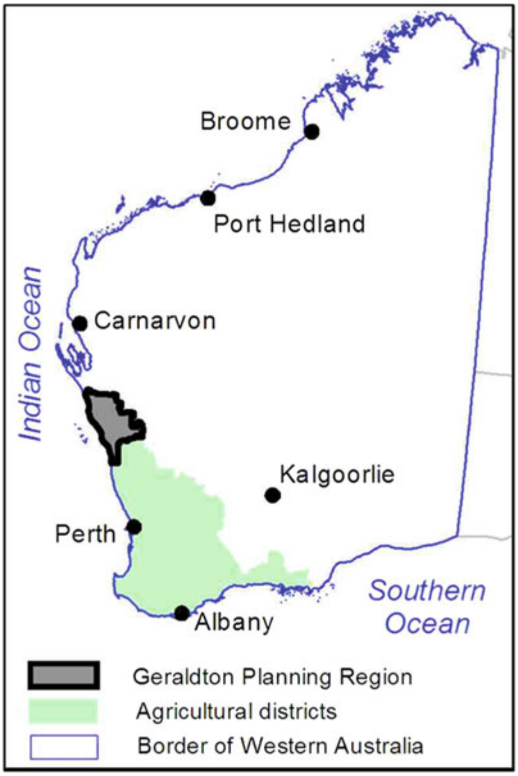

Fig. 21.1 Location of study area of HQAL pilot project

- place potential agricultural production using the resources in a broader (regional, state-wide or national) context.

High Quality Agricultural Land (HQAL) is identified from a combination of natural (soil, land capability, water resource, rainfall) and economic (production values, lot sizes) information as the most productive and versatile for either irrigated or broad acre agriculture.

The HQAL approach generates a series of maps and tables which characterise agricultural land in a way that planners and investors can readily understand. Relatively detailed maps show the area's potential for broad acre and irrigated agriculture (Figs. 21.2 and 21.3). These detailed maps were the basis for defining the simpler map of agricultural land areas (ALAs) across the Geraldton area (red lines shown in Figs. 21.2 and 21.3). ALAs are reasonably homogeneous in terms of agricultural productivity and are identified at a scale suitable for strategic planning.

An important part of the process is the characterisation of each ALA in two-page information sheets. These contain descriptions of the location, natural characteristics and agricultural importance, as well as listing its opportunities and constraints. Also included is information on remnant vegetation, lot sizes and the potential dollar value of agricultural production.

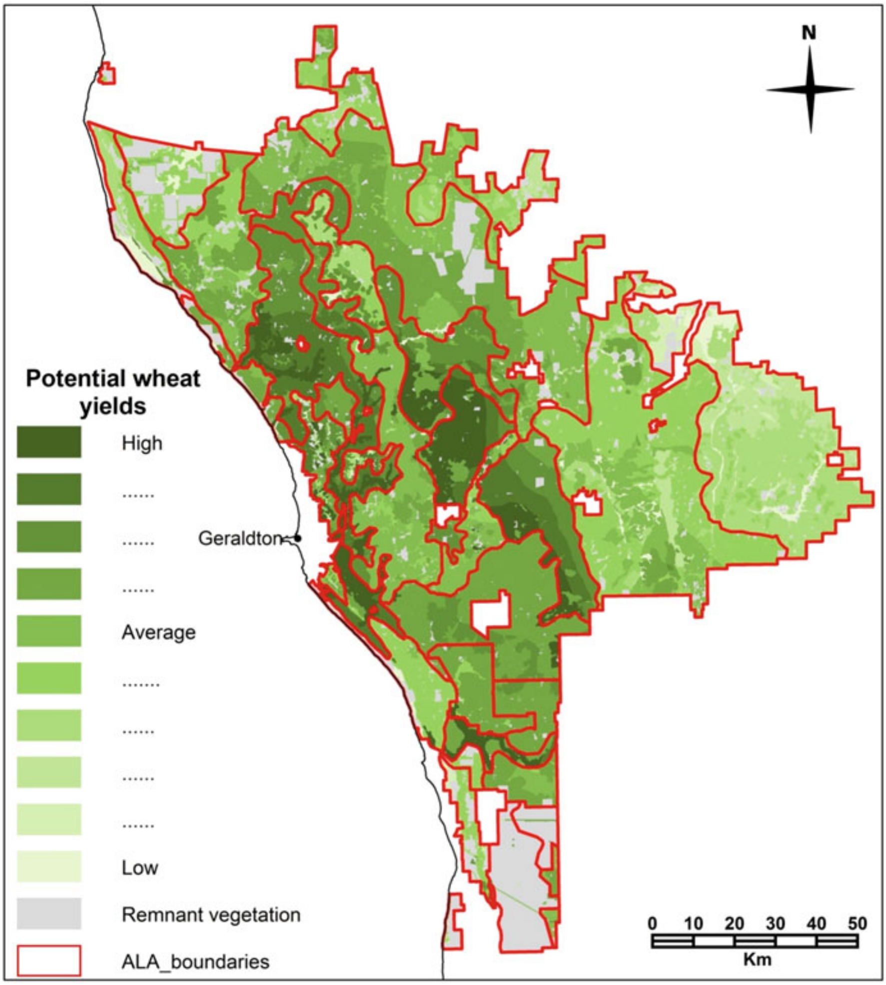

Fig. 21.2 Potential wheat yield (includes rainfall) overlain (in *red*) with boundaries of Agricultural Land Areas (Source: Tille et al. 2013)

Finally, the ALAs were grouped according to the level of versatility within the study region (Fig. 21.4) based on potential for both broad acre and irrigated agriculture.

This information has been provided to planners in the Geraldton area who are using it as an additional layer to inform their decisions. For the first time planners have access to clear, detailed and easy to understand information about land with agricultural significance to make evidence-based decisions. This complements the type of information available for competing land uses such as urban expansion, industrial development, conservation and mineral extraction.

It should be acknowledged that, while the data-driven methodology is viewed as a benefit, it is not a quick fix. The information takes time to compile and requires intense

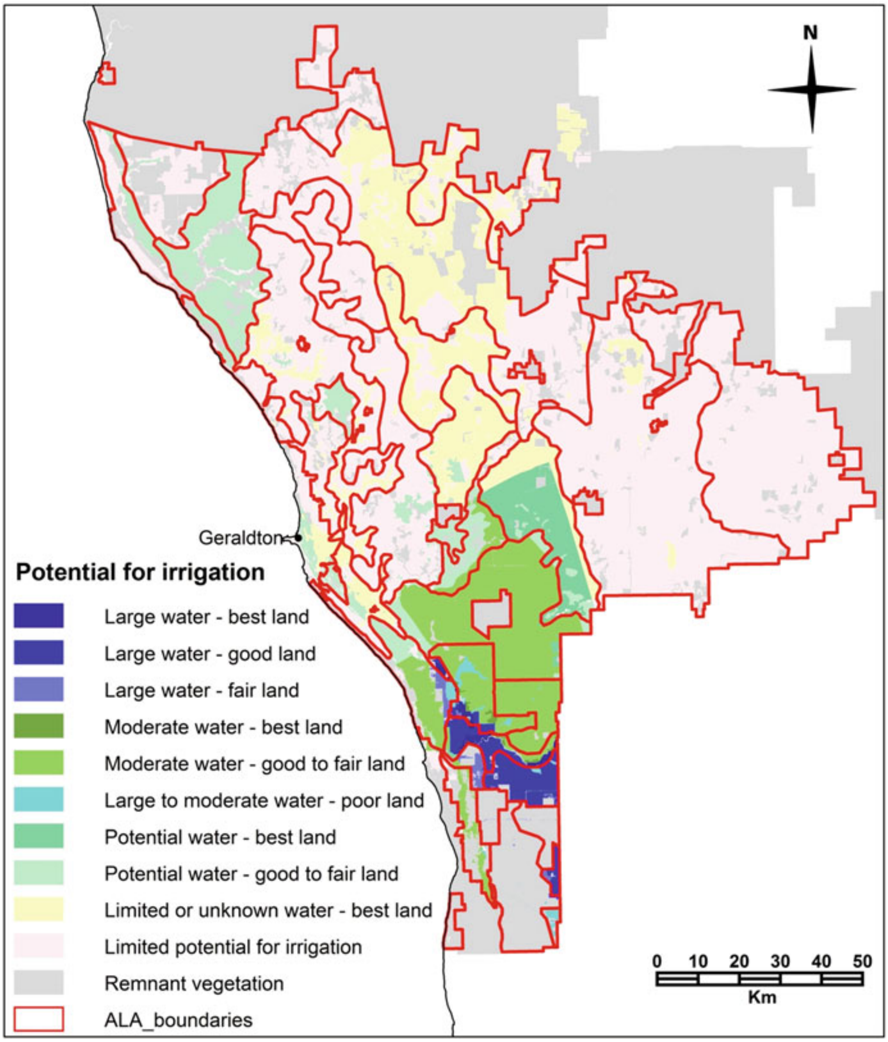

Fig. 21.3 Potential irrigated agriculture (includes ground water) overlain (in *red*) with boundaries of Agricultural Land Areas (Source: Tille et al. 2013)

input from experienced professionals across multiple disciplines. Since 2010 much soil related information has been available (ASRIS 2014). However, with the exception of isolated examples (CSIRO 2009) little progress has been made in preparing national fit-for-purpose interpreted land capability or land suitability maps for use in strategic planning. Additionally, in WA, as in other areas good water information, though available, has not been collated into consistent national data, hence is difficult to summarise meaningfully. Rushing the work will devalue the outputs or lead to errors.

It is not all bad. We do have the data available to achieve these outcomes. The catch is that a lot of time is needed to source the right data and communicate with

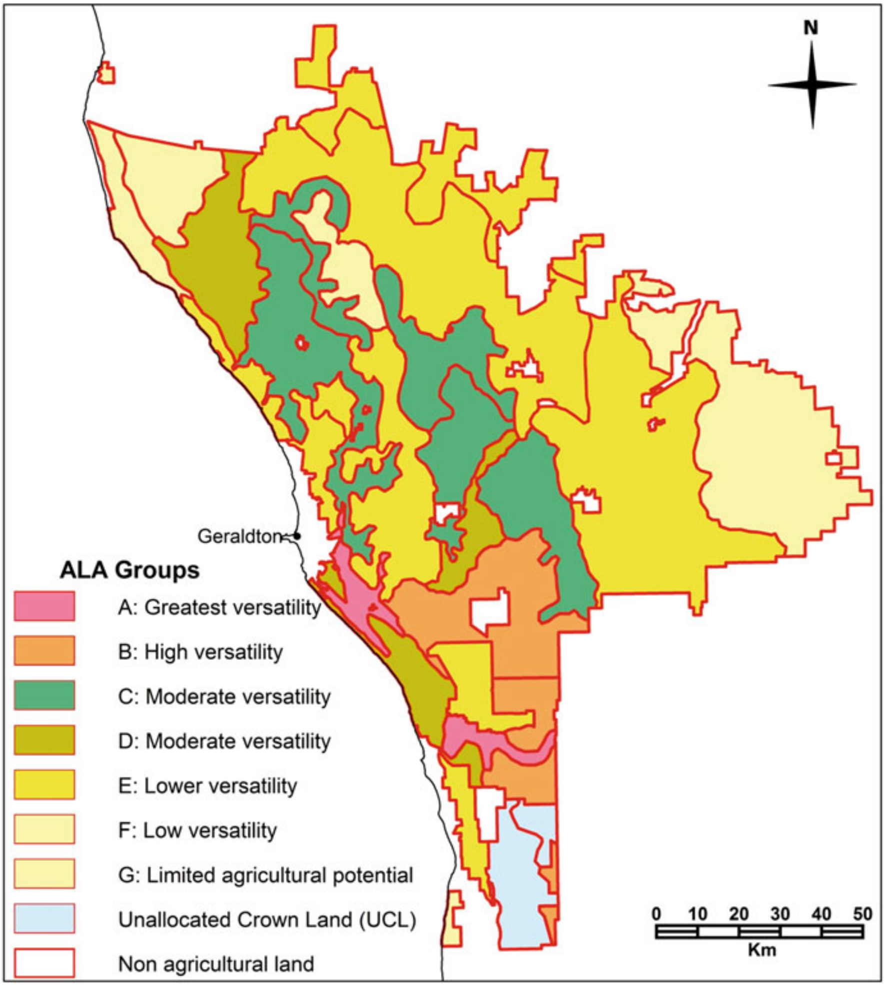

Fig. 21.4 Groupings of agriculture land areas in the Geraldton planning region (Source: Tille et al. 2013)

people who understand the detail. It then needs to be made consistent and assembled into an appropriate data structure and analysed. Consequently, the Geraldton HQAL report took three experienced professionals over a year to prepare.

21.2.1 Pressure at the Peri-Urban Fringe: What's the Issue for Agriculture?

In Australia, some of the most fertile land occurs in and around major urban areas (Budge et al. 2012). This is generally because European settlement concentrated around areas which were good for producing food.

Like other major urban areas across Australia, Perth is growing, populations are expanding and limited natural resources are becoming more sought after. At the same time, agriculture and food production are increasingly important both at a local grass roots level and as a significant part of the state and national export economy.

Clearly illustrating this growth pressure is the WAPC's plan for Perth, 'Directions 2031and beyond'. This plan addresses urban growth needs and potentials for the Perth and adjoining Peel regions of WA. It includes a series of published ABS population forecasts, indicating that the population of the Perth and Peel regions will increase from the 2010 figure of 1.4 million to somewhere between 2.40 and 2.88 million people by 2031. This would mean that there would be a need of up to 429,000 additional dwellings (WAPC 2010).

With such pressures on state and local governments around the Perth area to provide land for housing, existing planning mechanisms continue to allocate food producing areas to urban and rural residential development. Additionally, water supplies are allocated to "future urban water supply" making long-term agricultural developments impossible. As urban and lifestyle development expands and swallows up food production areas on the peri-urban fringe, the demand for food production also increases with the population growth.

So is it important to have food grown close to major centres? If we look at a graph of vegetable production around Sydney in New South Wales (NSW) (Fig. 21.5), we see that the majority of vegetable production occurs regionally, a long way from the city centre, so perhaps not?

However, if we look at the figures for perishable, leafy vegetables (Fig. 21.6) the graph looks very different. Not surprisingly perishable food is located close to where it is used.

In WA, like Sydney, a significant proportion of irrigated leafy vegetable crops occur in the local government areas at the periphery of greater Perth. For example, about 25 % of the state's lettuce crop was grown in the Perth region in 2010–2011 (ABS 2012). Over time with the expansion of the urban corridors, traditional growing areas have been displaced, meaning that they must either cease production or move to the next available patch of land that is suitable to continue their production (e.g. market gardens shifted from the Perth suburb of Spearwood to the outer suburb of Baldivis, where they are currently under pressure to move again).

Buxton and Low Choy (2007) have examined the pattern of development where, as urban areas expand, neighbouring agricultural production areas often intensify. There is generally a shift to higher yielding or higher value production in these areas, such as a move from grazing to intensive horticulture. Less intensive agricultural activities may relocate or decline. As reported by Mewett et al. (2013), peri-urban farmers benefit from being close to a larger, wealthier consumer base and a larger labour market. They can, however, be negatively affected by restrictions on farm activities such as noise, odour, stock movements and the use of agricultural sprays.

The choices of new areas for agriculture to move into are at greater distances from markets and may be less fertile or capable. Developing such areas requires massive energy inputs like fuel, fertilisers, irrigation and land levelling which,

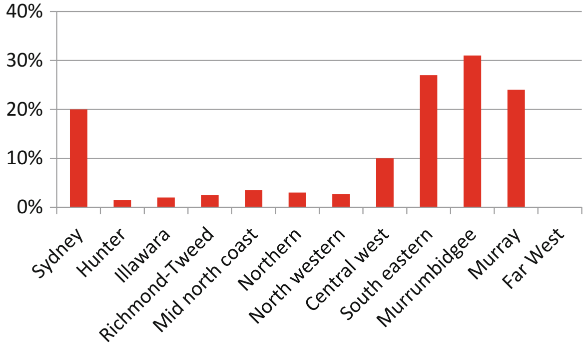

Fig. 21.5 NSW vegetable production 1997 (Source: ABS data in Sinclair 2003)

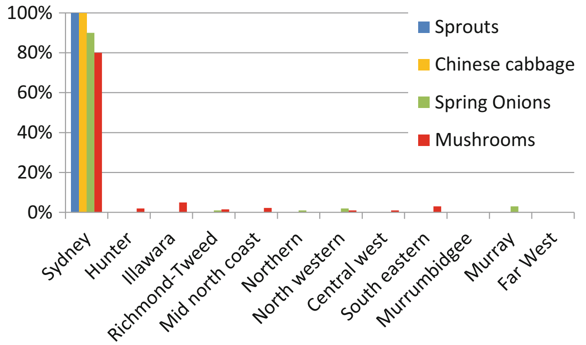

Fig. 21.6 NSW perishable vegetable production 1997 (Source: ABS data in Sinclair 2003)

according to Montarella (2014), ultimately results in highly unsustainable agricultural models. This finding accords with a study of urban expansion in China, where the new agricultural land developed to replace losses to urban expansion was 80 % less productive (Huimin Yan et al. 2009).

The decline of agriculture in peri-urban areas is driven by the gradual subdivision of larger areas of land to smaller lots of <5 ha (Fig. 21.7a, Short et al. 2011). Small lot sizes constrain the land use flexibility and are generally viewed as being unviable for profitable agricultural production, though part-time and niche production is common and important in some peri-urban areas.

Compounding this, there has also been more subdivision occurring on land with high capability for agriculture (Fig. 21.7b). It seems that lower quality land is readily subdivided when lot sizes are large. However, within rural residential areas there is more subdivision on high quality land – effectively removing this land from even niche or part-time production.

So, Santhanam-Martin and Lawrence (2011) ask, what happens in 30 years' time when both domestic and international food demands have increased substantially and perhaps the price signals, consumer tastes and market demands have changed? Thirty years on, some of our better, more versatile areas for food production close to Perth will have been overtaken by bitumen, bricks and concrete, and water supplies reallocated. Many food production areas will have moved even further to

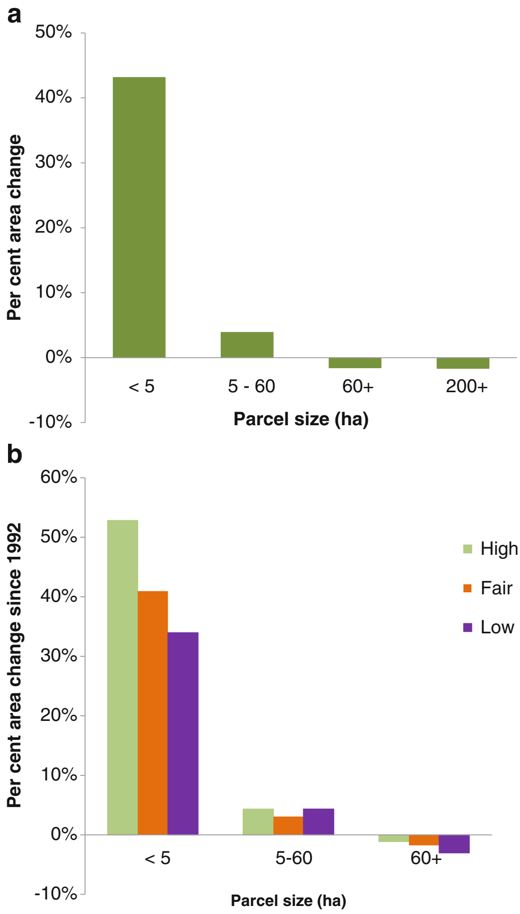

Fig. 21.7 (**a**) Percentage area change within parcel size categories from 1992 to 2008 in Coastal shires of South-West of Western Australia from Geraldton to Albany (Short et al. 2011). (**b**) Subdivision on high, fair and low quality agricultural land from 1992 to 2008 in Coastal shires of South-West of Western Australia from Geraldton to Albany (Short et al. 2011)

the north and south of Perth where the economies of distance from markets are more prominent. As Santhanam-Martin and Lawrence (2011) point out, there's an irreversibility here that does not feature in market calculus.

21.2.2 *Why Then Is Our Identification of High Quality Agricultural Land in the Geraldton Region So Important?*

The total additional groundwater available in the south-west of WA in 2009 was approximately 567,000 ML (Department of Water 2009). Additional surface water was estimated at 118,000 ML (Westrup et al. 2007). The Australian Water Resources Assessment (NLWRA 2000) estimated that 40 % of groundwater and 66 % of surface water supplies are used for irrigation. Hence a realistic potential increase in the area of land in the south-west which could be used for irrigation is perhaps 80,000 ha. One of the few areas where new large horticultural developments could occur extends from Gingin to Dongara, associated with the water resource potential of the North Perth Basin aquifers (D Bennett, DAFWA, pers. comm.).

These aquifers underlie part of the HQAL pilot study area with additional HQAL analysis expected to cover the rest of the North Perth Basin. To put the potential in the north Perth basin in context, it is similar in scale to the potential of readily available ground water in northern Australia (CSIRO 2009), but with a more temperate climate, closer proximity to markets and lower development costs.

21.2.3 Gaps in the Analysis

Useful contextual information about agricultural land applicable at regional or local scales is remarkably sparse in Australia. The HQAL methodology is limited in that it currently only ranks agricultural land within a specified region, but how important is it for the state or for Australia? For the high quality agricultural land methodology in the Geraldton planning region to be successful, more effort is needed in the relative assessments of agricultural land, water and agricultural industries at the state and national scale. In time this comparison might be possible, however a much larger area needs to be analysed for this to be achieved.

The data presented from opposite sides of the country in Figs. 21.5, 21.6, and 21.7 also highlights the problem. We have a lot of very good, very big picture data (e.g. the amount of vegetable production in Australia). We also have a lot of very detailed information such as the high quality agricultural land analysis in Geraldton. However, what we are missing is the intermediate level of data, which is usually regional and state summary information that looks at subcomponents of industries and resources (such as the graphs in Figs. 21.5 and 21.6). This information:

1. Allows ranking of agricultural land between regions (i.e. is my good land the same as yours?). Studies use different data and methods, which does not make them wrong, just hard to compare.
2. Provides summaries that allow us to sensibly connect the big picture with what is happening on the ground, and establish why managing the best agricultural land is important. For example, there is a lot of agricultural land, but agriculture is not a single industry. There are large areas of cropping land in south-west Western Australia which are not under pressure from urban growth. However, land suitable for intensive irrigated horticulture with a combination of good land and water are very scarce and difficult to replace. These areas are under pressure from urban growth.

21.3 Conclusion

The benefits of the HQAL process are that it can rank large tracts of land according to versatility for agricultural production and it highlights the local and regional benefits of these agricultural resources. By doing this, it identifies the "crown jewels", the best portions of land and associated water resources. These areas are small and difficult to replace.

The HQAL method is data-driven, transparent and defendable. There is a lot of information summarised as part of the process, and this is all available for making informed planning decisions. This will help rank agricultural land against competing land uses, such as urban, industrial, conservation and mining which are often better represented than agricultural land uses in planning processes. When HQAL areas are incorporated into town planning schemes, it will formally guide the development of agricultural resources.

Still missing from this process, however, is the state and national context. We have demonstrated that the most versatile land (and water) covers a small area, and is locally important. However, it is not immediately clear that the North Perth Basin aquifers are possibly the last remaining area with significant additional development potential for irrigated agriculture in the south-west of Western Australia. As such, it is an important resource for the state and Australia.

If this link from local through to state and national significance is not forged, the risk is that some of the most strategically important areas of agricultural land will fail to be identified. As a result, urban uses will continue to displace high quality agricultural land, without considering the long-term consequences for Australia.

References

ASRIS (2014) Australian soil resource information system. http://www.asris.csiro.au/. Accessed Nov 2014

Australian Bureau of Statistics (2012) Agricultural commodities, Australia 2010–2011. Australian Government. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7121.02011-12?OpenDocument

Budge T, Butt A, Chesterfield M, Kennedy M, Buxton M, Tremain D (2012) Does Australia need a national policy to preserve agricultural land? Research Report, Australian Farm Institute, Surry Hills, Australia

Buxton M, Low Choy D (2007) Change in peri-urban Australia: implications for land use policies, State of Australian cities conference, Adelaide, 28-30 November
CSIRO (2009) Northern Australia land and water science review. Full report. Northern Australia land and water taskforce. Report coordinated by the Commonwealth Scientific and Industrial Research Organisation, October 2009. http://pandora.nla.gov.au/tep/116124
Department of Water (2009) South west groundwater areas allocation plan, Water resource allocation and planning series no. 21. Department of Water, Perth, https://www.water.wa.gov.au/__data/assets/pdf_file/0013/1822/86107.pdf
Huimin Yan, Jiyuan Liu, He Qing Huang, Bo Tao, Mingkui Cao (2009) Assessing the consequence of land use change on agricultural productivity in China. Global Planet Change 67(2009):13–19. http://www.sciencedirect.com/science/article/pii/S0921818108002130
Mewett J, Paplinska J, Kelley G, Lesslie R, Pritchard P, Atyeo C (2013) Towards national reporting on agricultural land use change in Australia. ABARES Technical report 13.06, Canberra
Montarella L (2014) Could a global grab for fertile soil bring civil unrest? http://www.abc.net.au/news/2014-03-23/luca-montanarella-can-healthy-soils-feed-the-world/5332724
NLWRA (2000) Australian national water resources assessment 2000 – surface water and ground water – availability and quality. Commonwealth of Australia. http://trove.nla.gov.au/work/9878863
Planning Institute of Australia (2011) Submission to the national food plan issues paper. http://www.planning.org.au/documents/item/3206
Santhanam-Martin M, Lawrence G (2011) Farms, mines and foreign ownership. A case for regulation in the national interest? The Conversation, 4 July 2011. http://theconversation.com/farms-mines-and-foreign-ownership-a-case-for-regulation-in-the-national-interest-2107
Short N, van Gool D, Safstrom R, Percy H (2011) Rural subdivision trends in the South West of Western Australia. Internal report, Department of Agriculture and Food, Western Australia
Sinclair I (2003) Growth management and rural land. University of NSW Faculty of the Built Environment – Planning Law and Practice Short Course 2003. www.ruralplanning.com.au
SLIP NRM (2014) Natural resource management shared land information platform. http://maps.agric.wa.gov.au/nrminfo/
Tille P, Stuart-Street A, van Gool D (2013) Identification of high quality agricultural land in the mid west region: stage 1 – Geraldton planning region, Resource management technical report 386. Department of Agriculture and Food, Perth. http://researchlibrary.agric.wa.gov.au/rmtr/371/
WAPC (2002) Statement of planning policy no. 2.5: agricultural and rural land use planning. Western Australian Planning Commission, Perth
WAPC (2010) Directions 2031 and beyond – metropolitan planning beyond the horizon. http://www.planning.wa.gov.au/dop_pub_pdf/plan_directions2031_Part1.pdf
WAPC (2012) State planning policy 2.5 – land use planning in rural areas. Western Australian Planning Commission, Perth
WAPC (2014) Rural planning guidelines – version 2. Western Australian Planning Commission, Perth
Westrup T, Tille PJ, Bennett DL, Stephenson BE (2007) Potential capture of surface run-off for reliable water supplies in the 500–825 mm rainfall zone of South Western Australia, Resource Management Technical Report 314. Department of Agriculture and Food, Perth. http://researchlibrary.agric.wa.gov.au/rmtr/296/

Chapter 22
Food Efficient Planning and Design for Peri-Urban Neighbourhoods

Sumita Ghosh

Abstract Peri-urban areas are the strategically most important emerging built environments that need to integrate appropriate food efficient design and planning. This chapter aims to understand food responsive design and form specific characteristics of new residential neighbourhoods in peri-urban areas. A review of three key food urbanism approaches was conducted. Two international master planned community case studies from the United States of America (USA) that apply 'Agrarian Urbanism' principles were analysed. A small scale residential neighbourhood case study in Sydney, Australia was redesigned to test applicability of these principles as identified through the review and analysis. Results from these case studies, emphasise the importance of protecting land in the peri-urban locations. Appropriate design and planning approaches can contribute significantly. Developing a strong evidence base; understanding community aspirations; formulating appropriate planning policy and recognising trandisciplinary connections of food efficient design and planning would be vital for building resilient communities of the future.

Keywords Agrarian urbanism • Master planning • Food efficient design • Peri-urban planning • Local food production

22.1 Introduction

Increasing needs to accommodate future population have driven rapid urban expansion and consumption of food production spaces mainly agricultural land located at the rural-urban interface. Land use changes are shaped by demand, peoples' choices, environmental settings, socio-cultural factors and planning and design regulations (Hall 2010; Gleeson 2006). Research has recognised the importance of integrating local food production spaces and practices in designing new and retrofitting human

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environments (Grimm 2009; Duany and Duany Plater-Zyberk & Co (DPZ) 2010; Ghosh 2012; Donovan, Larsen and McWhinnie 2011). Peri-urban areas are strategically placed and have important transforming built environments that need to integrate appropriate food efficient design and planning for future. This chapter builds on the author's earlier research and focuses on exploring food efficient design and planning options for peri-urban neighbourhoods.

22.2 Aims and Objectives

Peri-urban areas are undergoing morphological changes through continuing urban development processes. This chapter aims to identify food responsive design and planning approaches, principles and form specific characteristics essential for new and existing peri-urban residential neighbourhoods. The main four objectives of this chapter are to:

- review three key food urbanism principles, models and methods for food efficient design and planning;
- analyse two master planned community case studies from the USA: Serenbe, Georgia and Prairie Crossing, Illinois;
- determine ways of incorporating principles from the review and two case studies in a small scale concept plan for a residential neighbourhood case study in Sydney; and
- identify a set of key future research areas that would significantly benefit and guide peri-urban neighbourhood planning and policy.

22.3 Research Method

The research methodology of this chapter integrated systematically the processes of review, analysis and recommendations and consisted of four main steps.

Firstly, three contemporary and relevant design and planning approaches: 'Conservation Subdivision', 'Typology of Continuous Productive Landscapes', 'Four Models of Food Urbanism' and 'The Transect' that are applicable to peri-urban neighbourhood planning were selected for a review. These three approaches are pertinent as they exemplify emerging as well as continuing urban design theories and practice. These approaches place central significance on design and planning for protecting natural areas and food production resources; creating a sustainable urban or suburban form; providing solutions for accommodating urban growth positively at the urban fringes; putting emphasis on context based social and community development and generating a local food economy as an integral part of responsive built environments. The review was conducted and the effectiveness of these approaches were discussed and compared based on nine factors: design with nature; agricultural and natural area protection; urban form typology; subdivision planning; social connectivity; environmental benefits; economic values; spatial scale and suitability to peri-urban planning.

Secondly, two international master planned food urbanism case studies from the USA were selected based on the outcomes of the review and were analysed from neighbourhood design and planning perspectives. Two case studies from the USA selected were: Serenbe, Atlanta and Prairie Crossing, Chicago, Illinois. These case studies are located in the peri-urban areas and followed new urbanism principles of place making and developing new communities and built environment patterns that are sympathetic to nature. The case studies were analysed based on nine important factors: design and planning; agricultural and natural area protection; built form typologies and neighbourhood design; social and cultural networks; environmental sustainability; ecological benefits; local economic values and greenfield development model. The most important elements applicable for successful peri-urban neighbourhood design and planning were identified from the analysis of these case studies.

Thirdly, applicability of food efficient planning and design principles in a Sydney case study was examined. A comparatively new residential neighbourhood case study from Penrith City Council in Sydney was selected. Penrith City is located approximately fifty four kilometres from Sydney Central Business District (CBD) at the fringes of Sydney Metropolitan Area (Penrith City Council 2014a). Using Geographic Information Systems (GIS) methods, existing morphological characteristics and allocation of different land cover patterns (such as built up roof areas, roads, paved driveways and surfaces, tree canopy cover and other areas) were calculated to understand conventional neighbourhood design for this case study. A hypothetical redesign exercise on a small scale Sydney case study was conducted applying the relevant principles identified from the review and analysis of two international case studies. A simple conceptual neighbourhood plan was prepared for the Sydney case study. This process allows validating how the present neighbourhood design characteristics could have been altered to accommodate food efficient design and planning principles. An evaluation and justification for the redesign assist in comprehending possible positive changes in peri-urban neighbourhood planning in an Australian context.

Finally, recommendations formulated as outcomes of this research include identification of a set of key beneficial future research areas and a discussion on essential peri-urban neighbourhood planning policy that could guide successful food efficient peri-urban neighbourhood planning at the urban fringes.

22.4 Literature Review

Peri-urban zones have been defined diversely by different research approaches and various typologies of peri-urban environments exist (Iaquinta and Drescher 2000). In general, peri-urban areas are non-urban; located at the urban and rural interfaces and have actively transforming land uses. In these areas '*quality of urban environments*, *including township character*, *ecosystems and productive agricultural land is under increasing pressure*' and therefore, '*planning for growth*' is vitally important for these areas (Department of Transport, Planning and Local Infrastructure, Victoria 2014). Current research on design and planning of human environments, in synergy with nature, covers a broad field. Provisions for growing food within built environments in different density developments are fundamental to this concept and closely link with design and planning agendas for cities and towns of the future. Literature review for this chapter focuses mainly on three of food urbanism approaches: 'Conservation Subdivision' (Arendt 2010a, b); 'Continuous Productive Landscape' (Grimm 2009) and 'Four Models of Food Urbanism' and 'The Transect' (Duany et al. 2010). These three approaches are significantly important as these approaches could be applied effectively to peri-urban planning.

22.4.1 'Conservation Subdivision' Approach

Arendt (2010a) argues that designing a new urban development using 'Conservation Subdivision' principles could maximise economic values, protect land resources and create a sustainable community. 'Conservation subdivision' approach follows a four step design process (Arendt 2010a). The first step includes identifying open spaces on site in order to preserve existing natural or environmentally responsive features and potential development zones. In the second step, potential housing locations are decided so that overall neighbourhood design and access to facilities (such as squares, greens and parks) could be finalised to maximise the environmental and economic values of the properties. Third step incorporates design and planning of various types of movement patterns which include pathways and trails for pedestrians or cycles as well as streets for vehicular accesses to houses. In the final step the different lot boundaries are decided which is considered the least significant part of the overall design process (Arendt 2010a). This 'Conservation Subdivision' design process is notably different to 'Conventional' design approach (Fig. 22.1)

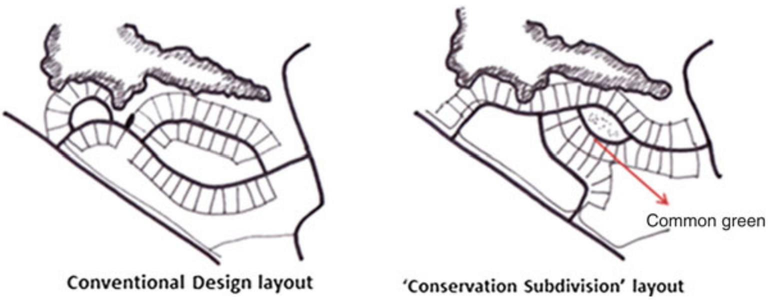

Fig. 22.1 Comparison between 'Conventional' and 'Conservation Subdivision' approaches (Source: Arendt 2010b, Drawn by: Sumita Ghosh)

and situates primary importance on the conservation of land in orchards, agricultural and other food producing areas, preservation of natural vegetation and historic features; maximises economic values of the properties with provisions for living within natural settings and creates minimal environmental and ecological impacts on earth. Provisions for different types of food growing spaces in home and community gardens at smaller urban scales and farmland managed by community supported agriculture (CSA) at a larger scale are possible using this approach (Arendt 2010a). 'Conservation subdivision' approach is very useful for applications to peri-urban planning. It acknowledges the immense value of 'The Transect' concept detailed later in this chapter.

22.4.2 'Continuous Productive Landscape' Approach

Grimm's (2009) research based on designing a 'typology of continuous productive landscapes' is integrated with new or retrofitted existing built environments. It adopts a complete food system design approach in relation to various typologies of urban spaces across low to high development densities at different spatial scales. '*An urban food system ….. food production*, *processing*, *distribution*, *marketing*, *consumption and waste management in an urban landscape*' (Grimm 2009, p. 8). In a case study of Story County, Iowa in the USA, six types of local food production sites determined what could be embedded in a settlement as important green infrastructure: private residence gardens, community/allotment gardens, food boulevards, institutional food gardens (religious/education/non-profit), neighbourhood farms and urban farms (Grimm 2009). The typologies of food spaces are categorised based on five key criteria based factors: user/producer/manger (management of the productive activity); scale (productive space area as a share of total site/activity); characteristics (utility infrastructure provided, level of community services and public ownership); production types (layout plan, circulation and facilities on production site) and distribution/markets (direct/indirect) (Grimm 2009). Figure 22.2 explains further how these different typologies of food production spaces could be integrated within our built environments. This research argues that integrating a complete food system in a built environment setting with daily activities would facilitate a healthy, sustainable and socially connected community. This is a meaningful approach which aims to reorganise, design and utilise to a greater extent any available urban spaces for food production. Thus, a primary focus of this approach on 'food urbanism' is relevant across peri-urban, inner city and suburban planning contexts.

22.4.3 Four Models of Food Urbanism and 'The Transect'

A pioneering urban design theory for planning and designing food efficient sustainable communities developed by Duany et al. (2010) in this field has identified four models of food urbanism: 'Agricultural Retention', 'Urban Agriculture', 'Agricultural Urbanism' and 'Agrarian Urbanism' (Duany et al. 2010). Designing

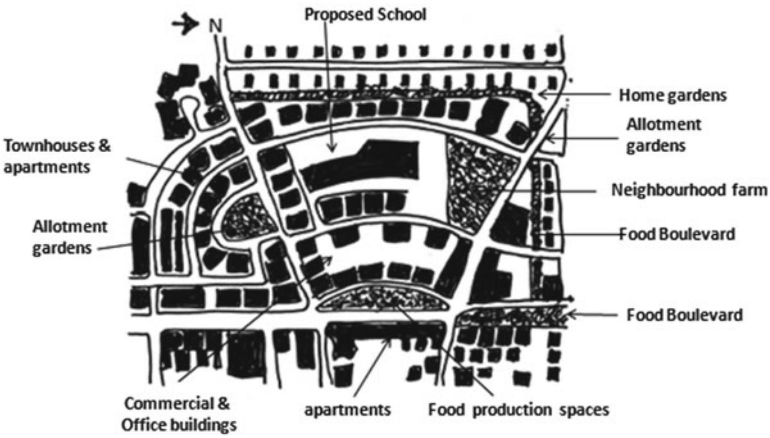

Fig. 22.2 Typology of 'Continuous productive landscapes' (Source: Grimm 2009, Drawn by: Sumita Ghosh)

and planning for food efficiency lies at the heart of built environment designs in these four models. The variations of these four models are reflected in their designs, economical settings, operational processes, opportunities, community development and outcomes. It is evident that each of these models is associated with or generates a set of unique form specific or morphological characteristics. The notion of 'Agricultural retention' relates to protection of farmland at a regional scale, while 'urban agriculture' idea refers to local food production on any available land such as vacant land, brown field sites, home gardens etc. at a local scale within a settlement (Duany et al. 2010 pp. 7–8). 'Agricultural urbanism' originated from Ebenezer Howard's garden cities conceptual framework and visualises a working agricultural farm on which resident community and businesses are economically dependent and 'food production forms the basis for urban density' (DPZ 2014c). Southlands development with an area of 218 ha in Vancouver, British Columbia is an example of a master planned community based on the 'Agricultural Urbanism' model (DPZ 2014c; Congress for New Urbanism (CNU) 2010). Principles of the 'Agrarian Urbanism' model link food efficient designs to new urbanism principles. This model initiates an intentional sustainable agrarian society and community development with a complete food system such as production, distribution and disposal (Duany et al. 2010 pp. 7–8). Hampstead is an area of 168 ha of traditional neighbourhood development in Montgomery, Alabama, USA which supports principles of 'Agrarian Urbanism' and 'Smart Code' or a transect-based zoning and planning model (DPZ 2014d). '*Agrarian Urbanism is a concept that involves food not as a means of making a living*, *but as a basis for making a life and structuring the places in which we live*' (DPZ 2014a). In this chapter, a total of two master planned community case studies: Serenbe, Atlanta and Prairie Crossing, Illinois from the USA are analysed following 'Agrarian Urbanism' principles to identify how food urbanism principles are incorporated in design and planning.

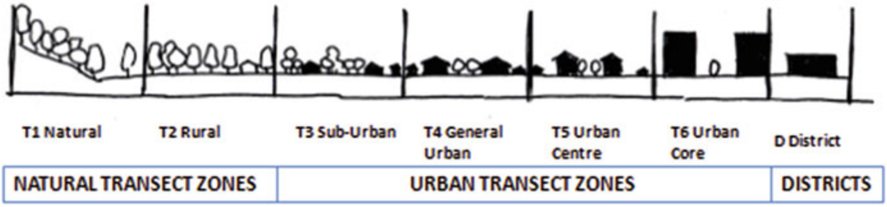

Fig. 22.3 Rural-urban continuum – 'The Transect' (Source: The City of Miami 2014; Drawn by: Sumita Ghosh)

The 'Agrarian Urbanism' approach is intrinsically linked to 'The Transect' concept (DPZ 2014b). 'The Transect' as a planning strategy (Talen 2002) provides a realistic basis of zoning for different types of development patterns along a rural-urban continuum (Duany 2002; Duany et al. 2010; The City of Miami 2014). 'The Transect' has special districts (SD) and six broad land use zones: natural (T1), rural (T2), suburban (T3), general urban (T4), urban centre (T5) and urban core (T6) (Duany et al. 2010; The City of Miami 2014). Special districts (SD) (such as airports, rail yards etc.) are special purpose or have larger areas and are regulated by specific zoning requirements different from these six land use zones (Sorlien 2015). Out of the six main land use zones identified, T2 Rural and T3 Suburban zones could link efficiently to peri-urban zones. Miami 21, an integrated zoning code was developed based on 'The Transect' conceptual framework and has been adopted for planning in The City of Miami (2014). 'The Transect' structures different urbanism elements for different zones; represents 'an index of diversity' (Duany 2002, p. 257) and integrates spaces for agricultural or food production practices in designing new food urbanist communities along the different zones of 'The Transect'. Figure 22.3 presents an overall cross section of different land use zones in 'The Transect'.

22.5 Research Analysis

22.5.1 Effectiveness of Three Food Urbanism Approaches

There are immense possibilities for incorporating attributes of three urbanism approaches in designing new communities in rural and suburban zones or in peri-urban areas. It is very clear from these approaches that preservation of natural vegetation and food producing spaces are absolutely important. The 'Agrarian Urbanism' model is considered the most comprehensive and holistic approach out of the four models as food has a significantly deeper meaning in terms of settlement planning and community development. Effectiveness of these three approaches: 'Conservation Subdivision', 'Continuous Productive Landscapes' and 'Agrarian Urbanism' approaches are compared in Table 22.1 following the analysis criteria for review.

Table 22.1 Effectiveness of three approaches

Criteria	Conservation subdivision	Continuous productive landscapes	Agrarian urbanism
Design with nature	Sympathetic with nature	Creating human-nature interfaces across various development densities	Design with nature, applies new urbanism principles and food as the basis of community development
Agricultural and natural area protection	Protection of natural areas and productive land through subdivision and house design	Utilises available land within development for establishing a food system network	Protection of land and conscious design to maximise productive land
Urban form typology	Low density	Low, medium and high densities	Low to medium densities
Subdivision planning	Highly important	Retrofitting subdivisions and urban spaces are important	Highly important
Social connectivity	Connected	Connected	Connected
Environmental benefits	Significant	Significant	Significant
Economic values	High property values	Local food economy	Local food economy
Spatial scale	Community to local	City to local	Community to local
Suitability in Peri Urban Planning	Excellent	Whole planning approach and part applicable	Excellent

Sources: (Arendt 2010a, b; Duany et al. 2010; Grimm 2009; Analysed by: Sumita Ghosh)

It is essential to reorient conventional design and planning practices and planning policy to adopt new approaches and to maximise the social, environmental and economic benefits of local food production, preservation of, and proximity to, natural areas, improvements in community health through human–nature interactions, self-sufficiency and thriving local economy in lower density developments. New approaches to design and planning would accommodate urban growth and lifestyle choices in the urban fringes in a sustainable and responsive manner; protect vital land resources and vegetation and generate sustainability awareness and resilient communities of future.

22.5.2 An Analysis on Two Master Planned Case Studies

22.5.2.1 Case Study One: Serenbe, Atlanta, USA

Serenbe is a master planned award winning community with an area of 1,000 acres or 405 ha built in the Chattahoochee Hills as part of a 40,000 acre or 16,187 ha city in Atlanta in the USA. Serenbe, located at the city fringes was developed by Steve and Marie Nygren (Development Concepts Incorporated 2014). It aims to accommodate a traditional lifestyle community; protect at least 70 % of the total site as a green space and to offer residents wellbeing and the benefits of living in natural settings (Development Concepts Incorporated 2014). Currently a total of 400 residents live at Serenbe; hamlets are villages responsively designed with minimal environmental impacts and have a variety of housing choices available (Serenbe Development 2014). Roads are designed maintaining natural topography of the land and pedestrian pathways and nature trails provide ample opportunities for easy walking. Significant tree canopy cover provides carbon storage and sequestration benefits. A certified organic farm, Serenbe Farms, produces 300 different types of vegetables, herbs, flowers, and fruits reducing farm-to-table distance, supplying to three local restaurants: Blue Eyed Daisy Bakeshop, The Farmhouse and The Hil (Serenbe Development 2014) thus forming a close loop local food cycle. The local food production in this development has adopted a community supported agriculture (CSA) program. Serenbe Farmer's and Artisan Market assists in the food distribution process within the local community (Serenbe Development 2014). Figure 22.4 presents design and site planning of Serenbe development.

Considering nine identified important factors for case study analysis, Table 22.2 presents the case study one, Serenbe in the USA. Concepts applied in Serenbe are also applicable in peri-urban neighbourhood planning in developing a food efficient sustainable community.

> *It is a national model for the future of balanced development in the U.S.— focusing on land preservation, agriculture, energy efficiency, green building, walkability, high density building, arts and culture, and community living for multiple generations.* (Imery Group 2016)

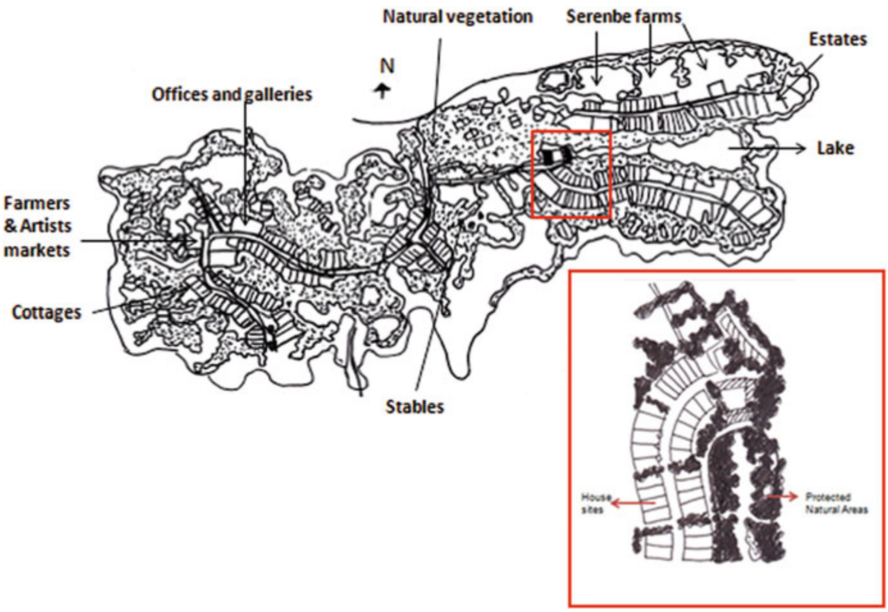

Fig. 22.4 Site plan and neighbourhood layout, Serenbe, USA (Source: Serenbe Development, 2014, Drawn by: Sumita Ghosh)

Table 22.2 Case Study One: Serenbe, Atlanta, USA

Criteria	Case Study One: Serenbe, Atlanta, USA
Design and planning total area of development	Organic design and planning with high importance to preservation of natural areas and creating a sustainable community, 1000 acres or 405 ha
Agricultural and natural area protection	70 % mandatory preserved green space on total site devoted to 30 acre or 12 ha farming and natural trails and vegetation;
Built form typologies and neighbourhood design	Mixed housing types: separate houses, town houses and live-n-work houses in low to high densities; transit oriented design, commercial spaces, omega shaped hamlet to initiate active living practices, walkable paths and curvilinear streets
Social and cultural networks	Serenbe Art Institute; Communal gathering spaces; urban design elements e.g. street facade design to maximise public realm
Environmental sustainability	Mandatory green building standards by EarthCraft Home and LEED certified buildings; geo-thermal heating for buildings; waste recycling and composting, alternative fuel usage; water efficient measures 25 % less water usage,
Ecological benefits	Tree canopy store 1,333,840 US tons of carbon and annually sequester 52,660 US tons of carbon and remove US1,484.01 tons of air pollution; bio retention, wetlands and other water sensitive practices; Landscaping with EarthCraft Certified Native and organic plants
Local economic values	25–50 % more values for properties as located around green spaces; Acts as a cultural destination for people in the town and tourists; Serenbe Farm with an area of 30 acres or 12 ha produce certified organic and biodynamic food products and distribution through CSA program and in weekend markets and farm tours; Community has three restaurants;
Greenfield development model	Excellent model for a greenfield development

Note: 1US ton = 0.907 Metric ton
Sources: (Serenbe Development 2014; Development Concepts Incorporated 2014)

22.5.2.2 Case Study Two: Prairie Crossing, Illinois, USA

Prairie Crossing is a ‘conservation community’ (Prairie Crossing 2014) built on 668 acres or 270 ha by Vicky and George Ranney in Chicago, Illinois in the USA (Ranney et al. 2010). This development actively engages agriculture as a central focus to creating a new community and development (Ranney et al. 2010). This case study integrates ‘Agrarian Urbanism’ principles and ‘New Urbanism’ methods in design and planning. Creating liveable environments with varied density patterns, public transport access, and organic nature of design which is vernacular to the native prairies landscape are unique to this development. Role of growing food extends beyond simply producing own food. Food establishes new pathways for enabling successful social networks and community participation processes and forms a reliable economic base for an agrarian society.

Community connectedness and a sense of belonging are created by activity patterns and generated by the development and gazebo concerts, farm markets and places like Byron Colby Barn offering venues for events, lectures, concerts within the Prairie Crossing development (Prairie Crossing 2014). Figure 22.5 presents the site plan for the Prairie Crossing development. Table 22.3 analyses the important

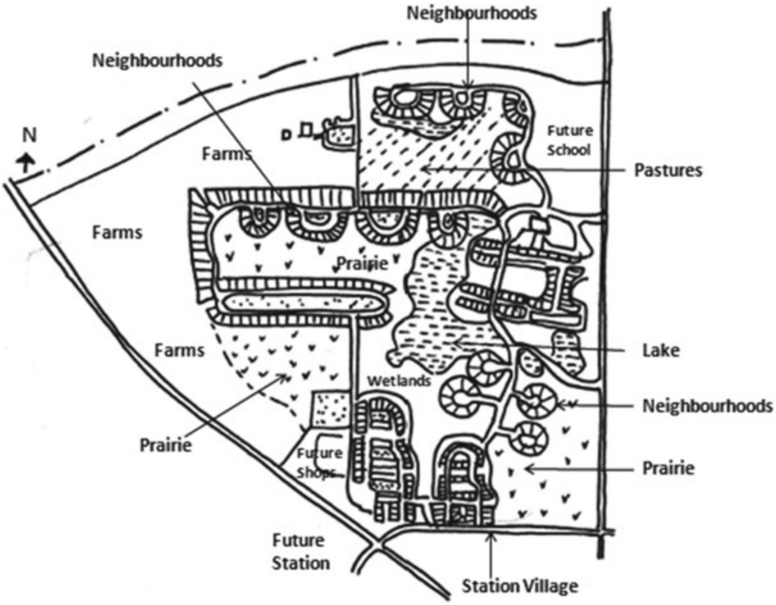

Fig. 22.5 Site plan, Prairie crossing, USA (Source: Prairie Crossing 2014, Drawn by: Sumita Ghosh)

Table 22.3 Case Study Two: Prairie Crossing, USA

Criteria	Case Study Two: Prairie Crossing, Atlanta, USA
Design and planning and total area of development	Design and planning with primary importance to provisions for agricultural or productive land and preservation of natural areas and creating a sustainable community around farming as the main activity. 668 acres or 270 ha
Agricultural and natural area protection	60 % of total site is open space and 100 acre or 40.5 ha devoted to organic farming for three separate farming organisations; Pastures, lakes and ponds, 165 acres or 67 ha of restored native prairies and 20 acres or 8 ha of restored wetlands and 16 acres or 6.5 ha of historic hedgerows form the outdoor environments
Built form typologies and neighbourhood design	Mixed-use commercial, housing types – 360 single family homes and 36 condos; transit oriented design with 2 train stations, 3 schools, learning institute and community centre
Social and cultural networks	Communal gathering spaces; urban design elements built forms, colours and landscaping of natural prairies for place making, public health and social wellbeing in working together in a food based community and 10 miles or 16 km of trails promoting active transport and engagement
Environmental sustainability	Strom water runoff filter through wetlands and ponds; U. S. Department of Energy-approved “green” construction techniques applied to buildings
Ecological benefits	Maintaining of large areas of natural vegetation and organic farming,
Local economic values	Prairie Crossing farm with an area of 100 acres or 40.5 ha creates a local food system and economic values. Three farm organisations and local businesses and connect to regional food initiatives and farm-based educational opportunities
Greenfield development model	Excellent model for greenfield development

Sources: (Prairie Crossing 2014; Ranney et al. 2010) characteristics of this development considering the nine identified important multi-dimensional factors for analysis.

22.5.3 Key Principles from Two Case Studies

The two case studies, Serenbe and Prairie Crossing, put an immense emphasis on the importance of protecting land in the peri-urban locations. Appropriate design solutions and case specific planning processes can assist in protecting land for food production; preserving natural areas and developing a responsive community.

Using a suitability analysis, building locations are suggested on the sites after finalising the preserving of natural features. In these two very different cases two unique patterns of development emerge at the city fringes. These case studies establish that agendas for resource efficiency, efficient environmental design and planning and applications of new urbanism principles of walkability, transit oriented design, mixed use housing, local economic development, good architectural styles and urban design concepts are feasible in creating new communities in peri-urban areas. Four key principles emerge that could be applied in a peri-urban residential neighbourhood context follow.

- Preservation and creating a connected open space network that integrates natural areas as well as food production spaces with built forms within and beyond the site;
- Designing and planning for traditional and compact built forms following 'Agrarian Urbanism' principles and sustainable new urbanist methods of responsive built design;
- Creating social activities that create new community connectedness and engagement and a sense of wellbeing and belonging to the place;
- Activities that promote local economic development through a complete local food system, quality property development potential and offer preferred lifestyle options at the least cost to the earth;

22.5.4 A Small Scale Case Study in Sydney

A comparatively new residential neighbourhood case study from the Penrith City Council in Sydney was selected. According to Penrith City Council proposed Local Environmental Plan (LEP), proposed zoning is R2 Low Density Residential and proposed subdivision size is 650 m^2 (Penrith City Council 2014b). Landscaped area containing private open space should cover a minimum of 50 % of the site (Penrith City Council 2014b). Using GIS the spatial distributions of land cover types were estimated. Land cover pattern at an overall site constitutes of 33.4 % built up area, 11.8 % road area, 5.6 % tree canopy cover, 11.2 % paved areas such as driveways, 20.1 % lawn and the remaining 18% includes land areas in other uses, grass verge

Table 22.4 Land cover pattern in the Sydney case study

Category	Sydney case study, Penrith City Council Area (m^2)
Site area	21,115 (21 ha)
Total parcel area	15,864 (15.9 ha)
Total building roof area	7044
Total road area	2494
Total tree canopy	1188
Total paved area (driveways and surfaces)	2358
Total lawn area	4239
Miscellaneous/others (land area in other uses, grass verge and ancillary structures)	3791
Dwelling density per hectare	18
Total number of parcels	38
Average parcel size	417 (100 %)
Average lawn coverage/average parcel	112 (26.7 %)
Average paved area coverage/average parcel	49 (14.9 %)
Average tree canopy coverage/average parcel	31 (7.5 %)
Average built roof coverage/average parcel	185 (44.4 %)

and ancillary structures. The existing pattern of design and planning of this peri-urban neighbourhood followed conventional design and is dominated mainly by large subdivisions, single detached housing with larger footprints and individual private gardens. Land uses/land covers were estimated for the overall site and together with parcel area levels are included in Table 22.4. Figure 22.6 presents the land cover pattern map.

Considering the four key design and planning principles from the review and case studies' analysis, this small scale case study was redesigned. Figure 22.7 outlines the concept plan and the built forms, movement network and open space/local food production network within this case study. The proposed concept plan of Sydney highlights that it is possible to design appropriate medium to low density built forms for new developments with protected land areas that could continue to be used as open spaces such as common greens which could be used as community gardens. An allocated community garden space could foster social networks and any food produced on site could build food efficient communities. Two housing types: town houses on smaller plots and separate houses on larger plots provide varied housing choices. A continuous street facade is created with two to three storied separate houses along the street. Ground footprints of separate houses are reduced maximising the open spaces in the backyards and the required floor spaces are allocated to the upper floors in each house. The home gardens create a continuous green/biodiversity corridor which is connected to other typologies of food production spaces such as pocket parks, community gardens, allotment gardens and linear boulevards for edible landscaping on the site and beyond. Penrith City Council's has design controls for creating a green corridor along rear boundaries; 'preserving

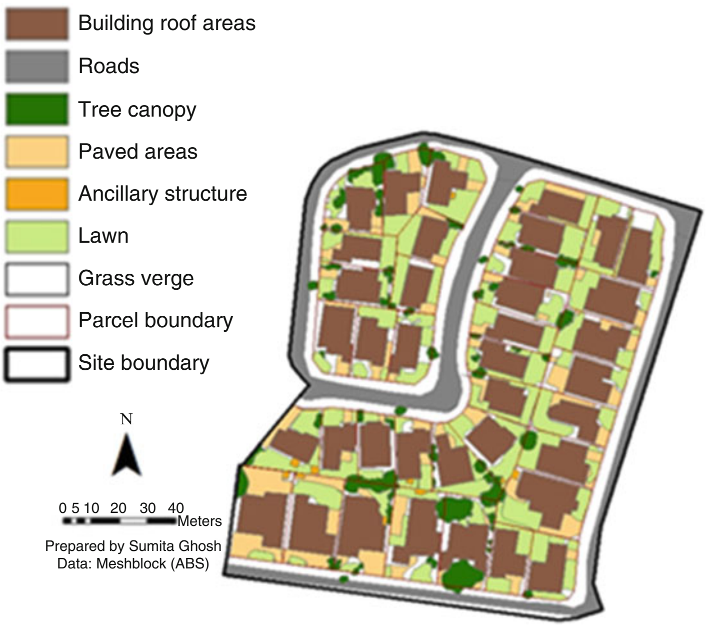

Fig. 22.6 Land cover distribution, Sydney case study, Penrith City Council

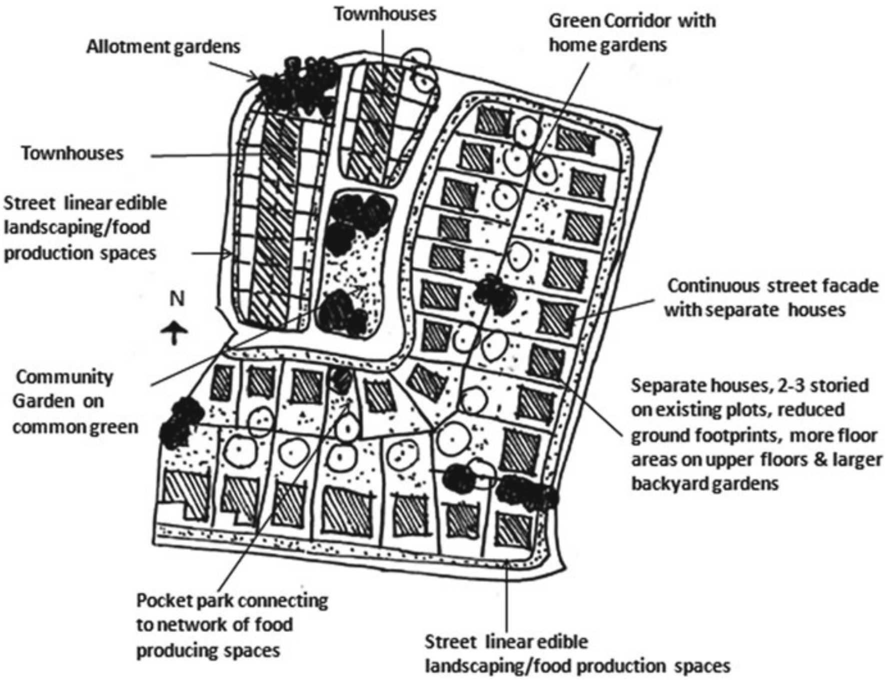

Fig. 22.7 Concept plan of Sydney case study (Drawn by: Sumita Ghosh)

remnant vegetation' and 'providing new shelter and habitat' (Penrith City Council 2006 p. 23). In this case, although overall density of the site in the concept plan lay at low density and mixed density development of built forms, integration of different food production spaces and altering the road network could create meaningful liveable environments and integrate new urbanist designs in rural or suburban settings.

This Sydney case study was focused on a small residential neighbourhood. In order to comprehend transit oriented and the farm based nature of neighbourhoods, a redesign exercise of a larger scale case study considering natural vegetation, agricultural land, built up areas and movement networks would be required to translate all the key principles of 'Agrarian Urbanism' and new urbanism. This concept plan tested an alternative design and planning option for a peri-urban residential neighbourhood.

22.6 Discussion

In this chapter three approaches: 'Conservation Subdivision', 'Typology of Continuous Productive Landscapes' and 'Four models of food urbanism and 'The Transect' were reviewed. This review provided theoretical understanding of current food urbanism approaches that are focussed on applicable and relevant design concepts in peri-urban planning and transition zones. The comparison of three conceptual approaches indicates that 'Typology of Continuous Productive Landscapes' (Grimm 2009) is at a human settlement scale where design and planning of hierarchical food production spaces could be integrated with new and retrofitted built environments. This could create significant changes in urban, suburban and rural morphologies and provide community resilience and self-sufficiency. The complete food system guides the design of built environments. In this approach, 'urban agriculture' as one of the four food urbanism models (Duany et al. 2010) of growing food on vacant land, brown field sites, home gardens etc. at a local scale is prominent. 'Conservation Subdivision' approach maximises the protection of land and natural areas but the 'Agrarian Urbanism' approach builds on the deeply rooted concept of creating a food efficient society; takes an integrated approach to design, planning and sustainability and incorporates new urbanist design and planning methods even in general lower density development settings.

The two international case studies, Serenbe (Serenbe Development 2014) and Prairie Crossing in the USA (Prairie Crossing 2014; Ranney et al. 2010) analysed in this chapter, present an agrarian community development initiative and are excellent examples of the 'Agrarian Urbanism' approach to master planning of new communities. In these examples, communities designed following the principles and techniques of new urbanism and protection of natural areas and farm lands are answers to future peri-urban policy implications and for accommodating urban growth in suburbs and rural areas in a compatible fashion. Growing food in home and community gardens and farms are associated with improved social connections;

enhanced mental wellbeing; healthy communities with increased access to nutritious and fresh food and reduced 'farm to plate' distance (Ghosh 2012). These case studies have demonstrated that significant environmental and ecological benefits could be achieved through improved energy and water efficiency, ecological design and planning by enhancing biodiversity protection, creation of wildlife corridors, tree canopy cover providing carbon storage and sequestration and reduction in air pollution benefits. Increased areas of pervious surfaces would reduce heat island effects, temperature rises and other climate change impacts. Quality urban design characteristics and proximity to nature could create liveable environments and amenity values and increases in property prices. Donovan et al. (2011) makes transdisciplinary connections between food sensitive planning and urban design. Four key principles of design and planning highlighted in these case studies support an integrated approach to peri-urban design and planning.

Hall's (2010) recent research on Australian backyards demonstrates an increasing trend of large sizes of contemporary detached suburban houses with comparatively small backyard spaces. The Sydney contemporary residential case study with a conventional design approach, generated a neighbourhood at an overall site level with high impervious cover of 23 %, larger building footprint cover of 33.4 %, and significantly lower tree canopy cover of 5.6 % with 20 % of areas allocated as lawn covers (Table 22.4). For this development a built up cover of 44.4 %, paved cover of 14.9 % and lawn cover of 26.7 % is estimated as an average parcel level. Higher lawn cover is positive as this land cover could be converted to productive uses while impervious cover by built up areas and paved surfaces should be reduced further. Immense social and ecological benefits are associated with Penrith City Council's single dwelling advisory controls such as maintenance of a green corridor of trees and shrubs along rear boundaries; conservation of remnant vegetation and improved biodiversity (Penrith City Council 2006: 23). However these are not well translated in the design and planning. Lack of careful considerations on existing natural and protection worthy features of the site at the design stage could result in a subdivision pattern of a fragmented landscape of open spaces and private gardens, non-sympathetic nature conservation and a loss of productive spaces. An alternative design option as presented in Fig. 22.7 for this neighbourhood puts a case forward that, in fact, spaces could be allocated to productive uses even within a small neighbourhood. Applications of the four step design process in the 'Conservation Subdivision' approach, suitable typologies of food production spaces and key principles of 'Agrarian Urbanism' and other food urbanism models together could create an efficient peri-urban neighbourhood design with optimum numbers of subdivisions designed in synergy with nature and with increased property values. Key future research areas were identified through the analysis process and should focus on exploring the following.

- To explore connections and build a strong evidence base on how food efficient design and planning of peri-urban areas could enhance social and community well-being;
- To conduct integrated performance assessments to understand the efficiency of operating food urbanism models at pre and post design stages for new and existing peri-urban developments;

- To undertake qualitative research on community aspirations, satisfactions and resilience in post occupancy phases in practical case studies;
- To understand how land use planning could be integrated with food oriented planning;
- To explore how new peri-urban planning and food policy could be effectively integrated with current urban planning policy;
- To develop a business model for farming communities for a successful complete food system plan so that a sound local economic base could be developed;
- To further comprehend trans-disciplinary connections of food efficient design of communities and planning.

Significant work needs to be done to build communities based on a food efficient design or from a food urbanism perspective. With the current patterns of a growing urban population, Australian cities are extending further and consuming rural landscapes. Planning for provisions for a secured food supply integrated with built environments is vital for current and future generations. It is also hugely important to preserve existing community characteristics as well as generating sustainability awareness and innovative food production and distribution programs. Future research should analyse global best practice examples, explore innovative solutions and develop principles and policy that would be specifically applicable for the Australian cities. Supports from local and State governments, private and non-governmental organisations, energy and water providers, developers, community and other stakeholders would be critical for the uptake. Education and awareness of communities and professionals would play an important role. An efficient, adequate and timely planning proposal approval process in an institutional setting would be essential for implementing the policies and plans efficiently.

22.7 Conclusion

Research presented in this chapter provides a snapshot of emerging design and planning theories, international progresses in building food focussed communities and possible applications of relevant principles in an Australian context. Three food urbanism approaches: ‘Conservation Subdivision’, ‘Typology of Continuous Productive Landscapes’ and ‘Four models of food urbanism’ and ‘The Transect’ concept provide deeper theoretical foundation for adopting food efficient design and planning. The two ‘Agrarian Urbanism’ case studies, Serenbe and Prairie Crossing, demonstrate that it is possible to protect land, natural areas and agrarian life style of communities; initiate local economic growth and accommodate urban growth sustainably using appropriate design and planning in peri-urban areas. The Sydney case study emphasise that conventional design approaches can be reoriented to create more meaningful solutions that can protect land for collaborative food production, such as community gardens; environmental and ecological benefits and can create successful social networks at a smaller spatial scale. This research highlights the immense importance of strategic and efficient land use planning and urban design processes, food system planning, effective marketing techniques and community and professional involvement. Developing an evidence base and mandatory food efficient planning guidelines; understanding communities' hopes; conducting transdisciplinary research; monitoring progress and continuing efforts to implement successful food efficient design and planning should be able to build resilient peri-urban communities of the future.

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References

Arendt R (2010a) Envisioning better communities: seeing more options, making wiser choices, 1st edn. American Planning Association, Washington, DC, 228 p

Arendt R (2010b) Conservation subdivision design for subdivisions: a practical guide to creating open space networks, 1st edn. Island Press, Natural Land Trust, American Planning Association and American Society of Landscape Architects, Washington, DC, 186 p

Congress for New Urbanism (CNU) (2010) Southlands: agricultural urbanism. doi:https://www.cnu.org/resources/projects/southlands-agricultural-urbanism-2010. Accessed 12 Mar 2014

Donovan J, Larsen K and McWhinnie J (2011) Food-sensitive planning and urban design: a conceptual framework for achieving a sustainable and healthy food system. David Lock Associates, University of Melbourne and National Heart Foundation of Australia, Melbourne, Australia, 80 p

Department of Transport, Planning and Local Infrastructure, Victoria (2014) doi:http://www.dpcd.vic.gov.au/planning/plansandpolicies/ruralandregionalplanning/peri-urban-areas. Accessed 12 Mar 2014

Development Concepts Incorporated (2014) The Serenbe story "the best reason to live here is the life here". http://development-concepts.com/wp-content/uploads/2014/04/Serenbe-Handout1.pdf. Accessed 11 Apr 2014

Duany A and Duany Plater-Zyberk & Co (DPZ) (2010) Garden cities: theory & practice of agrarian urbanism, 1st edn. Princes Foundation, London, 86 p

DPZ (2014a) Agrarian urbanism. doi:http://www.dpz.com/Technique/AgrarianUrbanism?from=Thought.AgrarianUrbanism. Accessed 5 Apr 2014

DPZ (2014b) Agrarian urbanism: background and research. doi:http://www.dpz.com/Technique/AgrarianUrbanism?from=Thought.AgrarianUrbanism. Accessed 5 Apr 2014

DPZ (2014c) Southlands. doi:http://www.dpz.com/Practice/0720. Accessed 5 Apr 2014

DPZ (2014d) Hampstead. doi:http://www.dpz.com/Practice/0514. Accessed 5 Apr 2014

Duany A (2002) Introduction to the special issue: 'The Transect'. J Urban Des 7(3):251–260
Ghosh S (2012) Sustainability of local food production: a review on energy and environmental perspectives. In: Ghosh D, Das S, Bagchi D, Smarta RB (eds) Innovations in healthy and functional foods. CRC Press, New York, pp 555–579
Gleeson B (2006) Australian heartlands: making space for hope in suburbs. Allen and Unwin, Crows Nest, New South Wales, 211 p
Grimm J (2009) Food Urbanism – a sustainable design option for sustainable communities. Landscape Architecture and Environmental Studies, Iowa State University, Iowa
Hall T (2010) The life and death of Australian backyard, 1st edn. CSIRO Publishing, Victoria
Iaquinta DL, Drescher AW (2000) Defining periurban: understanding rural-urban linkages and their connection to institutional contexts. Tenth World Congress of the International Rural Sociology Association, Rio de Janeiro, Brazil
Imery Group (2016) Serenbe. http://proudgreenhome.imerygroup.com/partners/serenbe. Accessed 19 Mar 2016
Penrith City Council (2006a) Penrith development control plan 2006 – Part 4. Adopted 21 August 2006. in force 15 December 2006 (as amended), 49 p
Penrith City Council (2014a) Penrith regional city: major developments and investment. Accessed 28 Nov 2014
Penrith City Council (2014b) Penrith City Council: Planning Proposal Penrith Local Environmental Plan – Part 1 of 2. doi:http://www.penrithcity.nsw.gov.au/uploadedFiles/Content/Website/Our_Future/Have_Your_Say/PlanningProposal.pdf. Accessed 18 Sept 2014
Prairie Crossing (2014) About Prairie crossing. doi:http://www.prairiecrossing.com/pc/site/about-us.html. Accessed 11 Apr 2014
Ranney V, Kirley K, Sands M (2010) Building communities with farms: insights from developers, architects and farmers on integrating agriculture and development. The Liberty Prairie Foundation, Grayslake, Illinois, USA
Serenbe Development (2014) Serenbe. doi:http://www.serenbecommunity.com/serenbeoverview.html. Accessed 12 Mar 2014
Sorlien S (2015) Special Districts (SD). Transect collection. Center for Applied Transect Studies (CATS), Florida, USA. doi:http://transect-collection.org/p682907711. Accessed 30 July 2015
Talen M (2002) Help for urban planning: the transect strategy. J Urban Des 7(3):293–312
The City of Miami (2014) The transect. doi:http://www.miami21.org/TheTransect.asp. Accessed 30 Nov 2014

Chapter 23
Role of Peri-Urban Areas in the Food System of Kampala, Uganda

Elly N. Sabiiti and Constantine B. Katongole

Abstract Peri-urban agriculture, especially livestock and vegetable farming, has deep roots in the food system of Kampala, the capital city of Uganda. The city's population is increasing rapidly: current population is slightly over 1.51 million people whose demand for food is also increasing rapidly. Wakiso district, a peri-urban area surrounding Kampala city, ranks as Uganda's number one and two producer of poultry and piggery respectively. The district of Wakiso accounts for about 7.4 % and 6.3 % of the total national populations of chickens and pigs respectively. However, agricultural land in these areas is increasingly at risk from urban encroachment, which is likely to adversely affect the city's food security. This chapter examines the role of peri-urban farming in the food system of Kampala city and how it is at risk from urban encroachment. The chapter demonstrates that population growth, artificial distortions to the value of land in Kampala city, the booming construction industry as well as the creation of recreation and leisure facilities have escalated the competition for land in peri-urban areas between agricultural use and urban-type developments.

Keywords Food system • Food security • Peri-urban agriculture • Population growth • Urban encroachment • Construction industry • Kampala

23.1 Introduction

Kampala, the capital city of Uganda, is one of the 48 African cities that counted more than one million inhabitants (Africa's million + cities) in 2010 (Vermeiren et al. 2012). It is the only city in Uganda and is the centrepiece of economic, political and social transformation. This makes Kampala an attraction for settlement for many people from other areas of the country. Kampala comprises of approximately

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25 % of Uganda's urban population, and about 5 % of Uganda's total population (Uganda Bureau of Statistics 2014). Its population has grown from 1.2 million in 2002 to the current population of slightly over 1.51 million people, representing a growth rate of 2 % per year. This population was projected to reach 3.03 million people by 2020 (Uganda Bureau of Statistics 2006).

Similar to many cities in developing countries, population growth in Kampala is happening in the face of poverty and inflation. This has made access to food in Kampala a critical issue, since the largest proportion of the population depend on the market for their food. They are net buyers of food (Simler 2009); hence they are adversely hurt whenever food prices increase. Inflation erodes their power to purchase food. To make matters worse, pursuing agricultural activities within the inner zones of Kampala is becoming increasingly impossible due to limited land accessibility. Consequently, the peri-urban areas of Kampala (where there still exists some agricultural land) play a key role in ensuring food security. However, farming in these areas is increasingly at risk from urban encroachment. Therefore, this chapter examines the role of peri-urban farming in the food system of Kampala city, and how it is at risk from urban encroachment.

23.2 Analysis of Results and Discussion

Kampala is surrounded by the district of Wakiso (to the North, East, West and Southwest, with Lake Victoria in the South East); hence the peri-urban areas of Kampala are located entirely in the district of Wakiso. Kampala, being the financial hub of the country, a large proportion of the population in the district of Wakiso prefer to live in the fringes of the city (peri-urban areas of Kampala). Data from the 2014 National Population and Housing Census (Uganda Bureau of Statistics 2014) show that Wakiso is the most populated district in Uganda with over 64 % of its total population residing in the areas neighbouring Kampala. These areas are key contributors to Kampala's expanding daytime population. Obviously, this population is exerting additional pressure on food availability and accessibility, which raises serious concerns about Kampala's future food situation.

Although food consumption data are unavailable, a significant share of the total supply of vegetables, pork and chicken products consumed in Kampala are produced from these peri-urban areas. According to the National Livestock Census of 2008 (MAAIF and UBOS 2009), the district of Wakiso registered the first and second highest number of chickens and pigs respectively in Uganda. The district of Wakiso alone accounted for 7.4 % and 6.3 % of the total national populations of chickens and pigs respectively (Table 23.1). The pigs are mainly fed on crop/food wastes generated in the various markets, hotels, restaurants, schools and homesteads, while the chickens are mostly fed on purchased concentrate feed. The contribution of peri-urban areas of Kampala to the national total production of crops (Table 23.2) is minimal, except for leafy green vegetables (but their production data are unavailable). Data from the Uganda Census of Agriculture 2008/2009 (MAAIF and UBOS

Table 23.1 Contribution of Wakiso district to Uganda's total livestock population

Livestock	Population	% Contribution to the national total population	National position
Cattle	114,770	1.0	Among the last
Pigs	199,960	6.3	2nd
Goats	132,964	1.1	Among the last
Sheep	27,560	0.8	Among the last
Chickens	2,783,510	7.4	1st

Source: MAAIF and UBOS (2009)

Table 23.2 Total production of major crops in Wakiso district

Crop	Production (metric tons)	% Contribution to the national total production
Cook-type banana	24,547	0.6
Cassava	21,712	0.8
Maize	5287	0.2
Common beans	1596	0.2
Sweet potatoes	23,200	1.3
Ground nuts	376	0.2
Leafy vegetables	[a]	[a]

Source: MAAIF and UBOS (2010)
[a]The growing of leafy green vegetables is common in peri-urban areas of Kampala; however production data are not available

2010) show that the district of Wakiso ranked among the bottom crop producing districts. This can be attributed to the decreasing land accessibility in the district for crop agriculture. Generally, crop production is more affected by limited land availability than livestock production.

No doubt a considerable amount of food is produced inside Kampala, but most of the staple foods consumed in Kampala are brought in from rural areas (Sabiiti and Katongole 2014). However, the prices of these foods have been sharply increasing since 2007. According to Cohen and Garrett (2010), the impact of high food prices is much more felt by the urban poor who devote more than half of their income to basic food purchases, and thus are highly sensitive to food price fluctuations. The cost of fuel for transport was highlighted by Sabiiti and Katongole (2014) as one of the major factors that directly and indirectly influence these food prices. Fuel prices in Uganda have been perpetually increasing due to inflationary pressures. Several reports (De Bon et al. 2010; Sabiiti and Katongole 2014; Padgham et al. 2015) have suggested that urban agriculture has transport cost advantages compared to agriculture in rural areas; hence ensuring lower food cost within the informal economy. However, due to the urbanisation trends, food production within Kampala is increasingly becoming impossible, leaving peri-urban areas to play a more central role in the supply of food, particularly fresh and perishable products.

Having said that, it must be pointed out that urban encroachment is increasingly placing farming in the peri-urban areas of Kampala at risk. Urbanisation of Kampala is occurring almost exclusively at the expense of agricultural land in the district of Wakiso (Abebe 2013). Currently, limited land accessibility ranks among the most critical challenges in the district of Wakiso. Hence, farmers compete for available land with urban-type developments, such as housing, brick-making and recreational facilities, which have a greater return on financial investment than farming.

Due to the high urban population, accommodation in Kampala has become insufficient and expensive (Nyakaana et al. 2007). Rent for a standard house in a respectable neighbourhood ranges between 200 and 400 US$ per month, which is far beyond the means of most Kampala dwellers. Hence, many people working in Kampala opt to live in peri-urban areas. There is movement of tenants from the inner zones of Kampala to peri-urban areas in search of cheaper accommodation. In response to the increased demand for accommodation in peri-urban areas, many peri-urban farmers are moving their small land areas away from agricultural activities in favour of constructing rental houses for better income generation (Katongole et al. 2012). This calls for policy and institutional arrangements directed towards supporting and protecting agricultural lands in the peri-urban areas of the expanding metropolitan Kampala. This may arouse public resentment because there is a widespread public perception that urbanisation and agriculture are conflicting activities; hence they do not see anything specifically wrong about Kampala expanding into prime agricultural areas.

The artificial distortions to the value of land in Kampala (largely attributable to speculation and corruption) have made it extremely difficult to construct houses at a price affordable to low and moderate income earners (Giddings 2009). The majority of the population in Kampala can no longer afford housing. This has prompted more people to buy plots of land and construct homes in the peripheries of Kampala (areas in the district of Wakiso), where land prices are a bit lower. This has greatly contributed to the expansion of Kampala into peri-urban areas, which would otherwise be agricultural land. Although land values, or rental on houses in these peri-urban areas, tend to be lower people residing in these areas often incur substantial costs; both in time and money, in commuting to work and where infrastructure and services are lacking or deficient (Giddings 2009).

Brick-making motivated by the high demand of bricks due to the booming house construction industry both in Kampala and the district of Wakiso is another factor which has caused a significant decline in agricultural land in the peri-urban areas of Kampala (Katwijukye and Doppler 2004). The sites where bricks are made not only become unusable for agriculture, but the soils also become predisposed to degradation. The soils at abandoned brick making sites are generally characterised by low fertility and poor physical conditions. This calls for policy and institutional arrangements directed towards identifying alternative materials for making bricks other than topsoil or mud. However, this may also arouse public resentment because brick-making is an income generating activity widely engaged in among the unemployed youths in the peri-urban areas of Kampala.

Last but not least, the creation of spacious recreation and leisure facilities is also increasingly subjecting farming in the peri-urban areas of Kampala to risk. As in other African cities, urbanisation in Kampala has resulted in significant changes in the lifestyles of many people. There is now a tendency for many Kampala dwellers to spend their leisure time in the nearby countryside (peri-urban areas) for a multitude of things (sports, games, entertainment etc.). Outdoor leisure and recreation as a lifestyle has become attractive to many people in urbanised Kampala (Chris 2001). However, most recreation and leisure activities require access to open spaces. For the reason that the inner zones of Kampala no longer have such open spaces, peri-urban areas of Kampala (entirely in the district of Wakiso) have gained a lot of importance as recreational and leisure areas. This creation of recreation and leisure centres/parks is occurring almost exclusively at the expense of agricultural land in the peri-urban areas of Kampala.

23.3 Conclusion

Although, peri-urban farming plays an important and positive role in the food system of Kampala city, it is at great risk from urban encroachment. Additionally, there is a strong need to quantify and document the contribution of peri-urban agriculture (excluding agriculture located intra-urban) to the aggregate supply of food in Kampala. This would help to convince politicians and government planners how peri-urban agriculture is central to the food system of Kampala, and hence strengthen its position at the national policy level.

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References

Abebe GA (2013) Quantifying urban growth pattern in developing countries using remote sensing and spatial metrics: a case study in Kampala, Uganda. http://www.itc.nl/library/papers_2013/msc/upm/abebe.pdf. Accessed 1 Dec 2014

Chris A (2001) A public open space typology for Kampala. http://www.collectionscanada.gc.ca/obj/s4/f2/dsk3/ftp05/MQ62709.pdf. Accessed 1 Dec 2014

Cohen MJ, Garrett JL (2010) The food price crisis and urban food (in) security. Environ Urban 22(2):467–482

De Bon H, Parrot L, Moustier P (2010) Sustainable urban agriculture in developing countries. A review. Agron Sustain Dev 30(1):21–32

Giddings SW (2009) The land market in Kampala, Uganda and its effect on settlement patterns, vol 33. International Housing Coalition, Washington DC, http://www.intlhc.org/docs/giddings-kampala.pdf. Accessed 1 Dec 2014

Katongole CB, Nambi-Kasozi J, Lumu R, Bareeba F, Presto M, Ivarsson E, Lindberg JE (2012) Strategies for coping with feed scarcity among urban and peri-urban livestock farmers in Kampala, Uganda. J Agric Rural Dev Trop Subtrop 113(2):165–174

Katwijukye AK, Doppler W (2004) The socio-economic analysis of land use changes and soil conservation in central and western Uganda. Uganda J Agric Sci 9:303–311

MAAIF & UBOS (2009) The National Livestock Census. A summary report of the National Livestock Census, 2008. Ministry of Agriculture, Animal Industry and Fisheries, and Uganda Bureau of Statistics. Kampala, Uganda. http://www.agriculture.go.ug/userfiles/National%20Livestock%20Census%20Report%202009.pdf. Accessed 1 Dec 2014

MAAIF & UBOS (2010) Uganda Census of Agriculture 2008/2009. Volume I Summary Report. Ministry of Agriculture, Animal Industry and Fisheries, and Uganda Bureau of Statistics. Kampala, Uganda. http://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/UCAholding.pdf. Accessed 1 Dec 2014

Nyakaana JB, Sengendo H, Lwasa S (2007) Population, urban development and the environment in Uganda: the case of Kampala city and its environs. Faculty of Arts, Makerere University, Kampala, Uganda. http://www.cicred.org/Eng/Seminars/Details/Seminars/PDE2007/Papers/NYAKAANA_paperNairobi2007-2.pdf. Accessed 1 Dec 2014

Padgham J, Jabbour J, Dietrich K (2015) Managing change and building resilience: a multi-stressor analysis of urban and peri-urban agriculture in Africa and Asia. Urban Clim 12:183–204

Sabiiti EN, Katongole CB (2014) Urban agriculture: a response to the food supply crisis in Kampala City, Uganda. In: Maheshwani B, Purohit R, Malano H, Singh VP, Amerasinghe P (eds) The security of water, food, energy and liveability of cities, Water science and technology library 71. Springer, Dordrecht, pp 233–242

Simler K (2009) The impact of higher food prices on poverty in Uganda. Processed. World Bank, Washington, DC, http://www.csae.ox.ac.uk/conferences/2009-EDIA/papers/262-Simler.pdf. Accessed 1 Dec 2014

Uganda Bureau of Statistics (2006) The 2002 Uganda population and housing census, population size and distribution. http://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/2002%20CensusPopnSizeGrowthAnalyticalReport.pdf. Accessed 1 Dec 2014

Uganda Bureau of Statistics (2014) National population and housing census 2014 provisional results. http://www.ubos.org/onlinefiles/uploads/ubos/NPHC/NPHC%202014%20PROVISIONAL%20RESULTS%20REPORT.pdf. Accessed 11 Dec 2014

Vermeiren K, Van Rompaey A, Loopmans M, Serwajja E, Mukwaya P (2012) Urban growth of Kampala, Uganda: pattern analysis and scenario development. Landsc Urban Plan 106(2):199–206

Part VIII
Climate Change Impacts and Adaptations

Chapter 24
Climate Change Adaptation Planning with Peri-Urban Local Government in Victoria, Australia

Carl Larsen and Shelley McGuinness

Abstract Climate change presents many challenges for local government in Victoria, Australia. In the Macedon Ranges local government area the future climate is likely to include more hot days, less rainfall and run-off and increased frequency and intensity of extreme events such as drought, flash flooding and wildfire. The purpose of this project was to identify, analyse and evaluate climate change risks and develop an adaptation plan that would assist the Macedon Ranges Shire Council on the outskirts of Melbourne begin to plan for likely impacts arising from climate change.

The development of the adaptation plan employed a best practice risk management approach in line with AS/NZS 31000:2009 and AS 5334:2013 and took and whole-of-council approach. Undertaking a risk assessment approach to climate change adaptation planning for a peri-urban local government area was successful. The approach assisted council to build capacity in climate change, adaptation and the process of undertaking a risk assessment and define their area of operation, influence and responsibility in regards to adaptation actions and the role of other external stakeholders. Further, it helped them to integrate the risks and associated adaptation options directly into the existing risk register system and understand the relativity of climate risks to non-climate risks that the council faces, such as land use change, increasing proportions of absentee landholders and an ageing demographic.

Keywords Climate change risk • Peri-urban planning • Risk assessment • Adaptation plan and local government

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24.1 Introduction

24.1.1 Climate Change Risks for Local Government

Climate change presents many challenges for local government in Victoria, Australia (SMEC 2010; Stanley et al. 2013). In Macedon Ranges the future climate is likely to include more hot days, less rainfall and run-off and increased frequency and intensity of extreme events such as drought, flash flooding and wildfire (BoM 2014; Inglis et al. 2014; IPCC 2012, 2013, 2014). These changes have the potential to: Damage or disrupt infrastructure that delivers core services such as power, transport, water and communications; Increase the costs and maintenance of community infrastructure such as pools, sporting grounds, parks and gardens, halls, cemeteries and libraries; Permanently modify the habitats of the region's flora and fauna; Increase risks to developments in floodplains and bushfire prone areas; and challenge the basis of the region's economic sectors and the provision of social services.

In several recent projects, we have assisted local government agencies to prepare climate change adaptation plans in Macedon Ranges Shire, Greater Shepparton City Council and Hindmarsh Shire in Victoria, as well as Wentworth, Hay and Balranald Shires in New South Wales. The knowledge requirements of stakeholders, and tools used, are critical to adaptation planning. We have identified a number of common principles that can be applied to future adaption planning (Larsen et al. 2013). We aim to use our experience to highlight factors that we believe are integral to successful adaptation planning using the Macedon Ranges Shire Council (MRSC) region as a case study.

24.1.2 Climate Change in Shire of Macedon Ranges

Macedon Ranges is a peri-urban municipality approximately located 70 km north-west of Melbourne and includes the townships of Macedon, Woodend, Kyneton and Gisborne (Fig. 24.1). The Macedon Ranges region experiences cool and relatively wet winters and warm dry summers. The current annual average temperature in the Macedon Ranges region is 14.8 °C with an observed warming of 0.7 °C over the last century. The average rainfall for the region is between 750 and 800 mm per year. There has been an observed trend of approximately 3 mm reduction in rainfall per decade over the last 110 years. For example, the recent drought period saw a 20–25 % reduction in annual average rainfall. The current number of frosts (days where the minimum temperature falls to 2 °C (DSE 2008)) are 35 with 44 days above 30 °C per year in the Macedon Ranges region.

A medium climate change scenario to 2030 plus the backcasting technique for extreme events was used to plan for the potential future climate in the Macedon Ranges region. The predicted changes in climate in the Macedon Ranges region are warmer and drier conditions on average, with an increase in frequency and severity

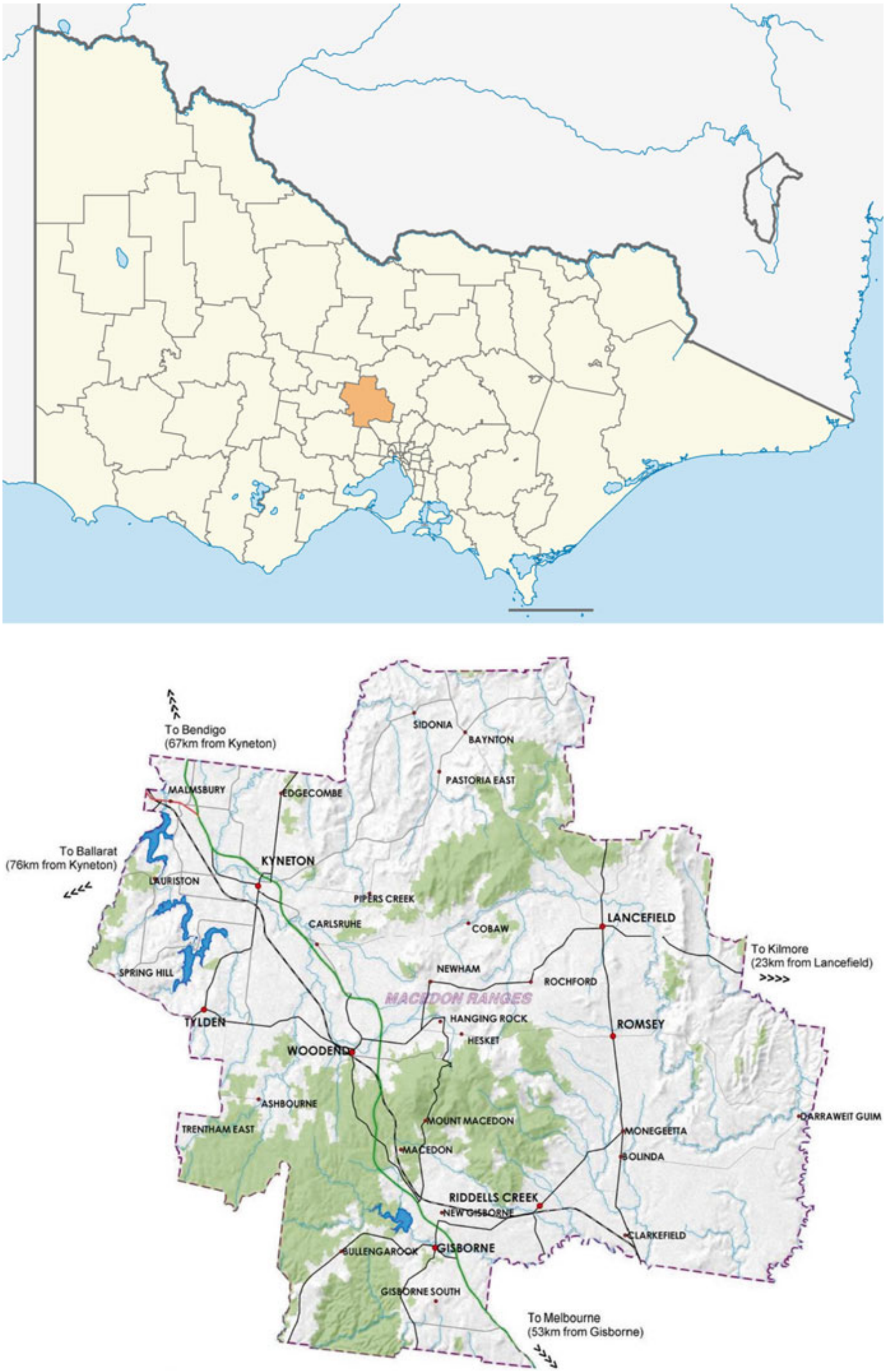

Fig. 24.1 Location of Macedon Ranges

of hot and wet extremes (DSE 2008; CSIRO and Bureau of Meteorology 2007). Climate change is likely to change the frequency and intensity of extreme weather events such as the heatwaves, drought, floods and storms in the Macedon Ranges region. The number of extreme hot days and heavy precipitation has increased since 1950 (IPCC 2012).

24.1.3 Drivers and Challenges for Climate Change Adaptation by Local Government

In addition to the risks that climate changes poses to local government as outlined above, local government have specific statutory duties to consider climate change under the *Local Government Act 1989* (Vic). This includes ecologically sustainable development (ESD) principles, mainly pertaining to mitigation or reducing carbon emissions, and the need to demonstrate a 'reasonable response', in relation to adaptation and responding to the likely impacts of climate change (England 2008).

State and federal government have implemented policy initiatives (DSE 2013; DIICCSRTE 2013) to assist local government to undertake climate change adaptation planning, recognising that local government plays a lead role in assisting communities to become more resilient to climate change and facilitate on-ground local action.

Local government has faced a number challenges in commencing climate change adaptation planning, including:

- Lack of clarity of the roles and responsibilities of council's in climate change adaptation. There is currently a process underway in Victoria to address this issue by developing a Memorandum of Understanding (MoU) between state and local government.
- A misapprehension that they lacked the in-house technical skills and knowledge of climate change to undertake adaptation planning.
- A range of views on the validity of climate change science across council and establishing whole-of-council support to undertake adaptation planning.

There is currently state government funding available to Victorian councils through the Victorian Adaptation and Sustainability Partnership (VASP) for individual councils or regional adaptation projects. Australian Government funding is available through the Local Adaptation Pathways Program to assist local government build their capacity to respond to the likely impacts of climate change.

24.2 Methodology

The development of the adaptation plan involved four main stages (MRSC 2012). This included (i) scoping and desktop review, (ii) consultation and development, (iii) analysis of risks and adaptation options and (iv) adaptation plan.

The development of the adaptation plan employed a best practice risk management approach in line with AS/NZS 31000:2009 (previously ASS 4360:2004) and AS 5334:2013 as outlined in Fig. 24.2 (AGO 2006; Standards Australia 2013).

A risk assessment workshop was held with Council managers and staff to:

- Confirm the key climate change risks.
- Identify any existing controls that may help mitigate the impact of these risks.
- Evaluate the risks – assigning consequence, likelihood and priority ratings to each of the risks. Table 24.1 outlines the risk rating matrix used in the workshop and for this project. This integrated best practice frameworks with those that existed within council to ensure compatibility.
- Identify potential adaptation options to treat the risks.
- Evaluate the adaptation options.

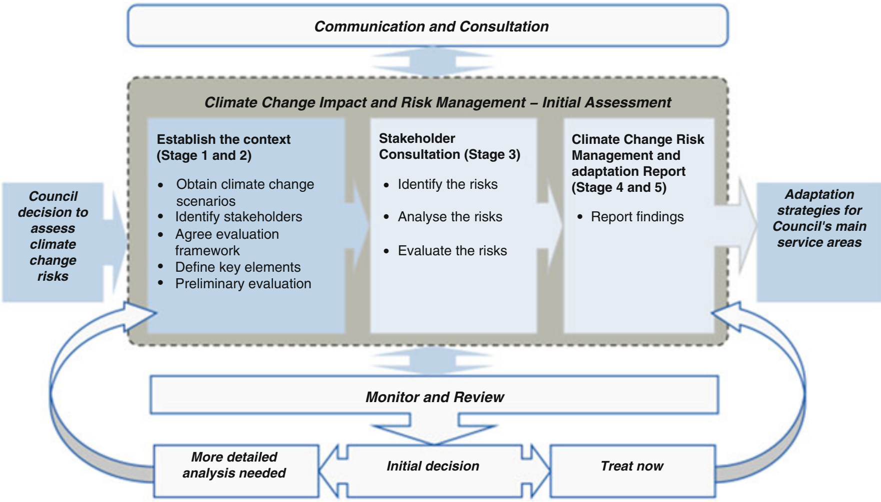

Fig. 24.2 Climate change risk assessment process for local government (AGO 2006)

Table 24.1 Priority risk rating matrix

Consequence					
Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	Major(4)	Catastrophic (5)
Almost certain (A)	Medium	High	High	Very high	Very high
Likely (B)	Medium	Medium	High	Very high	Very high
Possible (C)	Low	Medium	Medium	High	Very high
Unlikely (D)	Low	Low	Medium	High	High
Rare (E)	Low	Low	Low	Medium	High

The outcome of the workshop was a list of the significant risks, an understanding of their ability to be managed and potential responses to treat the risks. An outcomes paper was distributed to Council staff and managers to seek further input on the risks and adaptation options (including their rating and priority) and on identifying gaps including additional risks and adaptation options.

Following the feedback on the outcomes paper, the risks and adaptation options were refined and validated through one-on-one consultation with Council staff (MRSC 2012). Appropriate adaptation options that minimise the risks of implementation and deal with uncertainty can be broadly classified into four categories:

- No-regret options – adaptive measures that are worthwhile (i.e. they deliver net socio-economic benefits) whatever the extent of future climate change.
- Low-regret options – adaptive measures for which the associated costs are relatively low and for which the benefits, although primarily realised under projected future climate change, may be relatively large.
- Win-win options – adaptation measures that have the desired result in terms of minimising the climate risks or exploiting potential opportunities but also have other social, environmental or economic benefits.
- Flexible – involve putting in place incremental adaptation options, rather than undertaking large-scale adaptation all at once (ICLEI Oceania 2008; Inglis et al. 2014; UK CIP 2003).

24.3 Discussion

Information and knowledge needs of stakeholders involved in adaptation planning vary and are dependent on operating context. The tools required to undertake adaptation planning govern the process and outcome. We found drawing on people's learned experience from recent extreme events was a useful technique when coupled with climate change scenarios. A number of principles for adaptation planning have been identified across the development, planning, implementation and review spectrum. These are discussed further below.

24.3.1 Development

Scoping in the development phase of the adaptation process with local government is important to establish boundaries and clarify the roles and responsibilities of council. In undertaking scoping, the cross-directorate or cross-department nature of climate change is able to be identified and communicated to key decision makers. This takes the issues of climate change beyond just an 'environmental' problem or something for which the environment directorate only has responsibility.

To the contrary, scoping of the impacts of climate change in Macedon Ranges was found to affect seven main operation and service delivery sectors:

- Economy, including tourism
- Environment and biodiversity
- Utility infrastructure – water, energy, transport and telecommunications
- Community infrastructure such as parks, sporting and recreation facilities
- Health
- Emergency planning and management
- Council capacity to service the community.

Climate change scenarios provide data on expected changes to key climate parameters such as average temperature and average rainfall. We have found that most people find it difficult to imagine these future climate change scenarios, let alone forecast their impacts and implications.

We have found that backcasting or learning from the past and 'look back before we look forward' (Trück et al. 2010) to past extreme events is a powerful tool in climate change risk assessment. Analysis of recent (last 15 years) extreme weather events allows the practical assessment of the current vulnerability to climate variability in the Macedon Ranges Shire, which is an appropriate starting point for the preparation of an adaptation plan. The assessment involves working with Council to describe the impacts of storms (rain, hail and wind), floods, heatwaves and droughts (UK CIP 2003) and what Council has done differently as a result of the event. For example, approximately 284 mm of rain fell during the floods in January 2011. This caused:

- Kyneton police station, the local swimming pool, Woodend nursing home and houses in Malmsbury to be flooded.
- Power outages affected 2,300 homes in Kyneton, Gisborne, Macedon and Woodend.
- In some cases the cost of past extreme events has been quantified enabling future economic costs of climate change to be forecast.

Analysing past extreme weather events enables a greater understanding of:

- Roles and responsibilities of council and other organisations.
- Impacts on staff time and resources.
- Impact on business continuity, service delivery and operations.
- Estimated costs.
- Potential 'tipping points' if that particular event was to become more frequent and severe.

A significant lesson for councils from the analysis is recognition that they have already undertaken climate change adaptation in learning from their responses to extreme events. Identifying partner agencies by assessing the responsible organisations during these events is a useful starting point for ensuring collaboration and communication during the adaptation planning process. This was then built upon in the consultation stage through workshops and interviews.

Appropriately framing the debate and issues during the development phase obtains buy-in and ownership over the adaptation planning process and outcomes (CRED 2009; Rickards et al. 2012). Understanding the target audience and key messages for each of these is important. For example, framing climate change as an integral issue to address from a liability or best practice perspective may be more appropriate for executives and councillors. Assets and operations staff may be more interested in reducing maintenance costs and delaying replacement of stormwater assets due to increased intensity of rainfall events. While community wellbeing staff may want to see clear benefits for vulnerable populations, such as the elderly, from the occurrence of heatwaves.

24.3.2 Planning

In the planning phase of adaptation it is important to undertake a whole-of-business approach to drive a deeper and shared understanding of the issues. This ensures that potential climate change risks, exposure and vulnerability, opportunities and adaptation options were identified for all Macedon Ranges directorates. This included Community Wellbeing, Assets and Operations, Corporate Services, Planning and Environment and Organisational Development. Translating and communicating climate change information and scientific data in a meaningful way ensures that the issues are made real and relevant (CRED 2009; Trück et al. 2010). Much of this comes back to understanding the target audience within local government.

Using trusted and authoritative knowledge brokers to deliver climate change and scientific data assists in buy-in and builds greater understanding. The technique of ‘backcasting’, or learned experience from recent extreme events, neutralises climate sceptics to focus on real events and data, and in-house lessons. Significant capacity in climate change, adaptation and the process of undertaking a risk assessment is built in undertaking the steps in the development and planning phases. The process also enables further clarification of roles and responsibilities, which is important in adaptation planning (NCCARF 2012). This includes defining local government, directorate and personnel area of operation, influence and responsibility in regards to adaptation actions, and the role of other external stakeholders.

Risk assessments and vulnerability assessment are two quite different processes in determining the possible impact of climate change (Fig. 24.3). Although risk assessments take into account preventative measures and corrective actions from outside the system to reduce the risk, they generally do not explicitly consider any intrinsic capacity from within a system to adapt to the impacts. As a result, the risk assessment may identify a system as at high risk of impact when in fact it may actually adapt quite well without external support, while others that appeared to be at low risk but do not have the internal capacity to adapt on their own are overlooked (Jacqueline Balston and Associates 2012). While the risk assessment approach governed the process for Macedon Ranges, elements of the vulnerability assessment were also used to assess internal council and external capacity to respond to the impacts of changes in climate variables.

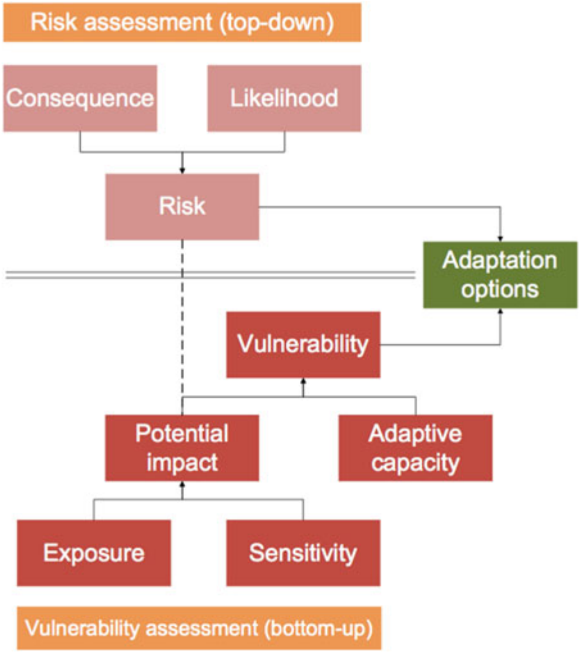

Fig. 24.3 Comparison between risk and vulnerability assessments

Determining the relativity of climate change risk and vulnerability to non-climate change related factors is also important. This involves understanding the relativity of climate risks to non-climate risks the council faces, such as land use change, increasing proportions of absentee landholders and an ageing demographic. This is usually best established through consultation with council staff following the risk and adaptation workshop and distribution of the outcomes paper.

24.3.3 Implementation

The first stage of adaptation planning and the resultant plan includes (Fig. 24.4):

- Information and guidance on climate change adaptation and planning.
- Understanding of and engagement in adaptation planning and implementation amongst council executive, council staff and councillors.
- Resources to conduct initial assessments and planning and to facilitate and monitor implementation (MAV 2011).

The implementation of the adaptation plan requires three key factors (Fig. 24.4):

- Technical advice and collaboration on issues as they arise during implementation of adaptation plans.

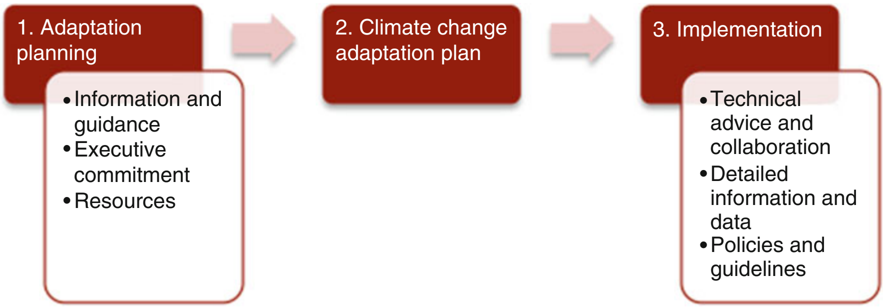

Fig. 24.4 Key needs of local government in climate change adaptation planning (MAV 2011)

- Information and data regarding projected changes in climate of sufficient detail to be integrated into Council's asset management and business continuity plans.
- Policies and guidelines that facilitate implementation of adaptation actions (MAV 2011).

To assist this it is integral to anticipate and avoid the tendency for adaptation planning to be treated as a process separate from the other functions of council (DSE 2013). One strategy is to identify synergies with existing plans and strategies to improve efficiency (Rogers 2009), for example the Asset Management Strategy, Heatwave Plan, Natural Environment Strategy and Economic Development Strategy. Another is to embed adaptation responses in existing frameworks, processes and planning documents. This can be done through integrating the risks and associated adaptation options directly into the existing risk register system e.g. Integrated Risk Management System (IRMS). This is easily adaptable to council processes because risk assessment across the business is usually established and most staff are familiar with the approach. This worked well in the case of Macedon Ranges with a suite of 'early adaptation actions' and additional adaptation actions that could be investigated and developed further.

24.3.4 Review

It is essential to employ adaptive management to address uncertainty, and undertake monitoring, evaluation and review of short-term adaptation strategies (NCCARF 2012).

Using the existing council risk register system integrates the adaptation actions into existing planning and operational processes. This allows unit managers to work with their business units to monitor and implement activities within agreed timeframes to effectively manage climate risk.

It is usually recommended that the adaptation plan be reviewed every 2–3 years to evaluate progress against the adaptation actions, validate the priority risks, and incorporate current climate change data and policy changes. This will ensure continuous improvement and constitutes best practice.

24.4 Conclusions

Climate change presents an additional element of uncertainty for peri-urban local government when undertaking strategic planning. In recognising the information and knowledge needs of various stakeholders and effective tools, it is important that local government agencies and associated organisations consider their operating context and learn from the past, while taking a holistic, iterative and flexible approach to adaptation planning.

Undertaking a risk assessment approach to climate change adaptation planning for a peri-urban local government area was successful. The approach assisted council to:

- Build capacity in climate change, adaptation and the process of undertaking a risk assessment.
- Define their area of operation, influence and responsibility in regards to adaptation actions, and the role of other external stakeholders.
- Integrate the risks and associated adaptation options directly into the existing risk register system.
- Understand the relativity of climate risks to non-climate risks the council faces, such as land use change, increasing proportions of absentee landholders and an ageing demographic.

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References

Australian Greenhouse Office (2006) Climate change impacts and risk management: a guide for business and government. Australian Greenhouse Office, Canberra

Bureau of Meteorology (2014) State of the Climate 2014. Australian Government, Canberra

Center for Research on Environmental Decisions (2009) The psychology of climate change communication: a guide for scientists, journalists, educators, political aides, and the interested public. Columbia University, New York

CSIRO and Bureau of Meteorology (2007) Climate change in Australia, in partnership with the Department of Climate Change and Energy Efficiency. Australian Government, Canberra

Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (2013) Climate adaptation outlook; a proposed national adaptation assessment framework. Australian Government, Canberra

Department of Sustainability and Environment (2008) Climate change in the North Central Region. Victorian Climate Change Adaptation Program, Melbourne

Department of Sustainability and Environment (2013) Victorian adaptation plan. State Government of Victoria, Melbourne

England P (2008) Heating up: climate change law and the evolving responsibilities of local government, Lawbook, 13 LGLJ 209:209–223

ICLEI Oceania (2008) Local Government climate change adaptation toolkit. ICLEI – Local Governments for Sustainability, Melbourne

Inglis J, Whittaker S, Dimitriadis A, Pillora S (2014) Climate adaptation manual for local government – embedding resilience to climate change. Australian Centre of Excellence for Local Government, University of Technology, Sydney

IPCC (2012) Summary for policymakers. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds) Managing the risks of extreme events and disasters to advance climate change adaptation, A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 1–19

IPCC (2013) Summary for policymakers. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Climate Change 2013: the physical science basis. Contribution of Working Group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

IPCC (2014) Summary for policy makers. In: Field C, Barros V, Mach K, Mastrandrea M (eds) Climate Change 2014: impacts, adaptation, and vulnerability. Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Jacqueline Balston & Associates (2012) Guidelines for undertaking an integrated climate change vulnerability assessment as part of developing an adaptation plan. Local Government Association of South Australia, Adelaide

Larsen C, McGuinness S, Annett S (2013) Adaptation planning with various levels of government in Victoria: knowledge, tools and principles, National Climate Change Adaptation Research Facility; Climate Adaptation 2013 Knowledge & Partnerships Conference proceedings, Sydney, 24–27 June 2013

Macedon Ranges Shire Council (2012) Climate change risk assessment and response final early adaptation plan, report prepared for MRSC by RMCG. Macedon Ranges Shire Council, Camberwell

Municipal Association of Victoria (2011) Stocktake of Current Victorian Local Government Climate Change Adaptation Planning, report prepared for MAV by RMCG. Camberwell

NCCARF (2012) Adapt note: eight principles of adaptation planning. Griffith University, Gold Coast

Rickards L, Hayman P, Eckard R (2012) Agricultural adaptation to climate change: acknowledging different frames. Primary Industries Adaptation Research Network, University of Melbourne, Melbourne

Rogers N (2009) A study of regional partnerships and collaborative approaches for enhanced local government adaptation to climate change. The Winston Churchill Memorial Trust Australia

SMEC (2010) Climate change adaptation actions for Local Government, report prepared for Department of Climate Change and Energy Efficiency. SMEC, Canberra

Standards Australia (2013): SAI Global Limited AS 5334–2013 Climate change adaptation for settlements and infrastructure – a risk based approach. Melbourne

Stanley J, Birrell B, Brain P, Carey M, Duffy M, Ferraro S, Fisher S, Griggs D, Hall A, Kestin T, Macmillan C, Manning I, Martin H, Rapson V, Spencer M, Stanley C, Steffen W, Symmons M, Wright W (2013) What would a climate-adapted settlement look like in 2030? A case study of Inverloch and Sandy Point. National Climate Change Adaptation Research Facility, Gold Coast, 221 pp

Trück S, Bradford W, Henderson-Sellers A, Mathew S, Scott J, Street M, Taplin R (2010) Assessing climate change adaptation options for local government. Adapt Strat Glob Chang 13:47–69

UK CIP (2003) Climate adaptation: risk, uncertainty and decision-making. In: Willows RI, and RK Cornell (eds). UKCIP technical report, Oxford

Chapter 25
Awareness of Climate Change Impacts and Adaptation at Local Level in Punjab, Pakistan

Zareen Shahid and Awais Piracha

Abstract Climate change awareness is an imperative to achieve sustainability in developing countries. Lack of awareness is a significant barrier to climate change adaptation in developing countries. Raising climate change awareness at the local level is critical for Pakistan as climate change impacts are exacerbating the number and extent of disasters in this disaster-prone country. Pakistan's vulnerability to climate change impacts is very high (ranked 12th in the world). This research assesses the awareness of climate change impacts among the local planning officials in Punjab, Pakistan. The research contextualises its findings in the context of Pakistan's resilience to deal with the adverse impacts of climate change given its unique and unusual set of socio-political circumstances. The findings of this chapter are based on a detailed survey conducted with local planning officials of Lahore, Pakistan. The survey explores the level of awareness of climate change, its causes and impacts in Pakistan. The survey and subsequent analysis in particular focuses on the potential role of use of Geographical Information System (GIS) in raising climate change awareness.

Keywords Climate change awareness • Impacts and adaptation • Geographical information system

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25.1 Introduction

Climate change is the most serious global environmental issue of the present time. It is a serious threat to the security and prosperity of the world in the twenty-first century. Increased awareness assists in preparing and implementing climate change adaptation measures, such as adjustments in natural and manmade systems to reduce the likely impacts of climate change. Raising climate change awareness at the local government level is critical for Pakistan as climate change impacts are exacerbating the number and extent of disasters in this disaster-prone country. According to a recently published index, Pakistan was ranked 12th on the list of countries most vulnerable to the impacts of climate change (IUCN 2009a). This chapter provides an in-depth analysis of the survey conducted with 150 Union Council local officials of Lahore. This survey attempts to determine the level of climate change awareness among the local officials.

Climate change is a broad term and has been researched widely in many disciplines. However, the major focus of climate change research has usually been on scientific analysis and its implications and overlooks the human dimension of climate change impacts in developing countries. The research on climate change awareness and its adaptation in developing countries is still in its early stages.

Environmental awareness of individuals, organisations and firms is an indicator of how people respond to the negative impacts on their surrounding environment. Different studies in developed countries demonstrate that enhancing environmental awareness leads to better outcomes in planning and management of environmental resources (Ekpenyong 2009). According to Oxley (2010), increased sense of awareness of and interest in disaster risk reduction in Pakistan can help to increase the disaster preparedness through developing and forecasting early warning and evacuation systems. As some of these disasters, like floods and droughts, are related to climate change, it makes good sense to investigate what is known about climate change impacts and adaptation among various sections of society. Local planning officials are a group of stakeholders in Pakistan and elsewhere that have strong influence over physical development. Improvements in their level of climate change awareness can lead to better adaptation outcomes.

25.2 Climate Change and Pakistan

Pakistan is geographically situated in South Asia between 24 and 37° N latitude and 62–75° E longitude and lies on the western margin of the monsoon region of the world. Pakistan's climate varies from temperate in the north to hot and dry tropical in the south. Temperatures and precipitation in Pakistan varies widely. Temperatures reach up to 52 °C in the central arid plains and are as low as −26 °C over the northern mountains (Sultana et al. 2009).

Pakistan is a poor country with a very large population suffering from many social, economic and political problems. Major cities of Pakistan are experiencing a high rate of population growth, ongoing degradation of agricultural land, potential water shortages and uneven distribution of resources. The current population of Pakistan in 2012 is 190 million. With an annual population growth rate of 2.2 % (Lieven 2011), it is growing faster than other regional countries such as India, Bangladesh, Sri Lanka and Nepal (Pakistan Views 2009).

Pakistan is already a resource stressed country suffering from water shortages and ongoing degradation of agricultural land. Climate change is an additional stress to the existing problems of this country. Temperatures have risen from 0.6 to 1 °C in coastal areas of Pakistan since the early 1900s (Shahid 2009).

One of the significant impacts of climate change on water resources in Pakistan is the unpredictable melting of glaciers leading to flooding followed by decreased river flows and groundwater due to shrinking/disappearing glaciers. According to IPCC Fourth Assessment Report (2007), "Glaciers in the Himalaya are receding faster than in any other part of the world and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps warming at the current rate." While there has been a disagreement among climate scientists on the 2035 date, the chief of the UN climate change panel has stressed that the devastating impacts of this glacier melting cannot be ignored (SMH 2010).

Punjab, the most populous and densely inhabited province of Pakistan, is highly reliant on the glacier melts for irrigation and potable water. About 90 million people live in the province that has an area of 205,344 km^2. There are 36 districts of the Punjab Province and Lahore District is the provincial capital (Fig. 25.1). The climate of Punjab is generally arid, hot in summers and cool or cold in winters. The temperature in the cities of Punjab goes up to 46 °C in summer, and drops to near zero in winter. The Punjab province has five rivers: *Indus*, *Jhelum*, *Chenab*, *Ravi* and *Sutlej*. These rivers originate from mountains in Kashmir and are mainly fed by water from melting snows. They provide substantial surface and groundwater resources and fertility. About 50 % of Punjab's land is cultivated using water from these rivers and groundwater (Piracha 2008). Eighty percent of the water in Punjab's rivers is made up of glacier melts.

25.3 Research Methodology

The Punjab Province is selected for this research because it is the most populated and densely inhabited among all the provinces of Pakistan. Lahore District is selected for in-depth analysis of this research because Lahore is the second largest city in Pakistan and the provincial capital of the Punjab Province. This district is made up of both urban and rural areas. Most provincial head offices, policy makers, and experts are based in Lahore. Some National level organisations (Water and Power Development Authority, National Engineering Services Pakistan) are also

Fig. 25.1 Punjab Province (Source: http://upload.wikimedia.org/wikipedia/commons/1/19/Punjab_Pakistan1.PNG)

located in the Lahore City District. Opinion and policies of local officials in Lahore reflect and influence other districts in Punjab. Lahore City District is divided administratively into nine towns. These towns are further subdivided into union councils. Lahore City District consists of 150 union councils. Each union council has planned and unplanned areas. These union councils have diversity in their socio-economic characteristics and physical conditions.

Union council was selected for the purpose of the survey because all existing members of each union council are local officials and are very close to their community. These local officials are well aware of the problems of their respective union council. This survey was conducted with a standard questionnaire to know the existing level of awareness of climate change impacts and adaptation measures among local officials in each union council of Lahore City District. Detailed surveys of local officials were conducted from February to May 2011 in the union councils of Lahore City District.

Local officials (secretaries, union councils) were selected for detailed survey from union councils of Lahore. There are three secretaries for different administrative functions/duties in each union council and are as follows: (1) Secretary, Community Development; (2) Secretary, Municipal Services; and (3) Secretary, Union Committees.

At least one secretary (out of three) named as a local official was selected for a detailed survey from each union council. First priority was given to the Secretary, Community Development. In the absence of this secretary, the survey was conducted with the Secretary, Municipal Services. Last priority was given to Secretary, Union Committees. Therefore 150 was the sample size of local officials in union councils of Lahore for the detailed survey.

25.4 Functions and Responsibilities of Local Officials

Punjab Local Government Ordinance (PLGO) 2001 described the functions and responsibilities of union council local officials in detail. One of the functions and responsibilities of union council local officials is to collect and maintain statistical information for socio-economic surveys. It is also the responsibility of local officials to consolidate village and neighbourhood development needs and prioritise them into union-wide development proposals. Local officials also provide and maintain public sources of drinking water. They also work with other public, private or voluntary organisations, engaged in activities similar to those of the union. It is also the function of local officials to carry out projects of the approved Union Annual Development Plan by contracting out to the private sector. Local officials may seek the support of the Town Municipal Administration or District government for implementation of the Annual Development Plan. They also assist the relevant authorities in disasters and natural calamities, and assist in relief activities, including de-silting of canals (PLGO 2001).

25.5 Climate Change Awareness

Climate change is referred to as a clear, sustained change over several decades or longer in the components of climate, such as temperature, precipitation, atmospheric pressure, or winds (Parliament of Australia 2008). Almost half of the respondents of the survey (53 %) were not aware of the phenomenon of climate change meaning that only 71 out of 150 respondents were aware of climate change

Table 25.1 Extent of climate change awareness

Responses		Frequency	Percent	Valid percent	Cumulative percent
Valid	Only heard	33	22.0	46.5	46.5
	Know something about it	29	19.3	40.8	87.3
	Know a great deal about it	9	6.0	12.7	100.0
	Total	71	47.3	100.0	
Missing	System	79	52.7		
Total		150	100.0		

Source: Survey of Local Officials by Author, 2011

phenomena. It shows that the level of awareness about climate change among local officials is very low.

Lahore District has more urban areas than rural. Out of the 150 local officials from union councils of Lahore that were surveyed, 132 were from urban union councils, 17 were from rural union councils and 1 was from a union council that is both urban and rural. Respondents in all rural union councils were unaware of the climate change phenomena which demonstrate that local officials in urban areas of Punjab have higher awareness and literacy rates as compared to rural areas.

Deeper understanding of the climate change phenomena is also very low among local government officials in Pakistan as compared to other developing countries. For example, local government units in Philippines are aware and responsive to the need of climate change adaptation (Lasco et al. 2008). The extent of awareness about climate change among local officials of Lahore can be seen in Table 25.1. Almost half of the local officials who claimed to be aware of climate change knew nothing beyond the phrase climate change. Very few local officials (6 % of all respondents) knew a great deal about the climate change phenomenon. It shows very high level of climate change ignorance among the local government officials in Punjab.

25.5.1 Climate Change Awareness and Education

Education is positively associated with environmental awareness such as climate change. According to Mainieri et al. (1997), Fransson and Garling (1999), and Raudsepp (2001), educated people are more concerned about their surrounding environment and they have better access to the information about the environment. Pakistan falls significantly behind many countries in providing access to education. Whatever education is available is of poor quality. Although Pakistan and India were at comparable literacy rates at partition in 1947, Pakistan now significantly falls behind India (Fair et al. 2010). This study shows that the educational attainments of the climate aware were slightly better than the climate unaware respondents. There are more respondents in the categories of Masters Degrees and above

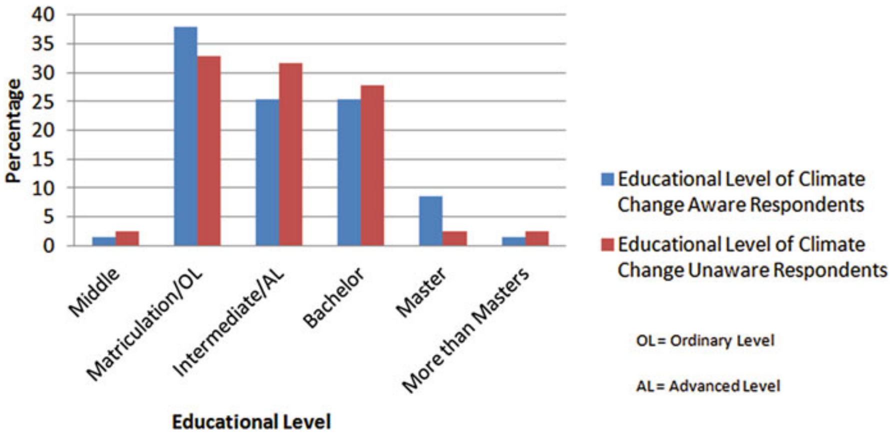

Fig. 25.2 Educational level of climate change aware and unaware respondents

in the climate aware category (Fig. 25.2). In general, though, both aware and unaware respondents seem to have low levels of educational attainments. This probably reflects the general low level of literacy and education in Pakistan.

According to the 1998 census in Pakistan (the last time a successful census was conducted there), the literacy rate in Lahore (one of the most developed parts of the country) was only 64.7 % (GOP 1998). According to the latest Pakistan Labour Force Survey 2009–2010, the overall literacy rate in Pakistan (age 10 years and above) is 57.7 % (69.5 % for male and 45.2 % for female). Low levels of education can also be seen from the fact that 37.5 % of the population in Pakistan has an educational attainment of below Matriculation (SSC). Quality of education is also very low in Pakistan because of the poor economic situation and peculiar socio-cultural conditions prevailing in the country. Most of the education budget is spent on salaries rather than on teacher training or curriculum development (GOP 2010–2011). Pakistan's literacy rate is very low among other developing countries e.g. literacy rate in India is 74.04 % (GOI 2011), in Iraq 74.1 %, in South Africa 86.4, in Sri Lanka 90.7 and in China 92.2 % (Index Mundi 2011).

The educational budget of Pakistan is miniscule at only 39,513 million PKR (437 million USD) (i.e. 1.7 % of total budget) out of a total Federal budget of 2,314,859 million PKR (25,605 million USD) for 2011–2012. A huge part of Pakistan's budget is spent on defence affairs and services. The expenditure against defence affairs and services has been allocated at 495,215 million PKR (5478 million USD) (i.e. 21.4 % of the total budget) in 2011–2012 (GOP 2011–2012). Pakistan's public spending on education as a percentage of Gross Domestic Product (GDP) is also very low as compared to other Asian developing countries. For example, Pakistan's public spending on education as a percentage of GDP is lowest at 2.1 % as compared to 5.2 % in Iran, 4.7 % in Malaysia, 3.5 % in Indonesia, 3.3 % in India and 3.2 % in Nepal (GOP 2010–2011).

25.5.2 Severity of Climate Change

Pakistan is a semi-arid and arid country and has already very meagre water resources. Pakistan's per capita water availability has reduced from 5000 to 1000 m^3 since 1947 (independence of country) because of an unprecedented population growth rate that is one of the highest in Asia (Majeed and Piracha 2011). In the survey, the 71 local officials who were aware of climate change were asked about the severity of the climate change threat to water resources. A majority of the respondents (73 %) believe that climate change is a very serious threat to the water resources of Punjab (Fig. 25.3). Only four local officials were unaware of the severity of the climate change threat to water resources in Punjab. While only a small percentage (13 %) of respondents has a deeper understanding of climate change (Table 25.1), a large percentage is convinced of its adverse impacts on water resources. This is perhaps due to present water shortages and widespread concern for the future of water resources.

25.5.3 Causes of Climate Change

A very big question in the climate change debate is its origins. Does it result from manmade causes or natural causes? Manmade causes of climate change include increases in greenhouse gases and emissions from automobiles, power plants,

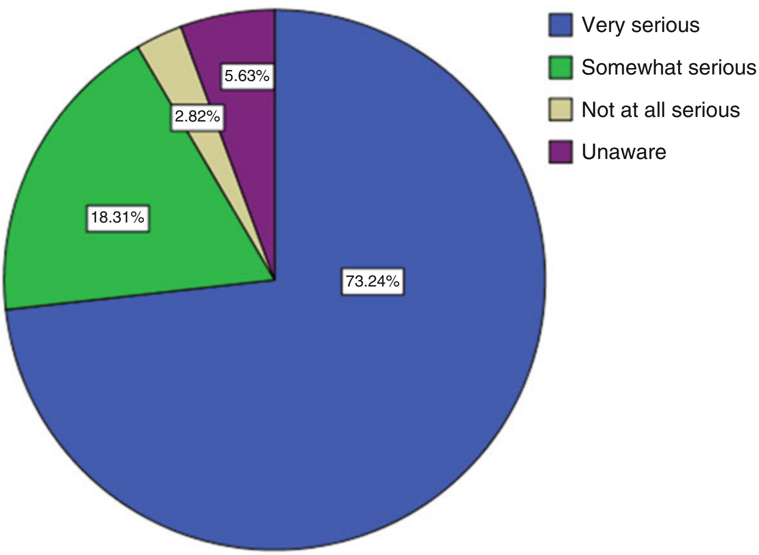

Fig. 25.3 Severity of climate change threat for water resources

Table 25.2 Causes of climate change

Responses	Frequency	Percent	Valid percent	Cumulative percent
Natural cause	5	7.0	7.0	7.0
Manmade cause	21	29.6	29.6	36.6
Both natural and manmade cause	44	62.0	62.0	98.6
Don't know	1	1.4	1.4	100.0
Total	71	100.0	100.0	

Source: Survey of Local Officials by Author, 2011

factories, etc. Literature shows that 97–98 % of the climate researchers believe humans are causing climate change (Anderegg et al. 2010).

In the survey the local government officials were asked about the causes of climate change. An overwhelming majority of respondents believe both natural and manmade causes are responsible for climate change (Table 25.2). Only 21 out of 71 (30 %) local officials think that climate change is only due to manmade causes. It further indicates a lack of knowledge about climate change phenomena among local officials in Punjab.

Media is an important factor affecting environmental/climate change awareness as it can create misinformation about climate change and lead to less awareness of the issue. For example, Nunn (2009) found in his study in the Pacific Islands that media focused on disastrous situations and extreme future climatic predictions of what might happen. This did not raise climate change awareness in Pacific Islands, but rather created misunderstanding about climate change. It was found during the survey that there is widespread concern in Pakistan about HAARP technology (High Frequency Active Research Program – USA military defence program aimed at studying the properties and behaviour of the ionosphere) causing climate change. A section of the Pakistani media has created hype on alleged usage of HAARP in creating artificial flooding in Pakistan. For example, in an article in the daily *Jang* newspaper (Pakistan) on March 23, 2011, a renowned Pakistani columnist Nusrat Mirza accused the USA of artificially causing the 2010 Pakistani floods, possibly through the use of HAARP technology at a scientific research centre in Alaska (Mirza 2011). According to a local news website Pakalert (2010):

> HAARP has recently been used in North-West area of Pakistan. The choice of starting point was perfect. All the flood is going in downstream i.e. Khyber (Hills) to Karachi (Sea).It is designed to submerge entire Pakistan and bring up the worst crisis and chaos ever happened. This flood disaster is more manmade than natural.

Electronic media in Pakistan is also highlighting the possibility of the use of HAARP technology in artificially creating 2010 flooding in Pakistan. For example, one of private TV channels, ARY News broadcast a detailed program named as '*Idraak*' (which can be roughly translated as understanding) on 25th June 2011, about the conspiracy of the use of HAARP technology in creating 2010 flooding in Pakistan. According to this program, monsoon clouds in Pakistan usually come from the east. But in 2010, monsoon clouds also came from the west causing flash flooding in Pakistan. The program alleged of a conspiracy about the use of HAARP technology in sending monsoon clouds from the west in Pakistan. The discussion around HAARP clearly shows misconception among people of Pakistan about the use of this technology. It also indicates lack of awareness in Pakistan about the causes of climate change.

25.5.4 Consequences of Climate Change

Global climate change impacts range from physical, to social and cultural aspects. Climate change is a great threat to the regions of developing countries because the effects of climate change are not equally distributed all over the world. The large and poor populations of developing countries are likely to be more affected by climate change impacts as compared to rich developed countries (Mertz et al. 2009). As developing countries, like Pakistan, are already suffering from high poverty levels and a scarcity of resources, populations of these areas are more vulnerable to the effects of climate change. Pakistan is ranked 12th among the countries that will be seriously impacted from climate change while its per capita carbon emissions (ranked 135th) are very low in international terms (IUCN 2009b).

Local official's opinion was sought during the survey about the present and future consequences of climate change for Punjab-Pakistan. Most of the respondents believe that water and food security of Punjab-Pakistan is threatened at the present time and in the future as a consequence of climate change (Fig. 25.4). Water, energy and agriculture sectors will be affected the most by climate change impacts in Pakistan (IUCN 2009b). According to Qureshi (2005), climate change will have adverse impacts on water availability for crop production. It is estimated that 40 % more food will be required by the year 2025 to fulfil the demand of an increasing population in Pakistan. This analysis shows consequences of climate change are very serious for Pakistan. While Pakistan will need much more food in future due to the pace of population growth, climate change is eroding even its current food production capacity. The local planning officials seem to understand that the situation is dire.

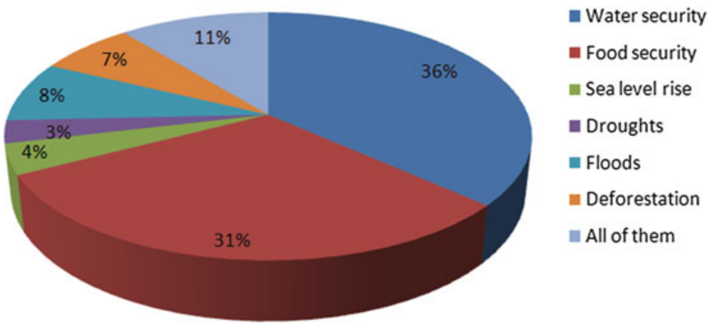

Fig. 25.4 Consequences of climate change

25.5.5 Government Role and Climate Change Awareness

The Government of Pakistan, with its limited financial and technical capacity, is trying to increase environmental awareness in various sectors such as energy, forestry, biodiversity and agriculture. The Government of Pakistan has also formulated and approved its first National Climate Change Policy but there is a need of coordination among different departments for implementation of such policies. It shows that the Government of Pakistan is at the very initial stages of dealing with the issue of climate change and raising climate change awareness at a local level.

The survey revealed that the majority of local officials believe that Provincial and National governments in Pakistan are not doing enough to increase awareness about climate change impacts. This perhaps is reflective of a lack of interest from Provincial and National governments in dealing with climate change issues. A central reason for governmental inaction in raising climate change awareness is the instability of the Pakistani government itself. Pakistan has experienced several waves of political violence, essentially related to various forms of sectarian, ethnic, tribal, and, more recently, so called global jihadi movements (Cohen 2011). This peculiar situation in the country is also creating a self-centered conspiracy based siege mentality in Pakistan that is hindering any government action for climate change awareness.

There are many barriers for local officials in promoting climate change awareness among the general public. Table 25.3 shows multiple responses of local officials about barriers in promoting climate change awareness among the public. Most of the respondents believe that a lack of funds and government awareness are the main barriers that need to be removed in promoting awareness of climate change among the public. Similarly Lata and Nunn (2012) described in their study that the lack of awareness is a big barrier to climate change adaptation in developing countries. Other responses of local officials about barriers in promoting climate change awareness are the lack of government interest, corruption, lack of attention/responsibilities of authorities and lack of planning. Many local officials in Lahore believe that political instability and the fragile economic situation of the country are also main barriers for government in promoting climate change awareness among the public. Lata and Nunn (2012) argue that cultural barriers to climate change adaptation in developing countries are short term planning perspectives and traditional governance structures.

Table 25.3 Barriers in promoting climate change awareness

Responses		Frequency		Percent of cases (%)
		N	Percent (%)	
Barriers in promoting climate change awareness	Lack of funds	30	33.3	42.3
	Lack of staff	11	12.2	15.5
	Lack of awareness	28	31.1	39.4
	Any other	14	15.6	19.7
	Unsure	7	7.8	9.9
Total		90	100.0	126.8

Source: Survey of Local Officials by Author, 2011

25.6 Awareness About Climate Change Impacts on Water Resources

Per capita water availability in Pakistan is very low at 1756 m^3/year/person as compared to the global average of more than 7000 m^3/year/person (Adeel and Piracha 2004). According to Mirza and Ahmad (2005), even small changes in climate can cause water resources problems in Pakistan. Pakistan's major reservoirs can only store 15.6 MAF (million acre feet) of water which has now been reduced to 12.8 MAF due to silting. Pakistan has only 150 cubic meters of storage capacity per capita as compared to 5000 cubic meters of storage per capita in the USA. Scarcity of water has also reached an alarming situation in Pakistan with almost 90 % of available water used by the agriculture sector. Hence a large section of the population suffers water shortages and high water pricing (Amir 2009).

The Punjab province has five rivers: *Indus*, *Jhelum*, *Chenab*, *Ravi* and *Sutlej* and these rivers are mainly fed by water from melting snow from glaciers. These rivers are the single most important natural resource in the province (Piracha 2008). High population density and growth has resulted in the scarcity of Punjab's water resources. Climate change is an additional stress to the Punjab's water resources. The local officials were asked about climate change impacts on water resources of Punjab. A vast majority of respondents in this survey are aware of the scarcity of water resources in Punjab due to climate change. Only 20 % of local officials were unaware of the scarcity of Punjab's water resources due to climate change.

One of the significant impacts of climate change on water resources of Pakistan is unpredictable melting of glaciers followed by decreased river flows. About two fifths (39 %) of the respondents were aware of Himalayan Glaciers melting due to climate change whereas almost the same number of respondents (38 %) were unsure about this fact. The World Bank Study 'Pakistan's Water Economy Running Dry' (2006) cited in (Amir 2009) stated that "Western Himalayan Glaciers will retreat for the next 50 years causing increase in Indus River flows. Then the glacier reservoirs will be empty, resulting in decrease of flows by up to 30–40 % over the subsequent fifty years".

Melting of seasonal snowfall and rapid glacier melting has resulted not only in a reduction of water resources but has also caused flash floods in many areas of Pakistan (Jilani et al. 2007). Pakistan's economy is also affected by glacier melting because it depends on this water. A question about the impacts of glacier melting was asked of the 28 local officials who were aware of Himalayan Glaciers melting due to climate change (Table 25.4). According to 36 % of local officials, flooding is the major impact of glacier melting on water resources of Punjab. Other impacts of glacier melting in Punjab are water scarcity and reduced agricultural yield. This analysis shows local officials have little understanding of Himalayan Glaciers melting due to climate change and its impacts on water resources of Punjab.

Flooding is the most damaging and frequent natural disaster in Pakistan. According to Abbas's (2009) Oxfam reports, 40 % of the population of Pakistan is vulnerable to multiple disasters and this vulnerability is predicted to be increased by

Table 25.4 Impacts of glacier melting on water resources of Punjab

Responses		Frequency		Percent of cases (%)
		N	Percent (%)	
Impacts of Glacier Melting	Water scarcity	11	33.3	39.3
	Reduced agricultural yield	10	30.3	35.7
	Floods	12	36.4	42.9
Total		33	100.0	117.9

Source: Survey of Local Officials by Author, 2011

increasing climate change impacts. Almost 10 % of the Pakistan's population was badly affected by the 2010 flooding (Polastro et al. 2011). Around 75 % of the local officials in this survey believe that the 2010 flooding in Pakistan was due to climate change impacts. Although local officials do not have a deeper understanding of climate change impacts, the majority of them believe that the 2010 flooding in Pakistan was due to climate change impacts.

25.7 Awareness About International Climate Change Agreements and Working to Reduce Climate Change Impacts

All local officials in this survey were unaware of the international climate change agreements, for example United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol and Intergovernmental Panel on Climate Change (IPCC). Pakistan has a few international commitments in the area of climate change like Medium Term Development Plan 2010–2015, United Nations (UN) Programme on Environment, National Environmental Policy, and National Energy Conservation Policy (NECP). These documents clearly describe the Pakistan government's commitment with the International organisations regarding climate change (Khan 2011). Survey with local officials shows a lack of awareness and concern at the grass root level about the environmental and climate change agreements.

Local governments in some developing countries are aware of the formulation of climate change plans. For example, local governments in the province of Albay in the Philippines are making climate a change adaptation plan e.g. “Albay in Action on Climate Change (A_2C_2)”. Local government in Philippines also have the capacity to meet the challenge of frequent and severe climate hazards (Lasco et al. 2008). Since mid-2007, a number of provinces in China set up special task forces to work on climate change and made specific plans for climate change research, mitigation and adaptation. China's central and local government established a National Leading Group on Climate Change (NLGCC), National Coordination Group on Climate Change Strategy (NCGCCS), Provincial Leading Groups on Climate Change and Provincial Plans for Climate Change Response (Qi et al. 2008).

The local officials in Lahore/Punjab were asked about the formulation of a climate change adaptation plan. Majority of the respondents (97 %) said that their union council is not making any climate change adaptation plans to deal with the climate change impacts for Punjab. It shows a high level of irresponsibility in dealing with the potentially devastating impacts of climate change in Punjab. Practically there is no climate change planning taking place at the local level in Lahore which is the most developed city in Punjab. It can thus be concluded that there is no planning at the local level in Punjab, Pakistan to adapt to climate change conditions.

Pakistan is a poor country with a very high population growth rate at 2.2 % per year and if it continues, Pakistan may have a population of 335 million by the middle of twenty-first century (Lieven 2011). There might be various reasons for not making any climate change adaptation plan by union councils in Lahore. One third (32 %) of local officials believe that a lack of awareness among local government officials is the main reason for not making any climate change plan by union councils. Many local officials described that it is not their responsibility to prepare climate change plans and it is the responsibility of Water and Sanitation Agency (WASA).

As discussed earlier flooding is one of the biggest disasters that occurs in Pakistan. Of the population who are affected by natural hazards in Pakistan, 90 % are subjected to flooding (Haider 2006 cited in Tariq and van de Giesen 2011). Most of the union councils (97 %) in this survey did not make any plan to reduce the impacts of future flooding in Punjab. This shows a culture of carelessness in Punjab about dealing with future flooding at a grass root level in the province. Local governments in other developing countries are taking initiatives to make plans to reduce impacts of flooding in their local areas. For example, Philippines's government had recently installed 15 rain gauges on the slopes of Mount Mayon – an early warning system against deadly floods and their plan is to install more sophisticated early warning weather stations to reduce the impacts of future flooding (Lasco et al. 2008).

25.8 Awareness About Geographical Information System (GIS) and Computer Use in Planning

GIS can be used efficiently for visual displays and preparing artistic community maps. These maps are cost-effective and efficient tools to increase public environmental awareness. According to Wood (1994), maps are a good way of communicating as they also show relationships with surrounding environments. Visual displays and maps are used in school curriculum to increase students' awareness about surrounding environment. Maps have become an educational tool to create awareness and public participation tool that helps unite the community.

The last part of this chapter attempts to determine the level of use of GIS has in planning and to determine the possibility of using this tool to increase awareness of local officials about climate change. Questions related to this section were asked

Table 25.5 Softwares used by Union Councils

Responses		Frequency N	Frequency Percent (%)	Percent of cases (%)
Type of software used by Union Councils	Microsoft Word	12	7.1	8.0
	Microsoft Excel	4	2.4	2.7
	Microsoft Power point	1	.6	.7
	AutoCAD	2	1.2	1.3
	CRMS (Civil Registration Management System)	150	88.8	100.0
Total		169	100.0	112.7

Source: Survey of Local Officials by Author, 2011

from both climate aware and unaware respondents (150 local officials). All union councils in this survey had desktop computers in their offices however local officials only have basic computer knowledge.

Union council is the lowest tier of the local government system in Pakistan and local officials working in these councils are not well qualified to use the latest computer software. Table 25.5 shows multiple responses of 150 local officials about the use of software for planning purposes at their respective union councils. All union councils' local officials are using Civil Registration Management System (CRMS) for registration of birth, death, marriage and divorce certificates. As shown in Table 25.5, only 12 out of 150 union council local officials were using Microsoft Word for documentation of their work. Union councils' officials are not using any software for planning purposes suggesting that planning tasks are probably not given to them.

The internet has now become a basic requirement for every planning office in the world. Internet access was asked of the local officials and 94 % of union councils did not have any internet access in their offices with only 9 out of 150 union councils having access to internet in their offices. It might be due to lack of resources of government to provide internet access in union councils. Poor internet access can also be due to a deficiency in English language skills and worries about inappropriate viewing, playing games and chatting.

Not a single union council in this survey ever conducted an electronic survey (email survey). Most of the local officials described the reason for not conducting electronic surveys is that people do not respond to email surveys in Pakistan. It was revealed in the survey that local officials were not using computers for planning purposes at their union councils. They were only using computers for documentation of their work. Seventy nine percent of respondents in this survey agreed that computer use saved time and money. Despite scant use of computers by local officials in their work, they are convinced of the importance using computers for planning purposes which demonstrates their willingness to increase computer use for planning purposes.

Geospatial technologies may play an important role in increasing awareness of climate change's irreversible and uncontrollable consequences among people and different public agencies. Among these technologies, GIS is an important tool to understand climate change phenomena in order to adapt. This survey attempts to find out the awareness of local officials about GIS. A majority of respondents (85 %) in this survey were unaware of GIS. In addition, major constraints to the use of GIS in Pakistan are (Zaidi 1998): (1) non-availability and high cost of GIS software, (2) acute shortage of GIS experts, and (3) the non-existence of relevant data in Pakistan to use with GIS.

At this stage of the survey, a few maps of climate change as examples were shown to local officials (see Annexure A). After seeing these maps, a majority of respondents (91 %) agreed that they could be helpful in raising climate change awareness among the public. Only 12 out of 150 (8 %) local officials were still unsure about the use of GIS maps to raise climate change awareness. It shows the readiness of local officials to use computer tools/GIS in raising climate change awareness among the public.

A question was asked of the local officials regarding their opinion of the preparation of climate change maps for Punjab using GIS. The majority of respondents (94 %) believed that climate change maps for Punjab should be prepared using GIS. It was revealed during the survey that a number of local officials wanted to display climate change maps in their offices to increase climate change awareness among the public but they do not have enough expertise to prepare such maps. These responses show a willingness of local officials to prepare climate change maps for Punjab using GIS.

At the end of this survey, a question about suggestions to reduce the adverse impacts of climate change was asked of the 71 local officials of union councils who were aware of climate change. Some local officials mentioned existing problems in the country (for example, corruption) rather than giving suggestions to reduce the impacts of climate change. Although the majority gave suggestions to increase awareness via campaigns, seminars and workshops about climate change, the reduction of pollution and increasing plantation. A few respondents gave religious suggestions to reduce the impacts of climate change such as to follow Islam completely and be good in deeds then God will solve all problems. These suggestions are similar to the study of Lata and Nunn (2012) in Rewa Delta, Fiji where people have spiritual beliefs that climate change impacts are the unalterable will of a god.

25.9 Conclusions

Pakistan is a disaster-prone country and climate change impacts are exacerbating the number and extent of disasters. Rapid population growth, poor urban management, and non-implementation of various policies are creating the peculiar situation for the country. Pakistan's resilience to deal with the adverse impacts of climate change is also very low because of the country's socio-political instability. Extreme poverty and a weak institutional capacity to effectively respond to the climate change impacts in Pakistan is also increasing vulnerability to existing disasters.

This chapter highlights that climate change awareness is at an alarmingly low level in local government in Pakistan. Understanding of climate change impacts and its consequences is very low at the lower level of local government among union council local officials in Punjab. Scarcity of water resources in Punjab is already at an alarming situation and climate change impacts will exacerbate it. Local officials are aware of the adverse impacts of climate change on water resources. There is little understanding among local officials about the causes of climate change and how it might exacerbate water security situation.

This chapter also revealed that local officials at union councils have a low level of education and are poorly trained. These officials are unaware of the Himalayan Glaciers melting due to climate change. They (those who are aware of climate change) believe that the 2010 flooding in Pakistan was due to climate change impacts. They have no knowledge about international climate change agreements. Local officials are ill-equipped to prepare any climate change adaptation plans to reduce future flooding in Punjab. Local officials are unaware of the use of GIS and their importance in planning. They believe, when prompted, that GIS prepared climate change maps can be helpful in raising climate change awareness among the public and these maps should be prepared for Punjab.

25.10 Recommendations

There are a very few studies on climate change research in Pakistan. However there is a need to strengthen the institutional setup to prepare and implement climate change adaptation strategies in Pakistan. Some policy recommendations to deal with the issue of climate change by local government in Pakistan are as follows:

- Climate change awareness raising campaigns are needed at a local level in Pakistan.
- Local government setup in Pakistan should be strengthened to implement National Climate Change Policy.
- Potential climate change adaptation actions are need at a local level to reduce the vulnerability of climate change impacts in Punjab.
- Water resources are very sensitive to the impacts of climate change. So water resources adaptation measures should be incorporated in planning and development policies of government.

References

Abbas Z (2009) Climate change, poverty and environmental crisis in the disaster prone areas of Pakistan. Oxfam GB Pakistan Programme, Islamabad
Adeel Z, Piracha A (2004) Critical links between environment and development in South Asia. In: Thakur R, Wiggen O (eds) South Asia in the world: problem solving perspectives on security, sustainable development, and good governance. United Nations University Press, Tokyo, pp 205–224
Amir P (2009) Climate change water vulnerabilities in Pakistan. International Union for Conservation of Nature (IUCN), Department for International Development (DFID), Government of Pakistan, Ministry of Environment. http://cmsdata.iucn.org/downloads/pk_cc_water_vul.pdf. Accessed 12 Nov 2011
Anderegg WRL, Prall JW, Harold J, Schneider SH (2010) Expert credibility in climate change. Proc Natl Acad Sci U S A 107(27):12107–12109
ARY News (2011) Idraak 25th June 2011. http://www.youtube.com/watch?v=X85R_JyvMks&feature=related. Accessed 12 Nov 2011
Cohen SP (2011) The future of Pakistan. Brookings Institution Press, Washington, DC
Ekpenyong E (2009) Environmental awareness as a panacea for sustainable environmental management in Africa. International Association for Impact Assessment, viewed 20th February, 2010. http://www.iaia.org/iaia09ghana/documents/cs/CS5-2_Ekpenyong_Environmental_Awareness_as_a_Panacea.pdf
Fair CC, Crane K, Chivvis CS (2010) Pakistan: can the United States secure an insecure state? RAND Corporation, Santa Monica
Fransson N, Garling T (1999) Environmental concern: conceptual definitions, measurement methods, and research findings. J Environ Psychol 19(4):369–382
HAARP (High Frequency Active Auroral Research Program) (2011) Program purpose. http://www.haarp.alaska.edu/haarp/gen.html. Accessed 18 Jan 2012
GOP (Government of Pakistan) (1998) City District Lahore at a glance. Population Census Organisation. http://www.census.gov.pk/PUNJAB/LAHORE.html. Accessed 5 Nov 2011
GOP (Government of Pakistan) (2010–2011) Pakistan economic survey 2010–11, Economic Adviser's Wing, Ministry of Finance, Government of Pakistan, Islamabad
GOP (Government of Pakistan) (2011–2012) Budget in brief 2011–12 Ministry of Finance. Government of Pakistan, Islamabad
Haider N (2006) Living with disasters: disaster profiling of districts of Pakistan. National Disaster Management Authority Islamabad, Pakistan, p 65
Index Mundi (2011) Country comparison: literacy. http://www.indexmundi.com/g/r.aspx?c=iz&v=39. Accessed 21 Jan 2012
IPCC (2007) Climate change 2007: impacts, adaptation and vulnerability, contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge
IUCN (International Union for Conservation of Nature) (2009a) Climate change an economic threat, say experts. http://www.iucn.org/about/union/secretariat/offices/asia/asia_where_work/pakistan/?2541/Climate-change-an-economic-threat-say-experts. Accessed 23 Aug 2009
IUCN (International Union for Conservation of Nature) (2009b) Government of Pakistan's agriculture and water policies with respect to climate change: policy gap analysis, IUCN Pakistan, Department for International Development (DFID) and Government of Pakistan
Jilani R, Haq M, Naseer A (2007) A study of Glaciers in Northern Pakistan. In: The first joint PI symposium of ALOS data nodes for ALOS science program in Kyoto Secretariat, Japan Aerospace Exploration Agency (JAEA), Kyoto International Conference Centre, Main Hall, 19–23 November, 2007
Khan JA (2011) Climate change patterns and their impacts with special focus on Pakistan. Paper presented to symposium on 'Changing environmental pattern and its impact with special focus on Pakistan', Pakistan Engineering Congress (PEC), paper no. 285, Pakistan

Lasco RD, Rangasa M, Pulhin FB, Delfino RJ (2008) The role of local government units in mainstreaming climate change adaptation in Philippines. Centre for Initiatives and Research on Climate Adaptation (CIRCA). http://www.albaycirca.org/THE%20ROLE%20OF%20LOCAL%20GOVERNMENT%20UNITS.pdf. Accessed 19 Nov 2011

Lata S, Nunn P (2012) Misperceptions of climate-change risk as barriers to climate-change adaptation: a case study from the Rewa Delta, Fiji. Clim Chang 110(1):169–186

Lieven A (2011) Pakistan a hard country, 1st edn. Perseus Book LLC, New York

PLGO (Punjab Local Government Ordinance) (2001) Punjab Local Government Ordinance, 2001, (ORDINANCE No.XIII OF 2001), Compiled by Ops Wing, NRB (National Reconstruction Bureau), May, 2006

Mainieri T, Barnett EG, Valdero TR, Unipan JB, Oskamp S (1997) Green buying: the influence of environmental concern on consumer behavior. J Soc Psychol 137(2):189–204

Majeed Z, Piracha A (2011) Water conservation of Pakistan's agricultural, municipal and industrial water. Int J Water Res Arid Environ 1(3):232–238

Mertz O, Halsnaes K, Olesen J, Rasmussen K (2009) Adaptation to climate change in developing countries. Environ Manag 43(5):743–752

Mirza N (2011) The Japanese earthquake and tsunami – natural or artificial? Daily Jang March 23, 2011

Mirza MMQ, Ahmad QK (2005) Climate change and water resources in South Asia: an introduction. In: Mirza MMQ, Ahmad QK (eds) Climate change and water resources in South Asia. Taylor and Francis Group, London

Nunn PD (2009) Responding to the challenges of climate change in the Pacific Islands: management and technological imperatives. Clim Res 40(2–3):211–231

Oxley M (2010) Pakistan floods: Preventing future catastrophic flood disasters'. In: Global Network of Civil Society Organisations for Disaster Reduction. Viewed 2nd January, 2011, http://duryognivaran.org/documents/Pakistan_Floods-Marcus%20Oxley.pdf

Pakalert (2010) Pakistan flood: HAARP used in Pakistan? – Urgent. Pakalert Press. http://www.pakalertpress.com/2010/08/06/pakistan-flood-photos-haarp-fingerprints-found-allover. Accessed 18 Sept 2011

Pakistan Views (2009) Pakistan's population growth highest in region: World Bank report, 25th January 2009. Viewed 10 Oct 2009. http://www.pakistanviews.com/business/pakistan-s-population-growth-highest-in-region-world-bank-report.html

Parliament of Australia (2008) Climate change and global warming – what's the difference? Commonwealth of Australia. Viewed 15th January 2012, http://www.aph.gov.au/library/pubs/climatechange/theBasic/climate.htm

Piracha A (2008) Geoinformatics for guiding industrial location in Punjab Pakistan. Paper presented to 2nd international conference on advances in space technologies, Islamabad, Pakistan, 29th–30th November, 2008

Polastro R, Nagrah A, Steen N, Zafar F (2011) Inter-agency real time evaluation of the humanitarian response to Pakistan's 2010 flood crisis, Inter-agency Standing Committee (IASC), Funded by United Nations Office for the Coordination of Humanitarian Affairs (OCHA)

Qi Y, Li M, Zhang H, Li H (2008) Translating a global issue into local priority: China's local government response to climate change. J Environ Dev 17(4):379–400

Qureshi AS (2005) Climate change and water resources management in Pakistan. In: Mirza MMQ, Ahmad QK (eds) Climate change and water resources in South Asia. Taylor and Francis Group, London

Raudsepp M (2001) Some socio-demographic and socio-psychological predictors of environmentalism. TRAMES: J Humanit Soc Sci 5(4):355–367

Shahid J (2009) Climate change effects to hit Pakistan hard: IPCC Chief, Daily Dawn, 14th January, 2009

SMH (2010) Climate panel chief admits glacier mistake. The Sydney Morning Herald, 3 Feb 2010

Sultana H, Ali N, Iqbal M, Khan A (2009) Vulnerability and adaptability of wheat production in different climatic zones of Pakistan under climate change scenarios. Clim Chang 94(1):123–142

Tariq MAUR, Van De Giesen N (2011) Floods and flood management in Pakistan, J Phys Chem Earth, Parts A/B/C, 47–48:11–20

Wood D (1994) Memory, love, distortion, power: what is a map? Orion Magazine, pp 24–33, viewed 18th February, 2012. http://www.deniswood.net/content/Orion.pdf. Accessed 18 Feb 2012

Zaidi SS-U-H (1998) Potentials and constraints of the use of GIS in City and Regional Planning. In: Conference proceedings: GIS applications to resource management and environmental planning, Rawalpindi/Islamabad, Pakistan

Chapter 26
Urbanisation, Nutrition and Food Security: A Climatological Perspective

Tom Beer, Brenda B. Lin, and Albert E.J. McGill

Abstract In this chapter the effects of climate change on food production are considered with particular reference to urban agriculture and the associated impacts on food security. The value of urban agriculture to the health and nutrition of developing and developed countries is described. The current status of related research by international agencies is outlined and their omissions highlighted. Proposals are made as to how theses overlooked areas of research might be addressed.

Keywords Urbanization • Climate change • Food production • Food security • Health • Nutrition

26.1 Introduction

To climatologists, nutritional security is dominated by the impacts of weather and climate on food systems. With growing urbanisation around our metropolitan cities and regional centres, extreme weather events such as tropical cyclones impact directly on agriculture and on the logistical distribution of food.

Drought affects human life and health as well as impacting dramatically on the sustainable development of society. It represents a pending danger for vulnerable agricultural systems that depend on the occurrence of rainfall, the security of water supply and the integrity of reservoirs. Developed countries are affected, but the impact is disproportionate within the developing world. Drought, especially when it results in famine, can change the life and economic progression of developing nations and stifle their development for decades. *A holistic approach is required to*

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understand the phenomena, to forecast catastrophic events such as drought and famine and to predict their societal consequences.

In the Food Security recommendations of the Rio+20 Forum on Science, Technology and Innovation for Sustainable Development, held as a preparatory scientific meeting to the 2012 UN Conference on Sustainable Development, one of the recommendations states that scientists need "To understand fully how to measure, assess and reduce the impacts of production on the natural environment including climate change, recognising that different measures of impact (e.g. water, land, biodiversity, carbon and other greenhouse gases, etc.) may trade-off against each other…".

The International Union of Geodesy and Geophysics (IUGG) is leading a consortium of international scientific unions to examine weather, climate and food security (WeatCliFS) as well as to look at the interaction of food security and geophysical phenomena. The following fundamental question underpins WeatCliFS: *What technologies and methodologies are required to assess the vulnerability of people and places to hazards [such as droughts that lead to famine] – and how might these be used at a variety of spatial and temporal scales?*

This chapter will consider the potential effects of climate change on urban agriculture specifically and the resulting impacts on food security.

26.2 Urbanisation and Food Security

26.2.1 Urbanisation, Food Security, and Health

Urbanisation is a major driver of land cover change worldwide (Grimm et al. 2008; McDonald et al. 2008) and has large effects on the biophysical and socioeconomic landscape. It is estimated that >60 % of the global population will live in urban areas by 2030 (United Nations 2006), and urban planners are increasingly concerned with food security in cities (Aubry et al. 2012). Many cities contain 'food deserts', areas where access to fresh produce is limited due to reduced proximity to markets, financial constraints, or inadequate transportation (ver Ploeg et al. 2009; Thomas 2010) thereby negatively affecting the health of urban residents (Shaw 2006).

Various actions can improve the health and sustainability of cities (Beniston and Lal 2012), especially in food insecure and under-served communities (Alig et al. 2004). The United Nations Development Programme's (UNDP) review of urban food supply around the globe has indicated that local production increases nutrition, enhances food security, and creates employment opportunities for communities (Smit et al. 1996), and studies have shown that those who participate in urban food production have more adequate nutrition compared to community members who are not involved (Alaimo et al. 2008; Zezza and Tasciotti 2010). Indeed, interest in urban agriculture has escalated due to the motivation to address food insecurity and childhood obesity issues in disadvantaged urban neighbourhoods (Yadav et al. 2012).

Urban agriculture can produce significant amounts of food for urban citizens and have a large effect on urban nutrition and health. Urban agriculture activities are broad and diverse and can include the cultivation of vegetables, medicinal plants, spices, mushrooms, fruit trees, and other productive plants, as well as the keeping of livestock for eggs, milk, meat, wool, and other products in both urban and peri-urban areas (Lovell 2010). Currently, urban food production systems provide an estimated 15–20 % of the global food supply through urban agriculture (Smit et al. 1996; Hodgson et al. 2011), yielding 2–7 kg m^{-2} depending on crop conditions (Beniston and Lal 2012). For example, urban agriculture provides 60 % of the vegetables and 90 % of the eggs consumed by residents in Shanghai (Bhatt and Farah 2009), 47 % of produce in urban Bulgaria (Premat 2005), 60 % of vegetable produce in Cuba (Premat 2005), and 90–100 % of the leafy vegetables in poor households of Harare, Zimbabwe (Mougeot 2005). Such local food production has been important in maintaining the health and wellbeing of residents in these cities.

26.2.2 Vulnerability to Climate Events

Climate variability and extreme climate conditions have increased in frequency in the last century (Porter and Semenov 2005). Figure 26.1 shows the number of climatological, meteorological, hydrological, geological and biological disasters recorded in the EMDAT database of disaster trends from 1980 to 2012. Extreme and variable climate conditions, such as stronger and more irregular precipitation or increased temperature, lead to significant declines in crop yields and crop stability (Lansigan et al. 2000; Olesen and Bindi 2002; Wollenweber et al. 2003). Unfortunately, despite the extreme impacts of climate conditions on agroecosystems and the broad implications for food supply and production, climate variability and climate extremes are rarely studied outside of rural agroecosystems. Specifically, there is a large gap in research on climate effects, and especially the effects of extreme climatic effects such as tropical storms on local urban food production. This is of particular concern given that urban landscapes frequently exhibit more extreme climate impacts than rural areas due to increased impervious land cover.

A number of environmental changes that have already come with urbanisation and affect the agronomic conditions necessary for food production (Pickett et al. 2001; Kaye et al. 2006) include changes in patterns of water availability, nutrient supply, soil degradation, and pest pressure affecting crop growth in urban areas (Eriksen-Hamel and Danso 2010). Extreme climate events add another layer of complexity affecting local production. However, urban agriculture systems may provide services that help regulate climate impacts. For example, many private and community gardens provide storm attenuation services to the urban landscape by decreasing the amount of impervious surface in cities. In German cities, allotment gardens used on green belts have been shown to facilitate drainage and reduce local flooding from storm events by allowing for a greater infiltration potential of precipitation (Drescher et al. 2006). In contrast, hard paving increases impervious surfaces,

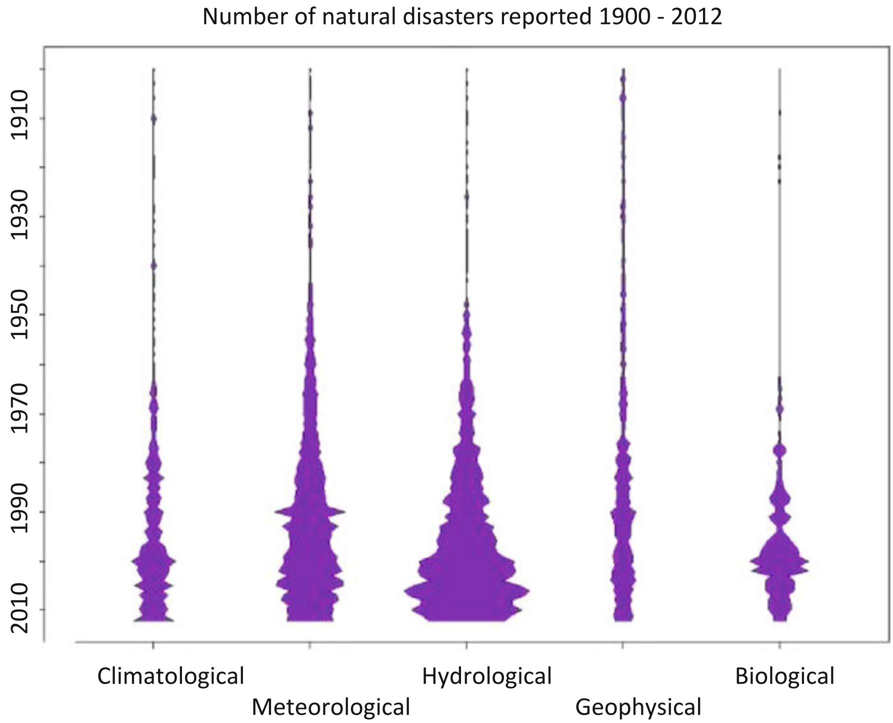

Fig. 26.1 Number of climatological, meteorological, hydrological, geological and biological disasters recorded in the EMDAT database of disaster trends (http://www.emdat.be/disaster-trends)

and in Leeds, United Kingdom (UK), increased hard paving in residential front gardens has been linked to more frequent and severe local flooding (Perry and Nawaz 2008).

Little is presently known about the effect of climate events on urban food production or the resilience of urban agriculture and urban food supply to extreme climate conditions (Eriksen-Hamel and Danso 2010), however, considering the increasing incidence of extreme climate events in many cities, and the potential threat to local food production, this presents an important area of future research to protect food access within cities.

26.2.3 Requisite Services

The wide range of urban agriculture types allows for urban agriculture systems to provide a broad variety of services to the city and to play a significant role in improving food security around the world (Smit et al. 1996; Pearson et al. 2010).

Two types of services are important to urban residents, especially in poor and under-served communities:

(1) ***Provision of improved nutrition***: Providing better nutrition to local residents by improving access to nutritious foods such as fruits, vegetables and medicines that may not be otherwise available. This will have a large impact on the health of local residents.
(2) ***Storm attenuation***: The additional green space infrastructure provided within urban food gardens may help protect urban residents and crop production from the damaging effects of storms (e.g. rain and wind damage, flooding).

There is a great diversity of food production available within cities, and different management methods will have different levels of service provision. The different types of urban food production systems include, but are not limited to, allotments gardens, community gardens, rooftop gardens, community orchards, as well as private gardens in household lots (McLain et al. 2012). It is expected that these various types of gardens will have different abilities to provide health/nutrition services and storm attenuation services.

A number of urban planners, architects and building designers are incorporating schemes for advanced urban agriculture in their current developments through various forms of Vertical Farms (Despommier 2010).

In regards to health/nutrition services, the various types of gardens may provide a good diversity of fruit, vegetables, proteins, and medicines that impact on local health and nutrition. For example, in Santarem, Brazil, a total of 98 plant species were identified in 21 sampled urban gardens and included a large diversity of fruit trees and shrubs (comprising 34 % of garden cover), ornamental plants (10 %), vegetable/herb plants (13 %), and medicinal plants (45 %) (WinklerPrins 2002). In another example from Leon, Nicaragua, 293 plant species belonging to 88 families were recorded across 96 surveyed patios/home gardens, ranging in habit and taxonomic origin (González-García and Sal 2008). In Toronto, surveys in community gardens showed that besides the typical local vegetables (cabbage, tomatoes, peppers, and eggplant), farmers grew an additional 16 vegetable crops to supply the local community with foods that were difficult to find in local grocery stores, including specialty, Asian, Indian, and Ethiopian vegetables (Baker 2004). Such studies point to the need to provide culturally appropriate food to communities in order to maintain health and nutrition. In their discussion of food security the FAO (n.d) note that the provision of a greater diversity of produce is critical to food security.

In regards to the second service, storm attenuation, resilience to climate events may increase by providing different levels and types of storm attenuation and water storage services through green infrastructure. Cities with vegetation, trees especially, intercept intense precipitation and hold water temporarily within their canopy, thus reducing peak water flow, easing demand on storm drains, reducing flooding, and minimising flood damage (Xiao and McPherson 2002). If developed in urban gardens, the green vegetation can contribute to climate resilience for the city as well as increasing the resilience of local gardens to storm damage. For example, tropical home gardens in and around cities have stratified vegetation similar to those seen in multi-stratified agroforestry systems (Moguel and Toledo 1999), and such systems have been shown to protect crops from storm damage when compared to systems with less canopy cover (Philpott et al. 2008). Many private and community gardens also provide storm attenuation services to the urban landscape by decreasing the amount of impervious surfaces in cities. In addition to the food supply, urban agriculture and even gardens also supply physical exercise and improved social contact for residents who might otherwise be very isolated even in a crowded city.

26.3 International Co-operation

As a general rule in relation to disasters, a major difference between the response in developing countries and developed countries is that in developing countries, fatalities dominate. In developed countries, infrastructure and property losses dominate. In relation to food issues, a major disaster in a developing country, such as a large scale drought, wildfire, or extensive flood has the potential to lead to famine whereas an analogous disaster in a developed country will lead to price increases (Fig. 26.2).

26.3.1 Future Earth

'Future Earth', previously known as the Earth Systems Science Partnership, is a major new initiative of the International Council of Science (ICSU) that brings together the existing work of four interdisciplinary programs – the International

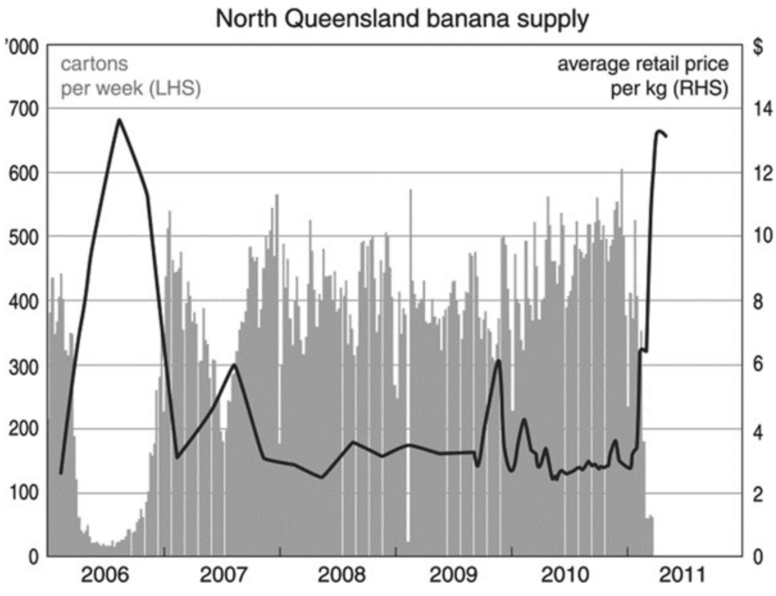

Fig. 26.2 Graph of the banana supply and banana price from the north eastern part of Australia demonstrating the sharp price rises in banana price following Tropical Cyclones Larry (*left*) and Yasi (*right*) both of which destroyed most of the Australian banana crop

Fig. 26.3 The research program Future Earth envisages Food Security as being composed of three components – utilisation, access and availability

Geosphere Biosphere Program (IGBP); IHDP, the International Human Dimensions Program (IHDP); Diversitas, an international biological program; and the World Climate Research Program (WCRP).

It was recognised that Food Security would be an important part of Future Earth (n.d) (Fig. 26.3) and thus Future Earth and the Consultative Group on International Agricultural Research (CGIAR), agreed that the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS) would become one of the initial research programs of Future Earth. Thus it may be stated that at an international level the Climate and Food Security link has been made in terms of Climate Change – Agriculture – Food Security through the work of CCAFS. Less international effort has been devoted to examining the Climate – Fisheries – Food Security link or the Climate – Supply Chain – Food Security link which is a particular concern of the International Union of Food Science and Technology (IUFoST).

There is also ongoing work on weather and food security, especially the role of seasonal forecasting in improving agricultural yields (IIzumi et al. 2013) which has more recently shown that improved forecasts can be achieved worldwide if the state of ENSO, the El Nino Southern Oscillation, is incorporated into yield forecasts. However, work by Asseng et al. (2013) indicates that a greater proportion of the uncertainty in climate change impact projections of crop yields is due to variations among crop models rather than to variations among the downscaled climate models.

26.3.2 WeatCliFS

The International Union of Geodesy and Geophysics (IUGG) is leading a consortium with the International Union of Food Science and Technology (IUFoST) and the International Union of Nutritional Sciences (IUNS) to examine weather, climate and food security. The consortium, known as the WeatCliFS Consortium has held symposia and workshops in Cancun (Mexico), Brisbane (Australia) and Granada (Spain) at which it was determined that the fundamental question that underpins WeatCliFS is: *What technologies and methodologies are required to assess the vulnerability of people and places to hazards [such as droughts that lead to famine] – and how might these be used at a variety of spatial and temporal scales?*

However when the focus is specifically on the urban aspects of weather, climate and food security then other questions also arise:

Does an increase in local urban food production increase the nutritional health of local residents?

Does an increase in vegetative cover and structure in urban gardens increase the resilience of urban residents and local food supply to storm events?

26.3.3 Research Tasks

Given increasing global food demands, climate-related crop failure, and consistent limitations in fresh food access within urban centres (ver Ploeg et al. 2009; Thomas 2010), the resilience of the urban food supply is becoming increasingly important to food security, yet increasingly vulnerable to climate effects. In order to understand how to design urban food production systems that are protected from climate events and provide healthy, nutritious food to local residents, the requirements are:

(1) Survey urban gardens across a city to document the types of gardens in the city as well as the types of crops grown in each of the urban gardens – maintaining cognizance of the cultural needs and desires of the local residents.
(2) Study spatially how these gardens are distributed across the cityscape and look for patterns of local food production (types of crops, amount of food produced) in relation to health variables of the local community.
(3) Survey the vegetative structure of urban gardens to observe which gardens are more resilient to storm damage.
    (a) For crops – establish a baseline level of production from each particular urban garden (with the assistance of those working the garden) and monitor rates of change in food production after storm events
    (b) For flood damage impacts – assess areas within the city that are prone to flood damage and compare flood damage levels to green infrastructure levels. Survey urban gardens to assess vegetative structure and use this data to investigate if urban gardens with greater area of green space or greater vegetative structure have an impact on flood damage.

26.4 Results

The results of such studies are expected to provide urban planners and local councils with a better understanding of how the management of urban food production systems impact local health and resilience to climate events. Such a study will provide guidance on what types of urban gardens provide greater health/nutrition benefits and which gardens provide greater storm attenuation benefits. It is possible that the two services may be provided by very different types of food production systems.

26.5 Conclusions

Despite the existence of the ICSU research program Integrated Research on Disaster Risk, the science plan for IRDR (ICSU 2008) indicates that food security is not an aspect of its research mandate. Thus the international aspects, including the urban aspects, of the agricultural disruption, economic disruption and logistical disruption to food availability, food access and food quality as a result of natural disasters remains an under-researched topic.

Climate change is affecting (and will affect) global food production and hence global food security. Urban agriculture plays a significant role in maintaining and improving the health of city dwellers, particularly those disadvantaged. Climate changes are likely to impact more severely on urban environments with associated negative effects on food security, as has been discussed. Existing research programmes are not addressing these aspects of climate change effectively and deserve immediate attention.

References

Alaimo K, Packnett E, Miles RA, Kruger DJ (2008) Fruit and vegetable intake among urban community gardeners. J Nutr Educ Behav 40:94–101

Alig RJ, Kline JD, Lichtenstein M (2004) Urbanization on the US landscape: looking ahead in the 21st century. Landsc Urban Plan 69:219–234

Asseng S, Ewert F, Rosenzweig C, Jones JW, Hatfield JL, Ruane AC, Boote KJ, Thorburn PJ, Rötter RP, Cammarano D, Brisson N, Basso B, Martre P, Aggarwal PK, Angulo C, Bertuzzi P, Biernath C, Challinor AJ, Doltra J, Gayler S, Goldberg R, Grant R, Heng L, Hooker J, Hunt LA, Ingwersen J, Izaurralde RC, Kersebaum KC, Müller C, Naresh Kumar S, Nendel C, O'Leary G, Olesen JE, Osborne TM, Palosuo T, Priesack E, Ripoche D, Semenov MA, Shcherbak I, Steduto P, Stöckle C, Stratonovitch P, Streck T, Supit I, Tao F, Travasso M, Waha K, Wallach D, White JW, Williams JR, Wolf J (2013) Uncertainty in simulating wheat yields under climate change. Nat Clim Chang 3:827–832. doi:10.1038/nclimate1916

Aubry C, Ramamonjisoa J, Dabat MH, Rakotoarisoa J, Rakotondraibe J, Rabeharisoa L (2012) Urban agriculture and land use in cities: an approach with the multi-functionality and sustainability concepts in the case of Antananarivo (Madagascar). Land Use Policy 29:429–439

Baker LE (2004) Tending cultural landscapes and food citizenship in Toronto's community gardens. Geogr Rev 94:305–325

Beniston J, Lal R (2012) Improving soil quality for urban agriculture in the North Central U.S. In: Lal R, Augustin B (eds) Carbon sequestration in urban ecosystems. Springer, Dordrecht, pp 279–313

Bhatt V, Farah LM (2009) Designing edible landscapes. Open House Int 34:5–7

Despommier D (2010) The vertical farm. St Martin's Press, New York. ISBN 978-0-312-61139-2

Drescher A, Holmer R, Iaquinta D (2006) Urban homegardens and allotment gardens for sustainable livelihoods: management strategies and institutional environments. In: Kumar BM, Nair PKR (eds) Tropical homegardens. Springer, Dordrecht, pp 317–338

Eriksen-Hamel N, Danso G (2010) Agronomic considerations for urban agriculture in southern cities. Int J Agric Sustain 8:86–93

FAO (n.d). http://www.fao.org/docrep/005/y4671e/y4671e06.htm

Future Earth (n.d). http://www.planetunderpressure2012.net/policybriefs.asp

González-García A, Sal A (2008) Private urban greenspaces or "Patios" as a key element in the urban ecology of Tropical Central America. Hum Ecol 36:291–300

Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM (2008) Global change and the ecology of cities. Science 319:756–760

Hodgson K, Campbell MC, Bailkey M (2011) Urban agriculture: growing healthy, sustainable places. American Planning Association, Washington, DC

ICSU (2008) A science plan for integrated research on disaster risk. International Council for Science, Paris. http://www.icsu.org/publications/reports-and-reviews/IRDR-science-plan/executive-summary

Iizumi T, Sakuma H, Yokozawa M, Jing-Jia Luo J-J, Challinor AJ, Brown ME, Sakurai G, Yamagata T (2013) Prediction of seasonal climate-induced variations in global food production. Nat Clim Chang 3:904–908. doi:10.1038/nclimate1945

Kaye JP, Groffman PM, Grimm NB, Baker LA, Pouyat RV (2006) A distinct urban biogeochemistry? Trends Ecol Evol 21:192–199

Lansigan FP, de los Santos WL, Coladilla JO (2000) Agronomic impacts of climate variability on rice production in the Philippines. Agric Ecosyst Environ 82:129–137

Lovell ST (2010) Multifunctional urban agriculture for sustainable land use planning in the United States. Sustainability 2:2499–2522

McDonald RI, Kareiva P, Forman RTT (2008) The implications of current and future urbanization for global protected areas and biodiversity conservation. Biol Conserv 141:1695–1703

McLain R, Poe M, Hurley PT, Lecompte-Mastenbrook J, Emery MR (2012) Producing edible landscapes in Seattle's urban forest. Urban For Urban Green 11:187–194

Moguel P, Toledo VM (1999) Biodiversity conservation in traditional coffee systems of Mexico Conservacion de la Biodiversidad en Sistemas de Cultivo Tradicional de Cafe en Mexico. Conserv Biol 13:11–21

Mougeot LAJ (2005) Introduction. In: Mougeot LAJ (ed) Agropolis: the social, political and environmental dimensions of urban agriculture. Earthscan, London

Olesen JE, Bindi M (2002) Consequences of climate change for European agricultural productivity, land use and policy. Eur J Agron 16:239–262

Pearson LJ, Pearson L, Pearson CJ (2010) Sustainable urban agriculture: stocktake and opportunities. Int J Agric Sustain 8:7–19
Perry T, Nawaz R (2008) An investigation into the extent and impacts of hard surfacing of domestic gardens in an area of Leeds, United Kingdom. Landsc Urban Plan 86:1–13
Philpott SM, Lin BB, Jha S, Brines SJ (2008) A multi-scale assessment of hurricane impacts on agricultural landscapes based on land use and topographic features. Agric Ecosyst Environ 128:12–20
Pickett STA, Cadenasso ML, Grove JM, Nilon CH, Pouyat RV, Zipperer WC, Costanza R (2001) Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. Annu Rev Ecol Syst 32:127–157
Porter JR, Semenov MA (2005) Crop responses to climatic variation. Philos Trans R Soc B Biol Sci 360:2021–2035
Premat A (2005) Moving between the plan and the ground: shifting perspectives on urban agriculture in Havana, Cuba. In: Mougeot LAJ (ed) Agropolis: the social, political and environmental dimensions of urban agriculture. Earthscan, London
Shaw HJ (2006) Food deserts: towards the development of a classification. Geografiska Annaler Ser B Hum Geogr 88:231–247
Smit J, Nasr J, Ratta A (1996) Urban agriculture: food jobs and sustainable cities. United Nations Development Programme (UNDP), New York
Thomas BJ (2010) Food deserts and the sociology of space: distance to food retailers and food insecurity in an urban American neighborhood. Int J Hum Soc Sci 5:400–409
United Nations (2006) World urbanization prospects: the 2005 revision. Department of Economic and Social Affairs, Population Division United Nations, New York
ver Ploeg, M, Breneman V, Farrigan T, Hamrick K, Hopkins D, Kaufman, P, Lin B-H, Nord M, Smith T, Williams R (2009) Access to affordable and nutritious food: measuring and understanding food deserts and their consequences. Report to Congress. Access to affordable and nutritious food: measuring and understanding food deserts and their consequences. Report to Congress. USDA Economic Research Service
WinklerPrins AGA (2002) House-lot gardens in Santarém, Pará, Brazil: linking rural with urban. Urban Ecosyst 6:43–65
Wollenweber B, Porter JR, Schellberg J (2003) Lack of interaction between extreme high-temperature events at vegetative and reproductive growth stages in wheat. J Agron Crop Sci 189:142–150
Xiao Q, McPherson EG (2002) Rainfall interception by Santa Monica's municipal urban forest. Urban Ecosyst 6:291–302
Yadav P, Duckworth K, Grewal PS (2012) Habitat structure influences below ground biocontrol services: a comparison between urban gardens and vacant lots. Landsc Urban Plan 104:238–244
Zezza A, Tasciotti L (2010) Urban agriculture, poverty, and food security: empirical evidence from a sample of developing countries. Food Policy 35:265–273

Chapter 27
Coastal Urban and Peri-Urban Indigenous People's Adaptive Capacity to Climate Change

Darryl Low Choy, Philip Clarke, Silvia Serrao-Neumann, Robert Hales, Olivia Koschade, and David Jones

Abstract This chapter discusses the adaptive capacity of coastal urban and peri-urban Indigenous People's to climate change. It is based on the findings of a National Climate Change Adaptation Research Facility (NCCARF) funded project that utilised a series of case studies that engaged key representatives from Indigenous organisations in five coastal locations in three states of south-eastern Australia (Low Choy D, Clarke P, Jones D, Serrao-Neumann S, Hales R, Koschade O et al., Aboriginal reconnections: understanding coastal urban and peri-urban Indigenous people's vulnerability and adaptive capacity to climate change, National Climate Change Adaptation Research Facility, Gold Coast, 139 pp, 2013). The study has highlighted the social, economic and environmental impacts on urban and peri-urban Indigenous communities inhabiting coastal areas throughout south-eastern Australia. These impacts include a loss of community and environmental assets, such as cultural heritage sites, with significant impacts on their quality of life and the establishment of potential favourable conditions for the spread of plant diseases, weeds and pests. The study also found that opportunities did not readily exist for engagement with climate change adaptation policy and initiatives and this was further exacerbated by acute shortages of qualified/experienced Indigenous members that could represent their communities' interests in climate change adaptation forums. The evidence emerging from this research clearly demonstrates that Aboriginal people's consideration of the future, even with the overlay of climate change and the requirements for serious considerations of adaptation, are significantly influenced and dominated by economic aspirations which are seen as fundamental survival strategies for their communities.

A number of specific climate change induced issues to emerge from the research included: the potential for Indigenous involvement in the 'bush tucker' industry utilising wild plant species will potentially suffer from changes in species

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availability; concern was expressed about changes associated with peri-urban and urban development which appears to be escalating micro-environmental changes; peri-urbanisation is a major environmental change which threatens cultural assets including Aboriginal sites; Indigenous communities need representation in climate change adaptation forums and to be more directly involved in land and sea care projects. The chapter concludes with recommendations to better position Aboriginal engagement and knowledge systems in the wider climate change adaptation policy discourse.

Keywords Climate change • Peri-urbanization • Micro-environmental change • Aboriginals • Indigenous communities

27.1 Introduction

This chapter adds to the foundation of Indigenous 'country' research and academic inquiries and aims to strengthen the 'community of knowledge', specifically in terms of the adaptive capacity of coastal urban and peri-urban Indigenous Peoples to climate change. The chapter draws from a study undertaken under the auspices of National Climate Change Adaptation Research Facility's (NCCARF) *National Climate Change Adaptation Research Plan for Indigenous Communities* (NARP) (Langton et al. 2012). That NARP identified five broad categories of information necessary to enhance decision-making about climate change adaptation for Indigenous Australians, namely: (1) the sensitivity and exposure of Indigenous individuals, households, communities, businesses and institutions to climate risks; (2) the vulnerability and adaptive capacity of Indigenous individuals, households, communities, businesses and institutions to climate change; (3) extreme weather events and emergency management planning for Indigenous communities; (4) indigenous population movement, displacement, community relocation, and severe climate variation; and (5) climate change adaptation and Indigenous biodiversity management.

The research addressed the NARP's Priority Research Topic 5 which specifically sought to "understand the capacity of Indigenous individuals, households, businesses and institutions to adapt to climate change and the identification of strategies to enhance this capacity" (Langton et al. 2012: 5). Consequently, the research aimed to provide a preliminary examination of south-eastern Australian coastal urban and peri-urban Indigenous peoples' vulnerability to, and capacity for climate change adaptation (CCA). This was achieved through a collaborative research approach whereby the researchers worked with five case study Aboriginal organisations to explore a number of relevant climate change futures with the intention of identifying a preliminary set of strategies to enhance their capacity to adapt to climate change. In response to the project's 1 year timeframe, the research was designed to establish a framework, processes and procedures that could evolve into a longer and more comprehensive research agenda at some future time.

The research's spatial focus was the 'peri-urban' regions which refers to the fringing landscapes adjacent to the edge of an urban area into which it expands or influences ('*peri*': around, about or beyond) (Buxton et al. 2006). These areas have experienced unprecedented rapid growth and have been defined as "the urbanized edges of cities plus the spaces into which they expand, both physically and functionally" (Burnley and Murphy 1995: 245).

However, in the context of different Indigenous groups' languages and cultures including their, beliefs and customs, reference to spatial dimensions is in the context of the notion of 'country'. In this sense, 'country' refers to Aboriginal or Torres Strait Islander people's traditional affiliation and responsibility for lands and waters which they collectively refer to as their 'country'. The responsibility to look after or 'care for country' is accepted by all levels of Indigenous society, individuals, family groups as well as the clan. Deborah Bird Rose (1996) explains 'country' as:

> *People talk about country in the same way that they would talk about a person: they speak to country, sing to country, visit country, worry about country, feel sorry for country and long for country … country knows, hears, smells, takes notice, takes care, is sorry or happy … Because of this richness, country is home, and peace; nourishment for body, mind and spirit; heart's ease* (Rose 1996: *7*).

27.2 Urban and Peri-Urban Indigenous Communities

The significance of the urban and peri-urban focus for this study lies in the fact that most Indigenous Australians live in urban or regional parts of the country. Biddle (2012) notes that in 2006, some 74.5 % of Indigenous Australian's lived in a major city or regional centre. The Australian Bureau of Statistics records some 43 % of Australia's Indigenous population residing in an urban centre (Australian Government 2010: 106). Increasingly, Australia's Indigenous population is becoming more urban and this pattern is likely to continue over the next few decades (Biddle 2012: 18). For example, projections by Biddle and Taylor (2009) suggest that Australia's Indigenous population residing in its major cities will increase by 34.0 % between 2006 and 2016 compared to 8.8 % for the Indigenous population in very remote areas.

The significance of the urban and peri-urban focus is further reinforced by Dugdale (2008) who has reported that in 2006 in Queensland, 24 % of the state's Indigenous population lived in the City of Brisbane municipality and 32.4 % lived in the essentially peri-urban South East Queensland (SEQ) region centred on Brisbane City.

Whilst conventional Indigenous research has tended to focus on traditional Aboriginal communities of remote and central and northern Australia, these residential facts highlight the importance of understanding the majority of Indigenous people, i.e. those residing in urban and peri-urban locations. Of note is a key difference between coastal urban and peri-urban Indigenous people and those residing in semi-arid, arid and tropical communities in northern Western Australia, Queensland and the Northern Territory. In essence, the former do not live in discrete

Indigenous communities and tend to be generally integrated into the wider urban and peri-urban community, i.e. the majority of urban and peri-urban Aboriginal people live 'off-country'. This fact had important methodological implications for the research engagement with the case study organisations.

27.3 Project Methodology

The research project adopted a case study approach and engaged with key representatives from Indigenous organisations in five case study locations in three Australian states. They included Elders, chief office bearers of Aboriginal organisations and knowledgeable people who could present the position of their communities. Over the 12 months available for the research, two series of case study specific meeting-like workshops were undertaken in each case study to introduce, discuss and understand stakeholder capacity as individuals, households, businesses, and institutions to adapt to climate change. A limited number of selected interviews were also undertaken to follow up a number of themes that emerged from the workshops.

The first series of workshops exposed the participants to the climate science through the use of one-page summaries in the form of "Climate Storylines" for each region. This information facilitated the identification and discussion on expected impacts and landscape changes that need to be considered in the future. The second series of workshops provided opportunities to identify and to commence to scope out strategies to enhance participant's capacity to adapt to future climate change. As the study progressed through its various stages, the research team sought constant feedback and confirmation of reported findings and minutes of meetings from the participating Aboriginal organisations and their representatives.

27.3.1 Indigenous Case Studies

Five coastal peri-urban case study areas across south-eastern Australia were identified through discussions and agreements with five autonomous Indigenous community organisations that were engaged from the outset of the project proposal. The participating Indigenous organisations included:

(i) **Kaurna Nation Cultural Heritage Association Inc**. of the Adelaide Plains – an urban Indigenous group within the Adelaide metropolitan region that was involved in recent strategic planning place-making expression activities and workshops. Kaurna country.

(ii) **Wathaurong Aboriginal Co-Operative Limited** at North Geelong – a community-based organisation providing Indigenous people within the Greater Geelong and surrounding areas with access to health, housing, education, employment and heritage services. Wathaurong/Wathaurung/Wada Wurrung country.

(iii) **Boon Wurrung Foundation Limited** in conjunction with the Mornington Peninsula Shire, Victoria (Melbourne City to Wilsons Promontory) – an urban/peri-urban Indigenous group on the south-east fringe of Melbourne experiencing extensive coastal urban sprawl and attempts by the (former) Victorian state government to enable increased sprawl into previously designated green belt areas within their 'country' that directly impact upon their cultural and natural environmental responsibilities. Boon Wurrung/Bunerong country.
(iv) **Quandamooka Lands Council Aboriginal Corporation** Stradbroke Island (Minjebrah) Moreton Bay, South East Queensland – a peri-urban Indigenous community that experiences major seasonal visitation impacts associated with their proximity to the Brisbane metropolitan region. At the time of this study, the State and local governments were undertaking a major land use planning study for North Stradbroke Island which involved the Quandamooka community and their 2011 awarded native title lands. Many members of this community reside and work off country in the Brisbane metropolitan area. Quandamooka country.
(v) **Jagera Ganay-Magil Aboriginal Corporation** in the Brisbane-Ipswich region – comprises and represents several urban and peri-urban Indigenous groups within the Brisbane-Ipswich metropolitan region. Jagera Ganay-Magil country.

The location of the five case study communities are shown on Fig. 27.1. A summary of the generic characteristics of each of the five case studies and their respective organisation is provided in Table 27.1.

27.4 Climate Change Projections and Aboriginal Country

Climate science comprises an evolving field of knowledge and is marked by uncertainties (Reilly and Schimmelpfennig 2000; Patt et al. 2005). This is particularly the case of future climate change projections specific to smaller scale areas such as defined native title areas. Drawing on the latest available climate science knowledge, Table 27.2 presents an overview of how climate change is likely to impact the three regions containing the five case studies, namely the Adelaide Plains, Southern Victoria and South East Queensland. Detailed projections and information for each region and case study area were contained in specific climate storylines and impact maps that were employed in workshops during the course of the research with the case study communities.

The literature highlighted that climate change impacts are expected to affect cities and regions differently (Füssel 2007). Additionally, there is no uniformity across individuals, groups within society, organisations and governments in terms of their adaptive capacity and how they can respond to current and future climate change impacts (Vincent 2007). Consequently, adaptation will need to occur at, and be specific to, various scales from local through to regional and national (Adger 2005).

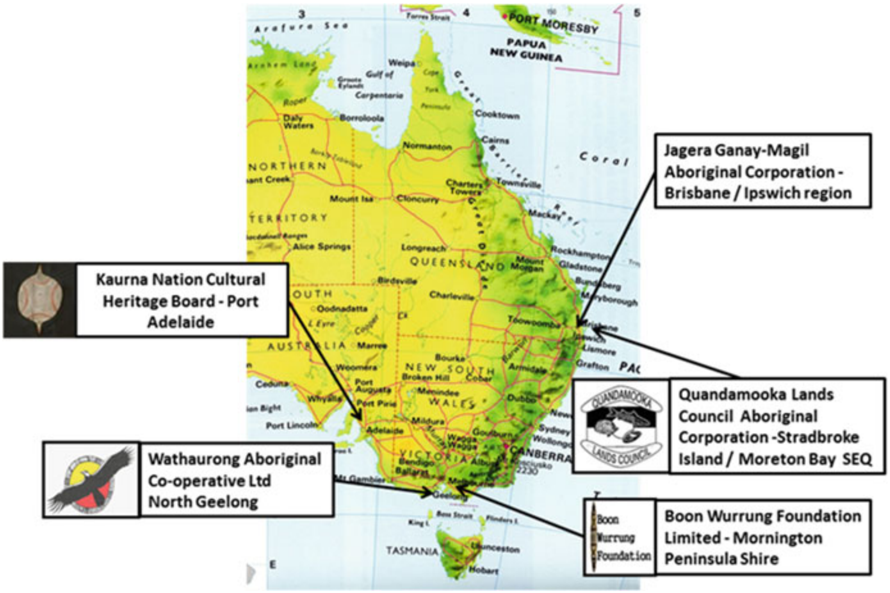

Fig. 27.1 Location of indigenous case study communities

Climate change is expected to have social, economic and environmental impacts on urban and peri-urban Indigenous communities inhabiting coastal areas throughout south-eastern Australia. These impacts include a loss of community and environmental assets, including cultural heritage sites, with significant impact on the quality of life of populations inhabiting these areas, and the establishment of potential favourable conditions for the spread of plant diseases, weeds and pests. Over most of south-eastern Australia, including southern Victoria and the Adelaide region, climate change is expected to lead to increased risk of heatwaves, longer drought periods, increased bushfire risk, increased risks of flood events and more frequent coastal inundation and associated impacts such as coastal erosion.

A review of the literature examining the impacts of climate change on peri-urban and urban Indigenous people found that there is limited research on the topic in Australia and globally. The review did show that lower socio-economic members of this group are more vulnerable to climate change compared to the general Australian population. Their adaptive capacity is low as a result of the same systemic issues confronting Indigenous people that have led to disadvantage. As such, research on climate change adaptation positions climate change as one of the many issues facing Indigenous people and needs to be addressed collaboratively and not in isolation. Research from other more remote regions in Australia and abroad indicate collaborative community-based approaches are needed for effective climate change vulnerability assessments and the building of individual and collective adaptive capacity.

Table 27.1 Summary of generic characteristics of the case studies

	Case study organisational name				
Generic characteristics	Kaurna National Cultural Heritage Association Inc.	Wathaurong Aboriginal Co-Operative Ltd	Boon Wurrung Foundation Ltd	Quandamooka Lands Council Aboriginal Corporation Inc.	Jagera Ganay-Magil Aboriginal Corporation Inc.
Country: geographical location and scope	Adelaide plains	Geelong and Barwon Region, south-west of Melbourne	Southern Melbourne to Wilsons Promontory including the Mornington Peninsula	Moreton Bay and North Stradbroke Island region east of Brisbane	Brisbane – Ipswich metropolitan areas
Corporate status	Incorporated with an aim of cultural heritage custodianship and referral	Co-operative with an aim of employment, social and health provision for Indigenous residents	Limited company serving as a spokesperson for the Boon Wurrung	Incorporated with an aim of cultural heritage custodianship and referral	Incorporated with an aim of cultural heritage custodianship and referral
Legal status	Advisory referral service	Advisory referral service; not a Registered Aboriginal Party (RAP)	Advisory referral service; not a Registered Aboriginal Party (RAP); application made	Quasi-local government entity arising from a successful Native Title claim	Advisory referral service
Urban characteristics	Urban and peri-urban Adelaide Plains metropolitan context	Urban and peri-urban Geelong metropolitan context	Urban and peri-urban southern Melbourne metropolitan context	Peri-urban Moreton Bay regional context	Urban and peri-urban Brisbane - Ipswich metropolitan context
Geographical characteristics	Plains landscape adjunct to the Gulf St Vincent	Rolling plains landscape adjunct to Port Philip Bay and the Bellarine Peninsula	Mixed environment from coastal to swamps to farmlands to national parks	Coastal and riverine landscapes including major islands	Mixed environment from coastal to swamps to farmlands to riverine plains

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Table 27.2 Comparative summary of climate change variables for each case study region

Climate change variables	Case study organisation				
	Kaurna National Cultural Heritage Association Inc.	Wathaurong Aboriginal Co-Operative Ltd	Boon Wurrung Foundation Ltd	Quandamooka Lands Council Aboriginal Corporation Inc.	Jagera Ganay-Magil Aboriginal Corporation Inc.
Vulnerability Rating (CSIRO 2007; Suppiah et al. 2007)	Medium	Medium	Medium	Hot spot	Hot spot
Temperature changes	Av temps increased by 1.2 °C since the 1950s (Suppiah et al. 2006); increase of 0.8 °C by 2030 and 2.3 °C by 2070 (Department of Environment and Natural Resources 2010)	Av an temps likely to increase by 0.5–1.1 °C by 2030 and 0.9–3.5 °C by 2070 (Kinrade and Preston 2008)	Av an temps likely to increase by 0.5–1.1 °C by 2030 and 0.9–3.5 °C by 2070 (Kinrade and Preston 2008)	Increase of 0.4 °C in the av temp; increase between 0.5 and 1.5 °C projected by 2030 (Suppiah et al. 2007; Department of Environment and Resource Management 2009)	Increase of 0.4 °C in the av temp; increase between 0.5 and 1.5 °C projected by 2030 (Suppiah et al. 2007; Department of Environment and Resource Management 2009)
Rainfall changes	Decline in an av of 4.5 % by 2030 and 15 % by 2070, greatest decline in winter and spring (8 %) (Department of Environment and Natural Resources 2010)	Decrease in av an rainfall by up to 8 % by 2030 and 23 % by 2070, higher reductions expected in winter and spring (Kinrade and Preston 2008)	Decrease in av an rainfall by up to 8 % by 2030 and 23 % by 2070, higher reductions expected in winter and spring (Kinrade and Preston 2008)	Decline by almost 55 mm per decade observed since 1950 (Gallant et al. 2007)	Decline by almost 55 mm per decade observed since 1950 (Gallant et al. 2007)

Rainfall events	More extreme rainfall events expected (Suppiah et al. 2006; Murphy and Timbal 2008)	Increase of up to 25 % in extreme rainfall events of 1–24 h in duration in at-risk areas by 2030 and up to 70 % by 2070 (Kinrade and Preston 2008).	Increase of up to 25 % in extreme rainfall events of 1–24 h in duration in at-risk areas by 2030 and up to 70 % by 2070 (Kinrade and Preston 2008).	Extreme rainfall events likely to increase across region; an increase of up to 25 % in the intensity of 1-in-20 year daily-rainfall event (Abbs et al. 2007; Hennessy 2004).	Extreme rainfall events likely to increase across region; an increase of up to 25 % in the intensity of 1-in-20 year daily-rainfall event (Abbs et al. 2007; Hennessy 2004).
Flooding and wind events	Not available	Potential increase in frequency or magnitude of flood events or flood heights (Kinrade and Preston 2008)	Potential increase in frequency or magnitude of flood events or flood heights (Kinrade and Preston 2008)	Moderate thunderstorm activity averaging between 20 and 40 days per year (Hennessy 2004).	Moderate thunderstorm activity averaging between 20 and 40 days per year (Hennessy 2004).
Coastal risks (storm surges and erosion)	More intense storm events as well as higher coastal storm surges (Suppiah et al. 2006)	Greater exposure to storm surge inundation - expected change from current 1 in 100 year to 1 in 1–1 in 4 year event by 2070 (Kinrade and Preston 2008)	Greater exposure to storm surge inundation - expected change from current 1 in 100 year to 1 in 1–1 in 4 year event by 2070 (Kinrade and Preston 2008)	Sea-level rise, projections indicate a rise of approximately 80 cm by 2100 (Parry et al. 2007)	Sea-level rise, projections indicate a rise of approximately 80 cm by 2100 (Parry et al. 2007)
Evaporation (CSIRO 2007)	Increased potential evaporation and reduction in relative humidity leading to drier conditions	Increased potential evaporation and reduction in relative humidity leading to drier conditions	Increased potential evaporation and reduction in relative humidity leading to drier conditions	Increased potential evaporation and reduction in relative humidity leading to drier conditions	Increased potential evaporation and reduction in relative humidity leading to drier conditions

(continued)

Table 27.2 (continued)

Climate change variables	Case study organisation				
	Kaurna National Cultural Heritage Association Inc.	Wathaurong Aboriginal Co-Operative Ltd	Boon Wurrung Foundation Ltd	Quandamooka Lands Council Aboriginal Corporation Inc.	Jagera Ganay-Magil Aboriginal Corporation Inc.
Bushfire events	Increase frequency and intensity of extreme fire weather days; longer fire seasons and reduced number of days suitable for controlled burning (Lucas et al. 2007)	Worsening fire weather conditions expected with an increase in the number of days of 'very high' or 'extreme' forest fire risk by 1–2 days by 2030 (Lucas et al. 2007)	Worsening fire weather conditions expected with an increase in the number of days of 'very high' or 'extreme' forest fire risk by 1–2 days by 2030 (Lucas et al. 2007)	Increase in av mean temp and severe weather events (eg extended drought); could also lead to more favourable conditions bushfires (Hennessy 2004)	Increase in av mean temp and severe weather events (eg extended drought); could also lead to more favourable conditions bushfires (Hennessy 2004)
Hot days and frost days	Increase in the frequency of extremely warm days (above both 35 and 40 °C) and nights along with a decrease in the frequency of extremely cool days and nights (McInnes et al. 2003)	Increase in extreme hot days (temp above 35 and 40 °C) and decrease in the number of frost days (City of Greater Geelong 2011; Department of Sustainability and Environment 2008)	Increase in extreme hot days (temp above 35 and 40 °C) and decrease in the number of frost days (City of Greater Geelong 2011; Department of Sustainability and Environment 2008)	Increase in mean temperatures will also increase the number of days over 35 °C in the region (Suppiah et al. 2007; Department of Environment and Resource Management 2009)	Increase in mean temperatures will also increase the number of days over 35 °C in the region (Suppiah et al. 2007; Department of Environment and Resource Management 2009)

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The SEQ region has been identified as a climate change vulnerability 'hot spot' due to on-going population growth and the location of urban development along its low-lying coastline and floodplains (Hennessy et al. 2007). While there is much uncertainty surrounding current climate science, models have shown that SEQ will be affected by changes in climatic averages, including rainfall and temperature, sea-level rise and an increase in extreme weather events. Resultant impact could include greater evaporation and decreased rainfall causing increased pressure on water supplies; potential favourable conditions for the spread of plant diseases, weeds and pests; increased coastal flooding and erosion due to sea-level rise and storm surges with subsequent damage to infrastructure and building structures; increase in heat related illness; and increased risk of tropical cyclones reaching the region (Queensland Climate Change Centre of Excellence and Department of Environment and Resource Management 2010).

In Southern Victoria climate change impacts are expected to have major effects upon the region and Wathaurong country because of its grassland, heathland, low saline coastal plains and deeply incised coastal fringes. Likely impacts include more frequent coastal inundation, increased coastal erosion impacts, increased bushfire risk, increased flood events risks, more frequent heat wave events, and longer drought periods (Roös 2013).

For the Adelaide Region the anticipated climate change impacts include increases in average temperatures, decreases in rainfall, increases in potential evapotranspiration, decreases in relative humidity and sea-level rise. This is expected to lead to increased risk of heatwaves, longer drought periods, increased bushfire risk and coastal hazards, including storm surges, coastal erosion and inundation.

27.5 Key Issues

27.5.1 General

The first series of workshops considered the most significant implications of climate change for the participant's organisations, themselves and their community members. This resulted in the emergence of a number of consistent themes from across the five case study groups, namely: (i) Indigenous representation; (ii) housing; (iii) employment; (iv) environmental and cultural assets; and (v) wild food network. These five themes were subsequently defined as follows:

Indigenous Representation refers to the opportunities for, and capacity of, Indigenous people to represent their interests and concerns in climate change meetings, decision-making forums and policy documents that are largely controlled by various tiers of government. This also relates to the availability of individuals who are capable of representing their community's interests in such forums and discussions.

Housing clearly identified by all workshop participants as a key theme for the consideration of CCA for urban and peri-urban Aboriginal and Torres Strait Islander peoples. It includes a category of issues related to the ability of Aboriginal people to either move or modify their existing housing to mitigate the effects of climate change. It also concerns the degree to which Aboriginal people can engage in energy and water saving schemes for CCA. All participants noted the large numbers of Aboriginal people from their communities who were reliant on public housing.

Employment concerns the negative aspects of job loss due to changing employment prospects through climate change and also included the positive aspects of job creation in industries involved in CCA and mitigation, such as carbon-trading and sequestering schemes and revegetation programs.

Environmental and Cultural Assets includes those connected to land managed by Aboriginal people as well as on-country not directly accessible to Aboriginal people. It includes cultural sites containing burials and archaeological materials, as well as native title areas, Indigenous-run farms, areas connected to fishing and hunting licences and national parks for which there are joint management agreements.

The Wild Food Network includes those concerned with the cultural and economic importance of Aboriginal people being engaged in the native bush food industry, particularly with wild harvesting, growing, processing, value adding, catering and spin-off guiding/talking businesses.

Drawing from the first round of community consultations a composite view has been developed of how the key issues were perceived across the case studies at the individual, household, business, and institutional levels (see Table 27.3).

Table 27.3 Composite matrix of CCA themes for case studies

	Indigenous representation	Housing	Employment	Environmental and cultural assets	Wild food network (indigenous)
Individuals	1, 2, 3, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 4, 5	2, 3, 4, 5
Households	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	2, 4, 5	2, 4, 5
Businesses	2, 4, 5	2	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5
Institutions	1, 2, 3, 4, 5	2, 4, 5	2, 3, 4, 5	1, 2, 3, 4, 5	2, 3, 4, 5

Low Choy et al. (2013)
KEY:
1. Kaurna Nation Cultural Heritage Association Inc (Adelaide Plains region)
2. Wathaurong Aboriginal Co-Operative Limited (North Geelong region)
3. Boon Wurrung Foundation Limited (Melbourne City to Wilsons Promontory region)
4. Quandamooka Lands Council Aboriginal Corporation (Stradbroke Island/Moreton Bay SEQ region); and
5. Jagera Ganay-Magil Aboriginal Corporation (Brisbane-Ipswich region)

27.5.2 Indigenous Representation

An analysis of existing State and regional policy plans, strategies etc. (covering land use and growth management, natural resource management, state and regional climate change adaptation) revealed that none contained any conscious effort to link climate change adaption policy or initiative with Indigenous Groups or Traditional Owners. Nor did these documents contain any specific Indigenous Climate Change (Adaptation) Policies and it appears that Indigenous people were not consulted in the preparation of these documents. These findings support similar conclusions from previous studies (Salik and Ross 2009). It was recognised however, that opportunities do exist to forge future links between climate change adaptation policy initiatives and Indigenous communities, including those communities constituting the case studies.

In summary, there was consistent recognition across the case study organisations that climate change is currently placing a disproportionate burden upon Indigenous people. This arises directly from the physical impact to sensitive areas (i.e. threat of fires, erosion etc.). More indirectly, Indigenous people who reside in urban/peri-urban areas of south-eastern Australia are highly vulnerable to climate change and climate change policies because of the wider perception that they are generally dependant on the same resources as non-Aboriginal people and that they possess less links to traditional country. As a strategy to overcome these challenges, there should be a collaborative approach to CCA, which builds-in traditional knowledge so that it does not undermine cultural identity. CCA with Indigenous communities in south-eastern Australia cannot be divorced from connection to country.

27.5.3 Housing

In most regions in south-eastern Australia, the responsibilities to service Aboriginal housing needs have been transferred from specific Aboriginal organisations to the control of mainstream public housing agencies. Where this has occurred, Aboriginal participants have claimed that it has resulted in less flexible housing conditions. Indigenous people in the public housing system have found it difficult to become involved in 'green' activities. While some tenants have wanted to get involved in waste water recycling, rainwater harvesting, wind power and solar panel installation, their tenancy agreements have effectively impeded this. In the past, when Aboriginal homes in Adelaide were managed by the Aboriginal housing funded unit, the community had access to funds which would have allowed them to engage in such activities. Within mainstream public housing there are no incentives to encourage tenants to spend their own money to make home improvements. The situation on North Stradbroke Island is different, with the more flexible practices of the Quandamooka Housing Co-Operative allowing residents to reclaim some benefits for improving their rented homes.

While it is difficult to obtain figures on recent movement patterns that are specific to certain Aboriginal communities, the overall pattern is for Indigenous peoples' migration towards major cities (Biddle 2012; Biddle and Yap 2010). The driving factors identified that were behind Aboriginal movements into and within south-eastern Australia were the availability of jobs and cheaper housing. It was predicted th future alterations to existing land values and land uses, perhaps exacerbated by climate change, are likely to affect Indigenous residency patterns surrounding the cities.

27.5.4 Employment

Negative impacts to country are highly likely to affect Indigenous people who are currently involved in industries based on their access to natural resources, such as fishing and shell fish collecting as on North Stradbroke Island. There was also concern that rising energy costs might affect the growth of their businesses, such as the glass crafts produced by the Wathaurong Aboriginal Co-Operative. On the positive side, CCA could offer Aboriginal people opportunities for greater involvement in land and sea care programs. For instance, the Boon Wurrung Foundation aspire to having Indigenous 'rangers', modelled on the sea ranger program in the Northern Territory, established within the Port Phillip Bay region. The Wathaurong Aboriginal Co-Operative is planning to link community training in land care programs with their management of their *Wurdi Youang* property. Quandamooka people have been employed in the national parks of North Stradbroke Island. The Jagera Ganay-Magil Aboriginal Corporation participants stated an interest in developing 'looking after country' type roles, particularly in native plant propagation, national park management and the wild food industry. The Kaurna community has similar aspirations with the development of ecotourism ventures, possibly through the Warriparinga Living Kaurna Centre. With greater inclusion in caring for country programs, Indigenous people will have more employment opportunities for individuals and be able to develop investment strategies for their businesses and organisations.

27.5.5 Environmental and Cultural Assets

Two of the case study communities are amongst a small number of Aboriginal communities in south-eastern Australia that have access to large portions of land. The Wathaurong Aboriginal Co-Operative is currently managing a 800 ha Kangaroo Grass (*Themeda australis*) grassland property, *Wurdi Youang*, which is situated near the You Yangs. The Co-Operative is seeking to have the land declared as an Indigenous Protected Area (IPA) in order to gain access to federal government resources to help undertake biodiversity and cultural resource conservation actions. On North Stradbroke Island in SEQ, the Quandamooka people have access to land through native title that would potentially enable them to engage in CCA-related businesses. The Jagera participants stated that they had difficulty in receiving funding from the Indigenous Land Corporation as they 'were people still without country'. Without land, the Jagera community experiences difficulties in determining what training young people required. With access to land, a future business plan could include their involvement in 'green industries', such as carbon farming.

In terms of cultural heritage management, senior members of Aboriginal communities are often involved with local heritage assessments, although it was stated that Indigenous consultations generally took place at the end of the process, which was not ideal. Proactively, cultural heritage management plans, incorporating CCA considerations, need to be used to protect sites containing stone artefacts, midden material and burials. There was universal agreement that an Indigenous perspective in holistically managed country is required for CCA. It was also noted that by not recognising the long held traditions of Aboriginal caring for country, European practices of land development were putting people at risk to natural hazards such as cataclysmic fires, floods etc. which in turn was putting their cultural assets at greater risk.

Participants of all five communities wanted greater recognition of Dreaming sites as cultural places to conserve. An example of sites at risk from climate change was the Tjilbruke sites, which are linked by a Dreaming Track that runs along the coast on the Gulf St Vincent side of Fleurieu Peninsula from the vicinity of Adelaide to Cape Jervis and inland to Brukunga near Mount Barker (Clarke 1996; Tindale 1987). In local Aboriginal society, Tjilbruke created many topographical features, particularly freshwater springs along the coast, before finally turning into a Glossy Ibis (*Plegadis falcinellus*). The Dreaming Track was important for redistributing goods and the transference of knowledge through trade. Climate change concerns extend to the Tjilbruke sites (many of them coastal springs – 'tears flowing from Tjilbruke') disappearing through a combination of the sea level rising and urban development.

The Wathaurong Aboriginal Co-Operative on the other hand believe that as the Wurdi Youang stone arrangement on their Wurdi Youang property appears to be based on the local Aboriginal calendar, it maybe a useful tool to explore the impacts of past climate change. Since climate change affects country, Indigenous participants considered it important that they develop a voice in the future debates concerning CCA. The Kaurna community have long held aspirations of establishing the Warriparinga Living Kaurna Cultural Centre, located on land within the Tjilbruke site in suburban Marion, as a means of communicating Indigenous environmental issues to the general public. They further argued that the Centre should become the public face of CCA for the whole state and that it should be framed using Indigenous ecological knowledge. Similar aspirations were expressed by Boon Wurrung participants who saw opportunities potentially stemming from the close partnership that the Boon Wurrung Foundation Limited has formed with the Port Philip EcoCentre at St Kilda.

There was general recognition of the importance of exhibitions in museums, interpretation centres and keeping places as a means of developing the awareness of the distinctiveness of Aboriginal cultures. An Indigenous perspective on the environment is useful for drawing attention to the short and long term changes to the environment. Senior members of many Aboriginal communities in south-eastern Australia see themselves as having a continuing role in caring for country, as did their ancestors. This is reflected in their ceremonial 'welcome to country' speeches made on official occasions.

27.5.6 Wild Food Network (Indigenous)

Under a variety of climate change scenarios, changes in timing of flowering and breeding cycles, coupled with higher temperatures and lower rainfall plus the likelihood of potential favourable conditions for the spread of plant diseases, weeds and pests, would impact negatively on the wild food network and various individual and collective activities operating at all nodes along this network (Fig. 27.2).

Interestingly, 9 of the 13 plant species which grower associations and government agencies consider as the mainstay of the Australian native food industry (Hele

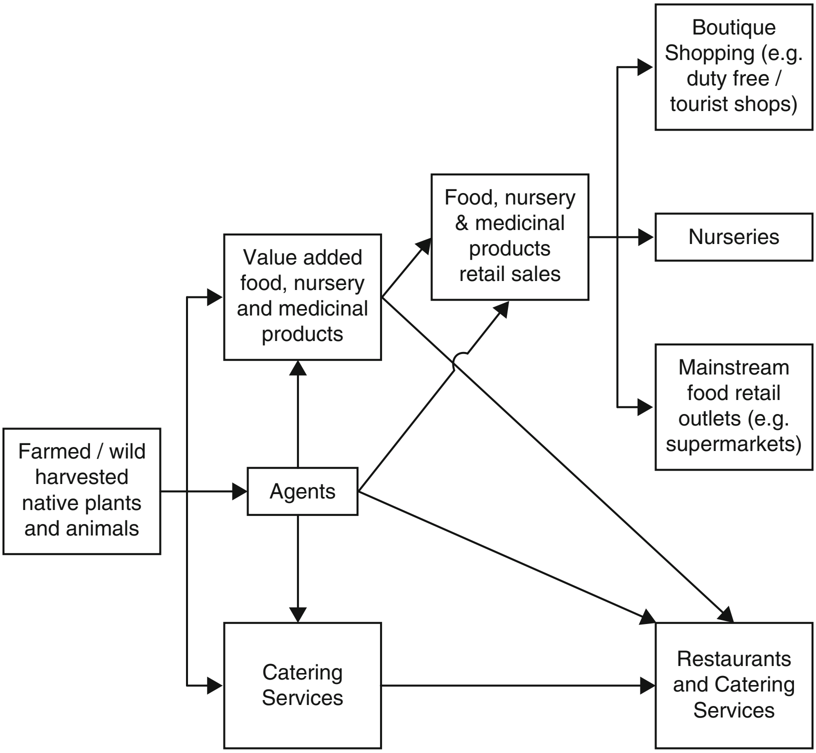

Fig. 27.2 Wild food (indigenous) network

2003; Ryder and Latham 2005; Ryder et al. 2009), are grown in south-eastern Australia. Indigenous people generally operate at the food service and tourism nodes of the network, with some wild bush harvesting and attempts at developing 'bush food gardens' as plant nurseries (Robins 2007).

The study engaged with a small number of single successful Indigenous operators in the wild food network. Universal aspirations were expressed by all case study organisations to develop businesses in this area and become involved in the wild harvesting or growing of plants as raw materials to help revitalise their hunter-gatherer crafts. In this latter regard, it is feared that the vegetation supporting some of these practices such as species of sedges and grasses used in basket making, may be threatened by climate change. The 'cultural authenticity' that Indigenous involvement brings to the whole bush food industry is recognised as significant for developing the market (Robins 2007). The industry has opportunities for small operators, as well as for larger community-run organisations. For example, Wathaurong Aboriginal Co-Operative have aspirations to develop businesses involved in the growing of bush foods, initially as suppliers and agents for high quality local restaurants that understand the benefit in promoting locally grown 'Aboriginal' produce.

The wild plants and animals have cultural importance in contemporary identity building that transcends their economic importance. Whilst there are opportunities to develop on-country tourism initiatives that incorporate bush foods and the environment as major themes, there are also strong beliefs amongst Aboriginal communities that their wellbeing was improved by the consumption of their 'traditional' foods and by their use of 'bush' medicines.

27.6 Discussion

In response to likely climate change and urbanisation impacts and landscape changes confronting their respective regions, urban and peri-urban Indigenous people consider themselves highly vulnerable largely because they do not possess strong links to traditional country, which places them at a disadvantage when attempting to participate in CCA forums. Clearly their adaptive capacity could be improved if they had enhanced access to their country. In their current circumstances they noted the significant difficulties they faced in influencing CCA at individual and family levels and in business and institutional settings. An acute shortage of qualified and experienced members further exacerbates their ability to engage in climate change debate and policy formulation. Thus there is an urgent need to ensure that the next generation of Aboriginal communities is across CCA and other environmental management issues related to country.

Due to their limited standing in urban and peri-urban environments, Aboriginal people's lack of resources, their limited access to their country, and their perceived powerlessness to influence the negative aspects of urbanisation and landscape changes, their attention to climate change impacts and adaptation tends to repeatedly take them back to considerations of social and economic equity and opportunities for improvement. Ongoing historical disadvantage leads to socio-economic issues overriding CCA considerations. There was a clear call for future serious considerations of CCA matters not to be divorced from the social and economic disadvantage of Indigenous people as their long standing economic and social aspirations are seen as fundamental survival strategies for their communities.

Whilst economically important, wild plants and animals have cultural significance in contemporary identity building. The exploitation of the wild food network presents important opportunities for urban and peri-urban Aboriginal people, such as the development of on-country tourism initiatives focused on bush foods and the environment. Perhaps more important is the strong belief held by Aboriginal communities that consumption of their ‘traditional’ foods and their use of ‘bush’ medicines significantly improves their wellbeing.

As a strategy to overcome the noted challenges, there should be a collaborative approach to CCA, which builds in traditional knowledge so that it does not undermine cultural identity. CCA with Indigenous communities in south-eastern Australia cannot be divorced from connection to country. Since climate change affects country, Indigenous people consider it important that they develop a voice in future debates concerning CCA. The ILUA process may provide opportunities to address CCA in a more formal and comprehensive manner. Future ILUAs should take the opportunity to address CCA relevant to urban and peri-urban Aboriginal people and provide resources to facilitate their adaptation requirements. This should lead to more meaningful engagement that maximises the gains from existing and emergent ILUA processes through the embedment of climate change adaptation intentions and support commitments along with serious employment of protocols in the ILUA process. All of these initiatives should lead to meaningful and higher order engagement by urban and peri-urban Indigenous communities in formal climate change adaptation policy agendas.

27.7 Conclusions

The evidence emerging from this research clearly demonstrates that Aboriginal people’s consideration of the future, even with the overlay of climate change and the requirements for serious considerations of adaptation, are significantly influenced and dominated by social and economic aspirations which are seen as fundamental survival strategies for their communities. This is largely because many other initiatives can be linked and/or run in parallel with climate change adaptation initiatives which can start to address some long standing issues of a socio-economic and human capacity nature.

The recommended collaborative and comprehensive approach involves a high degree of inclusive participation and youth engagement which should lead to greater Indigenous connection to country, thus improving the chances of enhancing the adaptive capacity of individual and collective Indigenous people.

In summary, there was universal recognition that climate change was placing a disproportionate burden upon Indigenous people. Circumstances contributing to this unsatisfactory situation included: the lack of specific CCA policy to support Indigenous people and communities; a lack of awareness and understanding of climate change and adaptation options by Indigenous urban and peri-urban people; and their dispossession and absence of direct access to their country. There was an overwhelming position that to adapt to climate change, access to land was important, change had to be seen, and there was a need to understand it.

Acknowledgments We acknowledge the elders, families and forebears of the Kaurna people of the Adelaide Plains region, the Wathaurong and Boon Wurrung peoples of the Port Phillip Bay region, the Jagera people of the Ipswich and Brisbane region, and the Quandamooka people of Moreton Bay and North Stradbroke Island, who were and are the custodians of the land and water for many centuries.

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References

Abbs D, McInnes K, Rafter T (2007) The impact of climate change on extreme rainfall and coastal sea levels over south-east Queensland. Part 2: a high-resolution modelling study of the effect of climate change on the intensity of extreme rainfall events. CSIRO, Victoria, Australia

Adger WM (2005) Social aspects of adaptive capacity. In: Smith JB, Klein R, Huq S (eds) Climate change, adaptive capacity and development. Imperial College Press, London

Australian Government (2010) Our cities: the challenge of change, background and research paper, Australian Government, pp 128

Biddle N (2012) CAEPR indigenous population project 2011: population and age structure, Census Papers 5. Australian National University, Canberra

Biddle N, Taylor J (2009) 'Indigenous population projections, 2006–31: planning for growth', CAEPR working paper no. 56, CAEPR, ANU, Canberra

Biddle N, Yap M (2010) Demographic and socioeconomic outcomes across the indigenous Australian lifecourse: evidence from the 2006 census. ANU E Press, Canberra

Burnley I, Murphy P (1995) Exurban development in Australia and the United States: through a glass darkly. J Plan Educ Res 14:245–254

Buxton M, Tieman G, Bekessy S, Budge T, Mercer D, Coote M, Morcombe J (2006) Change and continuity in peri-urban Australia: state of the peri-urban regions: a review of the literature. RMIT University, Melbourne

Clarke PA (1996) Adelaide as an aboriginal landscape. In Chapman V, Read P (eds) Terrible hard biscuits. A reader in aboriginal history. Journal of Aboriginal History, Allen & Unwin, Sydney, pp 69–93

City of Greater Geelong (2011) Geelong climate change adaptation strategy, City of Greater Geelong, Geelong, Australia

CSIRO (2007) Climate change in Australia. Technical Report 2007 (online), viewed 20 May 2010. http://www.climatechangeinaustralia.gov.au/technical_report.php

Department of Environment and Natural Resources (2010) Regional climate change projections: Adelaide and mount lofty ranges. Commonwealth of Australia, Canberra

Department of Environment and Resource Management (2009) ClimateQ: toward a greener Queensland. Queensland Government, Brisbane

Department of Sustainability and Environment (2008) Climate change in the corangamite region, the State of Victoria; geelong region alliance (2007) G 21 geelong regional plan – a sustainable growth strategy, Geelong Region Alliance, Geelong, Victoria

Dugdale A (2008) Where do Queensland's Indigenous people live? Med J Aust 188(10):614

Füssel H (2007) Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustain Sci 2(2):265–275

Gallant A, Hennessy K, Risby J (2007) Trends in rainfall indices for six Australian regions: 1910–2005. Aust Meteorol Mag 56(4):223–239

Hele AE (2003) Researchers' extension program for the native foods industry. 03/013. Rural Industries Research and Development Corporation, Canberra

Hennessy K (2004) Storms and climate change in Australia. International conference on storms. Storms science to disaster mitigation. Brisbane, Australia

Hennessy K, Fitzharris B, Bates BC, Harvey N, Howden M, Hughes L, Salinger J, Warrick R (2007) Australia and New Zealand. In: Parry ML, Canziani OF, Palutikof JP, Van Der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Kinrade P, Preston B (2008) Impacts of climate change on settlements in the Western Port Region. People, property and places, CSIRO, Marsden Jacob Associates and Western Port Greenhouse Alliance, Victoria.

Langton M, Parsons M, Leonard S, Auty K, Bell D, Burgess P, Edwards S, Howitt R, Jackson S, McGrath V, Morrison J (2012) National climate change adaptation research plan for indigenous communities. National Climate Change Adaptation Research Facility, Gold Coast, 50 pp

Low Choy D, Clarke P, Jones D, Serrao-Neumann S, Hales R, Koschade O (2013) Aboriginal reconnections: understanding coastal urban and peri-urban indigenous people's vulnerability and adaptive capacity to climate change. National Climate Change Adaptation Research Facility, Gold Coast, 139 pp

Lucas C, Hennessy K, Mills G, Bathols J (2007) Bushfire weather in Southeast Australia: recent trends and projected climate change impacts, report prepared by Bushfire CRC, Australian Bureau of Meteorology and CSIRO Marine and Atmospheric Research, Bushfire Cooperative Research Centre, Melbourne, Victoria

McInnes K, Suppiah R, Whetton P, Hennessy K, Jones R (2003) Assessment of climate change, impacts and possible adaptation strategies relevant to South Australia, Undertaken for the South Australian Government by the Climate Impact Group, CSIRO Atmospheric Research, CSIRO, Australia Queensland

Murphy B, Timbal B (2008) A review of recent climate variability and climate change in south-eastern Australia. Int J Climatol 28(7):859–879

Parry M, Canziani O, Palutikof J, Van Der Linden P, Hanson C (eds) (2007) Climate Change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change, International Panel on Climate Change (IPCC). Cambridge University Press, Cambridge

Patt A, Klein R, De La Vega-Leinert A (2005) Taking the uncertainty in climate-change vulnerability assessment seriously. Compt Rendus Geosci 337(4):411–424

Queensland Climate Change Centre of Excellence & Department of Environment and Resource Management (2010) Climate change in Queensland. What the science is telling us, Brisbane, State of Queensland, Department of Environment and Resource Management, Brisbane

Reilly J, Schimmelpfennig D (2000) Irreversibility, uncertainty, and learning: portraits of adaptation to long-term climate change. Clim Chang 45(1):253–278

Robins L (2007) Outback spirit bush foods: a learning model in marketing and supply chain management. 06/037. Rural Industries Research and Development Corporation, Canberra

Roös P (2013) Indigenous knowledge and climate change: the Wathaurong and Gadubanud narrative for the great ocean road region. In: Davies R, Menzies D (eds) Shared wisdom in an age of change 2013 Aotearoa New Zealand, IFLA50, proceedings of the 50th IFLA [International federation of landscape architects] world congress. Sky City Convention Centre, Auckland, 10th–12th April 2013, NZILA, Wellington, New Zealand, pp 226–263. ISBN 978-0-473-24360-9

Rose DB (1996) Nourishing terrains, Australian aboriginal views of landscape and wilderness. Commonwealth of Australia, Canberra, p 7. http://www.environment.gov.au/heritage/ahc/publications/commission/books/nourishing-terrains.html

Ryder M, Latham Y (2005) Cultivation of native food plants in south-eastern Australia. 04/178. Rural Industries Research and Development Corporation, Canberra

Ryder M, Walsh F, Douglas J, Waycott M, Robson H, Singh Z, Sousa Majer M, Collins T, White J, Cheers B (2009) Sustainable bush produce systems: progress report 2004–2006. Desert knowledge CRC working paper 31. Desert Knowledge CRC, Alice Springs

Salik J, Ross N (2009) Traditional peoples and climate change. Glob Environ Chang 19:137–139

Suppiah R, Hennessy K, Whetton P, McInnes K, Macadam I, Bathols J, Ricketts J, Page C (2007) Australian climate change projections derived from simulations performed for the IPCC 4th assessment report. Aust Meteorol Mag 56(3):131–152

Tindale NB (1987) The wanderings of Tjirbruki: a tale of the Kaurna people of Adelaide. Rec South Aust Mus 20:5–13

Vincent K (2007) Uncertainty in adaptive capacity and the importance of scale. Glob Environ Chang 17(1):12–24

Part IX
Legal, Policy and Institutional Challenges

Chapter 28
Effect of Social and Institutional Fragmentation on Collective Action in Peri-Urban Settings

Paul Martin, Elodie Le Gal, and Darryl Low Choy

Abstract Voluntary collective action is essential to natural resource governance. In peri-urban settings, a complex behavioural and institutional matrix frames such action, and the net balance of incentives and disincentives, supports and impediments determines the likelihood of effective action on any issue. Coupled with this, each issue has its own biophysical and social characteristic, which intersects with the character of the community. Taken together these issues suggest the need for a realistic understanding of what will make collective action feasible, and design of institutional arrangements to manage the totality of the behavioural setting and the reality of the problem being addressed. Taking invasive species (and in particular invasive animals) as an example, this chapter explores the dynamic nature of the challenge of collective action in a peri-urban setting.

Keywords Community • Biophysical characteristics • Incentives • Disincentives • Natural resources • Peri-urban setting

28.1 Introduction

Peri-urban environments have a key role in the establishment and spread of many invasive species, offering an attractive combination of habitats, land uses and human activities that allow harmful species to establish and spread. The result is a rich variety of impacts within the peri-urban area spreading into the urban and rural areas, with adverse effects on people and environmental assets. Institutional arrangements have not proven to be sufficiently effective to stem these problems.

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By ‘institutions’ we refer to the norms of behavior within a society, and the organisations that create or give effect to them. These can be formal (e.g. laws, planning instruments, contracts) or informal (cultural or religious norms), and they can arise from government, business or civil society (North 1994). Many studies and proposals for reform of invasive species law and organisational arrangements exist (Beale et al. 2008; Miles et al. 2009; Norris et al. 2005; Martin 2008), but the peri-urban context poses particular difficulties and to date has not been a priority area of attention for research and planning and governance reform. The mixture of complex biophysical, social, economic, and cultural conditions interacts with many rural and urban institutional arrangements that increase the transaction costs of collective action (Kruger 2012). This problem is a matter of strategic importance, but finding a strategy to address it is far from simple.

There are competing perspectives on institutional complexity and collective action. One influential stream of scholarship (championed by Elinor Ostrom) suggests that forms of institutional complexity characterised as ‘nested governance’ or ‘polycentricity’ benefit voluntary collective action (Aligica and Tarko 2012). The alternative view from efficiency and transaction costs economics is that institutional complexity causes waste and impedes collective action (Martin and Shortle 2010). These perspectives lead to different views about the value of ‘streamlining’ institutional arrangements to manage natural resources and to govern the commons. What both approaches do highlight is that institutional arrangements provide a framework for citizens’ collective natural resource management and that institutional complexity (and thus transaction cost) is a factor in collective action.

Spanning both perspectives we propose that institutional effectiveness depends upon the details of the issue and the context within which collective action is to take place. It is unrealistic to separate the institutional aspect from the biophysical, economic, social and political dimensions. The degree to which institutional complexity may impede or support action depends on (among other things) the strength of the net incentive to take action – a small impediment will have a substantial impact when there is a weak incentive – and the totality of the incentives, supports and impediments that are in play. This suggests that a strategic approach is required, which reflects context and the nature of the problem to be managed (Burgman et al. 2009). Part of this (at least in the peri-urban setting) should be to address the transaction costs that alter the net balance of incentives for collective action.

‘Strategising’ what institutional frameworks will be effective requires an integrative approach (Majchrzak 1984). It involves selecting a direction; predicting challenges, opportunities and context, and understanding the capacity of the strategists’ organisation (Ohmae 1982; Martin and Verbeek 2006). The choice of an institutional ‘tool’ like a law or market instrument makes little sense without knowing who is responsible for its implementation, how the strategy is to be resourced, the implementation commitments, and the plan for monitoring performance and adjusting to changing circumstances. The likelihood of any strategy being effective is a function of how well it fits its context, the resources that are used (including human resources) and the quality of implementation (Faure 2012). Decision making requires a mixture of empirical analysis (viz. the state of resources, success of prior strategies etc.), judgment (viz. anticipated conditions, priority goals, preferred strategy) and making tradeoffs (viz. implementation, resource allocation).

The great variety of governance instruments created by government, the private sector and civil society highlights that many institutions influence resource consumption and conservation in different ways. We need to work with a complex natural/human system that is 'coupled' at many points. This focus of planning and management attention is at the intersection of the human and biophysical environments – the socio-ecological system or what Selman refers to as the *landscape scale* (i.e. "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors") (Selman 2006). It is important to understand how the elements in the system interact, and how (for example) changes to economic incentives and market institutions can influence regulatory or social arrangements. Interventions by different sectors are inter-dependent, but natural resource governance thinking often fails to reflect this. A comprehensive approach should result in more effective interventions than a simpler (but less realistic) static and 'siloed' approach.

We acknowledge the lack of objective standards against which to test whether peri-urban governance is achieving sufficient success in natural resource sustainability. Should peri-urban governance effectiveness be measured in social, economic or environmental terms; against what objective function is efficiency to be assessed; and against what interests is fairness to be judged? Should peri-urban area sustainability be judged as part of urban environmental performance, or should the conversion of farmland to urban uses be judged as an intrinsically unsustainable change in land-use? Even if the objective function can be agreed, measures require data that may be difficult to obtain, as well as judgement based upon perceptions. We are left to rely upon the broad observation that natural resource governance has not resulted in a sustainable, productive and just society, and that peri-urban areas show many characteristics of unsustainability (Low Choy et al. 2008).

28.2 Framing the Issue

The human 'footprint' calculation shows that human consumption of resources exceeds renewable production of those resources by 1.5 times (Global Footprint Network www.footprintnetwork.org). The World Wildlife Fund (WWF) indicates that

> '(*f*)*or more than 40 years*, *humanity*'*s demand has exceeded the planet*'*s biocapacity – the amount of biologically productive land and sea area that is available to regenerate these resources. This continuing overshoot is making it more and more difficult to meet the needs of a growing global human population*, *as well as to leave space for other species. Adding further complexity is that demand is not evenly distributed*, *with people in industrialized countries consuming resources and services at a much faster rate*. (World Wildlife Fund Living Planet Report 2014)

Economic growth is considered to be essential to modern societies. Its imperatives permeate political debate, economic development, public and social media, and commerce. Greater wealth drives more resource consumption. This is reflected in the demand for technology, urban water, meat, or exotic plant-based food, all of which have a substantial footprint (United Nations, Department of Economic and Social Affairs, Population Division 2014), along with food waste and or the expansion of urban areas. Whilst it is argued that with dematerialisation of the economy less natural resources can create greater wealth, the degree to which this is possible is uncertain (Weizsacker et al. 1998). The natural resource governance system drives resource consumption more effectively than it supports conservation and restoration. Nowhere is this more obvious than with the conversion of farmland and undeveloped green spaces into peri-urban uses.

Harmful invasive species include plants (“weeds”), animals, insects, diseases and other living beings that harm human and ecological interests. They invade ecosystem types from oceans to mountains (*Global Invasive Species Database*, http://issg.org/database/species/search.asp). Weeds invade domestic gardens and farmlands, and can trigger dangerous allergies. Rodents destroy standing or stored produce, contaminate products or spread disease; wild dogs, feral pigs and other pest animals spread human or animal diseases; marine invasive species contaminate water and damage fisheries; mosquitos spread serious disease – the list of economic, social and environmental impacts of invasive species is daunting. Particularly in urban and peri-urban environments the role of pest animals as vectors of disease adds a health risk to this problem. Adding biodiversity loss caused by pest species to this list, and the problem of harmful invasive species in peri-urban areas comes into focus as significant in many parts of the world.

Australia reports 166 agricultural invasive species from a total of 409 invasive species. For urban invasive pests, Australia reports 154 with many of these occurring in urban, rural and peri-urban settings. Riverine and marine invasive species also impact on urban interests, such as water quality, marine foods and recreational use. Insects impact upon lifestyle and spread disease.

Invasive vertebrate pests, particularly foxes, wild dogs, feral cats, rabbits and feral pigs cause much economic damage. Feral pigs cause losses to sugar cane and bananas in north Queensland while rabbits ring-bark trees and shrubs and prevent regeneration, contributing to poor land condition. These invasive vertebrates collectively generate an agricultural cost exceeding $A1b per year: Rabbits cost $206 million per year, wild dogs, $48.5 million per year, foxes, $21.2 million per year, and feral pigs, $100 million per year (Gong et al. 2008).

Invasive animals also have a substantial ecological impact (Roberts et al. 2013). In New South Wales they are implicated in 40 % of the threatened biodiversity, threatening 388 native species that constitute 83 % of endangered animal populations and 38 % of endangered ecological communities. Rabbits impact 156 threatened species, wild dogs and foxes impact 76 threatened species and feral pigs more than 20 threatened species. Feral pigs prey on as much as 70 % of sea turtle nests in north Queensland, foxes are significant predators of a wide range of native fauna such as potoroos and bandicoots in Victoria, chuditch in Western Australia and shorebirds including pied oyster catchers and little terns in New South Wales.

It is not surprising that invasive species control outcomes (like many other rural sustainability outcomes) fall short of what is needed to protect agricultural, biodiversity and social values. Whilst there are no specific assessment of the state of peri-urban environments, the Australian 2011 *State of the Environment Report* (Hatton et al. 2011) states that the impact of invasive species on inland waters is 'high' and conditions are deteriorating; and for biodiversity that the impact is 'high' to 'very high' and conditions are deteriorating. The weak link between governance instruments and on-ground outcomes, and the lack of scientifically disciplined performance improvement (Martin et al. 2012) is highlighted as follows:

> *It is extremely difficult to assess the effectiveness of management in relation to invasive species and pathogens from some reports from most states and territories … These reports mostly list plans, strategies and inputs to management, but rarely report on the effectiveness of processes or on outputs and outcomes … Some SoE reports state that actions are not achieving desired results, while this conclusion is implicit in other SoE reports since the effects of invasive species are assessed as getting worse. Some SoE reports conclude that there is not enough information to assess trends or the magnitude of effects.* (*p. 665*)

At pages 666–7 the report notes that for invasive species and pathogen control:

- 'Understanding' is substantially ineffective but improving;
- 'Planning' is substantially ineffective but improving;
- 'Inputs' into control are both ineffective and declining;
- 'Processes' are ineffective but improving; and
- 'Outcomes' are ineffective but improving.

Given the characteristics of invasive species management, socio-economic characteristics of the affected community, and insufficient resources (Invasive Species Council 2011), these outcomes are not surprising. Collective action to control invasive species harm faces complex barriers. At the heart of the difficulty is that invasive species have unique problem characteristics:

1. Resilience: many breed rapidly and can survive in a variety of (sometimes hostile) conditions. They may also be resistant to controls.
2. Adaptability: through rapid breeding and adaptation to different environments, or learning to evade human control or predation by other species.
3. Mobility: many can spread rapidly, often over large areas by using vectors or other means.
4. Economic harm: economic impacts include loss of agricultural production, predation upon or competition with desirable species, control costs or second-order disease or other harms.
5. Environmental impact: either as individual species or in conjunction with other species or other harms they degrade natural systems and cause harm to biodiversity.
6. Risk: to human health, amenity, economic interests and to natural values.

Invasive species often have ‘autopoietic’ (self-generating) characteristics. Urban environmental harms such as traffic congestion, waste, and air pollution (other than photo-chemical smog) are essentially ‘accumulative’ and have linear dynamics. Controlling the source of the problem can eliminate or substantially reduce the problem. However once an invasive species is established any episodic, localised or small-scale efforts or control that is not comprehensive will not materially reduce the harm or the risk. It may create other problems such as loss of community confidence, or species ‘rebound’ that increase the problem.

28.3 The Peri-Urban Setting

Peri-urban areas are unique ecotones, an intersection of urban and rural communities with diverse social, political and economic interests and activities and mixed landscape characteristics. Travelling through such an area you encounter varied land uses and social geographies. You can see extravagant homes set on large manicured blocks, alongside an impoverished farm, next to a golf course that services a residential estate or a retirement village. A typical peri-urban area is thus a complex mosaic of diverse ecological systems, land use, social and ethnic types (Low Choy et al. 2007). From an invasive species point of view, this diversity can create ideal conditions for a harmful species. Diverse production and consumption activities provide ‘easy pickings’, poorly managed lands provide shelter and the many vectors increase mobility of the problem.

A United Nations evaluation shows that by 2014, 54 % of the world’s population was living in urban areas. By 2050 this is expected to grow to 66 % (United Nations, Department of Economic and Social Affairs, Population Division 2014). Urban growth causes complex social, environmental and economic challenges and has impacts that are hard to precisely assess (Elmquist et al. 2013). Collective action based management of invasive species in this setting is very difficult (Van Ham et al. 2013).

In Australia two-thirds of the population is concentrated in major cities (Australian Bureau of Statistics). The US Central Intelligence Agency estimated in 2011 that the urban population represented 89.2 % of the total population, (Central Intelligence Agency) and that the projected rate of increase in urban population to 2015 was 1.49 % annually.

The expansion of the urban footprint into farming or undisturbed areas raises distributional and natural resource management issues. Such issues include: the preservation of natural systems to absorb pollutants and emissions, the exploitation of the non urban landscape for outdoor recreation and tourism activities, essentially by urban dwellers, the capture and cleaning of water, food supply and food safety and other ‘services’ for cities. Urban expansion can add to the pressures on ‘First Nations’ or vulnerable communities, creating a social justice issue (Morgan 2006). Biodiversity protection requires undisturbed or extensive areas of land. Conservation parks often serve cultural and recreational values of urban populations as well as conservation functions, particularly when close to urban areas. These competing roles can generate conflicts between conservation and recreational or other uses.

A very diverse peri-urban enterprise mix undermines the incentive to collectively control harmful species. For example, whilst foxes may be a problem for people with chickens, they are unlikely to be an issue for a vegetable grower or an occupant of a townhouse. A wool producer or an organic vegetable grower may be affected by the spread of burrs, but a cattle producer or a quarry master may not be at all affected. What is a cost or risk for one person can be a benefit to another – for example hunters value the presence of trophy species like feral deer or pigs, whereas these may impose cost or risks to a primary producer. Because control requires sustained investment, differences in economic incentive can result in the costs being carried by a small proportion of landholders, or alternatively being imposed upon the whole community for the benefit of the few. Interviews we have conducted indicate that institutional arrangements for these allocations are problematic in areas with very diverse enterprise types (Martin and Verbeek 2013).

28.4 The Diverse Social Context

Control of many species requires collective action over a large area of private and public land tenures that are under the stewardship of owners with different incentives and characteristics. Fragmentation of ownership is greater in peri-urban than in rural areas and thus more landowners must be engaged. 'Nil-tenure' approaches to management are suggested as a framework for invasive species action' (Hunt and Brindabella Working Group 2005), but in the peri-urban setting implementation is daunting. The diversity of peri-urban citizens and their land uses makes it hard to build the common platform for cooperation, increasing the transaction costs of engagement.

A wave of new settlers are moving into peri-urban areas. This raft of new "actors" on the peri-urban land ownership stage who now have stewardship responsibilities for increasing proportions of these landscape have been characterised (for the Australian context) as:

- The Seekers: "tree/sea change" life stylers, "blockies/homesteaders", religious communities and alternative life stylers.
- The Survivors: DIY home builders, the horse community, "truckies" and "adaptive" farmers.
- The Speculators: farm stays and retreats, the pet industry, boutique farmers, recreational providers, landscape suppliers, the equine industry and developers and real estate agents.
- The Strugglers: characterised by the "holding-on" farmers.

Environmental and natural resource management initiatives must now engage this full range of private landowners who have repopulated the peri-urban landscape and who now have a duty of care and full management responsibilities for these areas (Low Choy 2012).

Living and working in these diverse areas will be, amongst others, university professors, chartered accountants, entrepreneur shopkeepers, farmers, rural workers, retirees, truckers, criminals and unemployed people. Often there will be a reasonably high proportion of new migrants. This can mean cultural diversity and transience that is greater than for either urban or rural communities. For example in one Melbourne peri-urban area, 38 % of the population was born overseas. Population diversity considerations have significant implications for public management (Foster et al. 2013). This diverse range of peri-urban inhabitants has chosen their primary residential location over traditional urban and suburban localities, whilst others have sought these locations for their second (holiday) home. A distinguishing characteristic of many of these new settlers is the absence of prior experience with non-urban living and the consequential implications for sustainable management of these peri-urban landscapes (Low Choy and Harding 2010).

Extensive land fragmentation has occurred in the outer peri-urban region. In the Melbourne metropolitan region, over 53,000 rural lots exist, with the vast majority under 4 ha in size. Undeveloped clusters of even smaller lots exist across rural landscapes. Over 24,000 of these lots do not contain dwellings and a further 6,881 lots could be created by further subdivision. The progressive development of these lots would change fundamentally the appearance and functions of these rural landscapes. This situation is similar to other highly peri-urbanised areas such as the SEQ region (Low Choy and Buxton 2012).

The combination of fragmentation in tenures, ecosystems, social systems and institutional arrangements in peri-urban settings comes alongside issues of variable economic and managerial capacity of citizens (Southwell et al. 2011).

We illustrate the broad patterns of the economic mosaic with a map of the presence of households with incomes above $A24,000 per year. This map also significantly under-represents the complexity of the mosaic of peri-urban economic diversity, as many different economic circumstances are present in most peri-urban regions.

Effective control of invasive species requires spatial coverage sufficient to address the extent and rate of spread of harmful species. Relevant considerations include rates of natural increase, resilience and adaptability of the species; and the effectiveness of human and non-human vectors. People, animals, and vehicles moving through an area affect invasive species spread (Buxton et al. 2006).

28.5 Control Complexities

Small-scale holdings alter which control methods are feasible and safe. Controls like shooting, trapping or poisoning do risk non-targeted impacts upon people, plants or animals. This leads to demands for stringent restrictions where control sites are within settled areas. Alternative methods are generally more costly, labour-intensive or not available. Typically, established agricultural users suffer the adverse effects of such restrictions; increasing pressure upon farming as adjacent lands are developed.

Control of invasive species can encounter implementation or political issues due to citizen attitudes and behaviours that are not easy to manage. Some weeds are valued as garden or landscaping plants, or for food or medicinal purposes. Pretty garden plants whose hardiness and easy establishment contributes to their appeal are 'traded across the back fence' as cuttings or gifts (Buxton et al. 2006). It is not unusual for a weed to be imported illegally because it provides a food or flower with cultural value, particularly to migrants. Many harmful species have also been introduced through peri-urban use for landscaping, soil stabilisation, stock-feed or agricultural purposes. Weeds that have become major problems in Australia through domestic mechanisms include Lantana, Cabomba, Broom, Water Hyacinth, Blackberry and Asparagus Fern.

The predation of feral dogs and the impacts of cats upon native biodiversity is well known (Hewitt 2009; Wornarski et al. 2014). There can be opposition to controls that involve the killing of animals that are valued as pets (e.g. dogs or cats) or which have aesthetic or cultural appeal (e.g. deer, horses, donkeys, dingoes), because of antipathy to killing, or because of perceived risks (e.g. accidental poisoning or impacts on desirable species). Distrust of government or a sense of independence or antisocial attitudes can contribute to difficulties. These social factors translate into institutional action through politic activism and thence as legal or administrative arrangements.

A less 'mainstream' but increasing problem is the introduction of exotic birds and amphibians through legal or illegal collectors and traders. The introduction of exotic species, particularly birds and reptiles, is driven by collectors (sometimes involving criminal commerce) and the establishment of pioneer populations in peri-urban areas is well-known (Department of the Environment 2015; Bricknell 2010). In a peri-urban area there are many harbourages, pathways and vectors for invasive species. Fledgling problems can easily establish, mature and spread within this hard to control environment. The intermixing of urban and rural landscapes, and of human activities, provides a rich setting for naturally robust species to thrive. Diversity and richness can be both a blessing and a governance problem in managing natural and economic resources.

Peri-urban areas have many more and smaller-scale land tenures than rural areas (Pritchard et al. 2012) The more tenures and the smaller the area of each, the more agreements that must be reached for effective action and thus the higher the transaction costs. Should it be necessary to use regulation, the more expensive the legal cases (and the smaller the area secured by each prosecution) then the less cost-effective will be regulation. Transaction costs of government action are thus high. Whilst there are many more residents in a city, the size and nature of their holdings means that relatively few have the potential to provide serious invasive species habitats, particularly for species which use substantial space.

In governing peri-urban areas the intersection of values and economic or environmental interests can cause complex social and political conflicts (Aslin et al.

2004; Oliver and Walton 2004). One illustration is the conflicts involving pet animals and production or environmental interests, particularly when pets are fertile and allowed to roam. This can result in demands for stringent legal control over pets, leading to neighbourly and political disputes. It can result in a different type of dispute if control methods, particularly trapping or lethal control, offend the sensitivities of some residents. Disagreement over controls can lead to heated conflict and action to ban or constrain methods. This adds to the difficulties of control, making cost-effective methods non-viable and adding transaction costs such as notification requirements and additional steps in the control process (Fitzgerald 2009).

The literature of community engagement and voluntarism highlights that achieving the involvement of large numbers of people is difficult. Effective communications requires precisely tailored messages and incentives, but to create such messages involves a lot of effort (McKenzie-Mohr and Smith 1999; Hine et al. 2014). Encouraging the collective action essential for invasive species control in communities with varied interests, diverse attitudes, and different behaviours, is a major challenge (Fitzgerald et al. 2007; Thompson and Kruger 2013). The more variations, the more difficult it is to create an effective communications program and thus the more that economies of scale and specialisation are foregone.

A particular engagement problem in the control of invasive species is ensuring citizens have the competence to comply with the requirements. Farmers can be expected to develop specialised skills in land, plant and animal management that can be adapted to the problems of invasives management, or to rely upon farming neighbours for support. Where they lack specific skills, rural extension can often be effective. In peri-urban areas many landholders lack farming and land management experience and thus the associated competence and resources for efficient natural resource management. Their social and occupational interests and their sources of information are often not oriented towards land-management. It is difficult to find efficient communication channels and to shape messages to target such diverse interests. As a result the transaction costs of capacity building for natural resource management are likely to be high (Low Choy and Harding 2010).

If people perceive that there is a risk to an interest that concerns them then it is more likely that they will participate in control, and develop the required competence. Botterill and Mazur (2004) note that

> […] *success of a range of agricultural and natural resource management policies and programs that are designed to increase productivity and sustainability is clearly dependent on understanding how farmers*' (*and rural communities*) *perceive risk and how those perceptions vary among individuals*, *groups and communities* (Botterill and Mazur 2004).

The farmer or environmentalist who has managed invasive species and other land management risks for a long time may feel that the use of fatal control for pest animals or poisons for weeds is safe and reasonable. A resident whose experience is urban and who does not understand farming or other risk is likely to perceive things differently.

28.6 Responding to the Peri-Urban Institutional Challenge

The context discussed above highlights the need for institutional arrangements that can improve the context for effective collective action. Five issues are particularly significant for institutional improvement.

1. Complex controls: particularly when control requires killing animals or methods that may be harmful to humans or the plants and animals that they value. Issues of actual and perceived risk, and moral opposition, can impede effective control.
2. Intersecting institutions: Peri-urban areas encounter urban and rural issues and complex issues of development and change. There are many intersecting institutional jurisdictions (both rural and urban) in operation as a result, adding administrative transaction costs and impeding action.
3. Costly controls. Controls can be complex and costly to administer, particularly in closely settled areas. Additional requirements can make 'conventional' least cost methods unviable and can create social or legal conflict or economic risk that can be costly.
4. Non-comprehensive or ineffective control efforts can be counterproductive. Partial effectiveness can undermine collective action, or create 'reservoirs' and second-order problems like resistance or 'rebound effects' that add to future problems. Securing agreement in peri-urban areas with many small tenures and getting effective action by landholders who are un-used to land and pest management add to the difficulties.
5. Rules may require landholders to control pest species and risks, and programs may support control. Implementation is hampered by the transaction costs of supervision and administration and capacity development, compounding the problem of inadequate public funds or under-resourced or under skilled private action.

The complexity of Australian invasive species legal institutions has been documented and adjustments to government arrangements proposed (Cattanach et al. 2013; Glanznig and Kessal 2004). What has not been as well considered is the interaction with other social and legal arrangements, including those of non-government institutions. These intersections are particularly important in a peri-urban setting, where norms for managing urban issues and for managing land-use changes interact with rural governance requirements.

Separate to invasive species laws, local and state government health and safety arrangements establish standards of property management and for managing human risk, or danger to property (such as livestock or crops), including aspects of what types of invasive species control are acceptable. Land-use zoning partly determines the size of properties and their permitted uses; and this intersects with private arrangements for the management of risks of control, or of failures of control, of hazards. Insurance, political and regulatory risk acceptability has many second-order effects, for example establishing the standards of risk-management applied by local and state government officers or heightening sensitivity around decisions.

This is just one example of how the interaction between government and private institutions is important to effective governance. Community political institutions such as chambers of commerce and citizen environmental bodies work with elected or appointed officials, and their stance on invasive species issues is important in determining what will happen in practice. Non-government institutions are also important to the resourcing and implementation challenge. Whilst we have mainly considered impediments to effective collective action, citizen and commercial organisations can create conditions for collective action.

For these reasons an effective strategy for collective control of invasive species requires a broad institutional perspective. It requires consideration of the total suite of government rules and administrative and resourcing arrangements, not merely those that are specific to invasive species. It requires careful consideration of the impediments arising from all forms of institutional and social complexities.

For this reason it is necessary to shift the focus of governance towards more effective systems, moving beyond concerns for public sector instruments and organisations. Strategies that can reshape the decisions that most influence the coupled social/economic/environment system must address the roles of government, private industry and citizens. It is necessary that strategies target specific behaviours, and commit to plans that are feasible given the context and resources. A targeted, implementation focused approach should lead to better integration of legal, economic, and social approaches and more precise interventions.

It is essential that objective review and evaluation of the performance of strategies institutions drives government towards more effective, efficient and fair outcomes. For this reason there must be institutionalised mechanisms to develop a body of knowledge and practice. *Ex-ante* and *ex-post* institutional evaluations should specifically assess the distributions of costs and benefits of governance action and potential inequities or incapacities. Improvement reviews should consider invasive species management within the context of all other instruments and strategies that affect the issue. For example, industry support and taxation arrangements may be just as important as biodiversity protection rules and incentives. Community groups and buying chain actions may be far more powerful than government in shaping the many transactions that create invasive species outcomes.

Finally, learning from the experience of engineering or commerce, it is necessary to analyse the risk of failure in major projects. This helps make strategies more robust, and reduces the risks of failure or catastrophic consequences. Natural resource governance interventions do fail, or have unanticipated undesirable consequences. This suggests the need for an effective system of policy risk analysis in natural resource governance.

The focus of this chapter has been upon institutional arrangements to improve collective action in peri-urban settings. The analysis has supported the general belief that transaction costs are significant in determining the likelihood of collective action but it has indicated that the complexities that are important go well beyond formal institutional arrangements. Social and economic dynamics and community relationships and politics are also sources of transaction costs and complexities that can impede effective collective action. The chapter points to the necessity of managing these issues as a behavioural systems problem, creating a more effective governance system rather than merely a set of public instruments or organisational arrangements. This major shift in approach challenges conventional public governance practice, but it is hard to see how better results can be achieved within the limits of the current paradigm.

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References

Aligica PD, Tarko V (2012) Polycentricity: from Polanyi to Ostrom, and beyond. Governance 25(2):237–262

Aslin H, Kelson S, Smith J (2004) Peri-urban landholders and bio- security issues – a scoping study. Bureau of Rural Sciences, Canberra

Australian Bureau of Statistics (2012–2013) Feature article: capital cities: past, present and future. http://www.abs.gov.au/AUSSTATS/abs@.nsf/featurearticlesbyCatalogue/AC53A071B4B231A6CA257CAE000ECCE5?OpenDocument. Accessed 12 Jan 2014

Beale R, Fairbrother J, Inglis A, Trebeck D (2008) One biosecurity- a working partnership -the independent review of Australia's quarantine and biosecurity arrangements. report to the minister for agriculture fisheries and forestry. http://www.daff.gov.au/quarantinebiosecurityreview/report_to_the_minister_for_agriculture_fisheries_and_forestry

Botterill L, Mazur N (2004) Risk and risk perception: a literature review 04/-43 project no BRR 8A. Canberra ACT Australia: Rural Industries Research and Development Corporation.

Burgman M, Walshe T, Godden L, Martin P (2009) Designing regulation for conservation and biosecurity. Australas J Nat Res Law Policy 13(1):93–112

Buxton M, Tieman G, Bekessy S, Budge T, Mercer D, Coote M, Morcombe J (2006) Change and continuity in peri-urban Australia, state of the peri-urban regions: a review of the literature. RMIT University, Melbourne.

Cattanach A, Harris A, Horne J (2013) Mapping Australia's weed management system. RIRDC, Canberra. https://rirdc.infoservices.com.au/items/13-019

Central Intelligence Agency. The world factbook – field listing: urbanization. Available at https://www.cia.gov/library/publications/the-world-factbook/fields/2212.html. Accessed 12th Jan 2014

Department of the Environment (2015) 'Keeping exotic (non-native animals). Available at http://www.environment.gov.au/biodiversity/wildlife-trade/exotics. Accessed 13 Jan 2015; See also Samantha Bricknell (2010), Environmental crime in Australia (AIC Reports Research and Public Policy Series 109), pp 49–64. Available at http://www.aic.gov.au/documents/2/1/1/%7b211B5EB9-E888-4D26-AED4-1D4E76646E4B%7drpp109.pdf. Accessed 14 Jan 2015

Elmquist et al (2013) Urbanization, biodiversity and ecosystem services: challenges and opportunities – a global assessment (Springer, 2013); World Bank. Planning, connecting, and financing cities – now: priorities for city leaders. 2013. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0

Faure MG (2012) Instruments for environmental governance: what works. In: Martin P et al (eds) Environmental governance and sustainability, IUCN Academy of Environmental Law. Edward Elgar, Cheltenham.

Fitzerald G (2009) Public attitudes to current and proposed forms of pest animal control. Invasive Animals CRC, Canberra

Fitzgerald G, Fitzerald N, Davidson C (2007) Public attitudes towards invasive animals and their impacts – a summary and review of Australasian and selected international research. Invasive Animals CRC, Canberra

Foster H, Towers B, Whittaker J (2013) Peri-urban Melbourne in 2021: changes and implications for the Victorian emergency management sector. Aust J Emerg Manag 28(3):6–11

Glanznig A, Kessal O (2004) Invasive plants of national importance and their legal status by state and territory. WWF, Sydney

Global Footprint Network for methodology and data. www.footprintnetwork.org

Global invasive species database. http://issg.org/database/species/search.asp. Accessed 2nd and13th Jan 2015

Gong W, Sinden J, Braysher M, Jones R (2008) The economic impacts of vertebrate pests in Australia. (Invasive Animals Cooperative Research Centre, Canberra). CRC, I. A. Extension Program (2012–2017). (IA CRC, 2012). http://www.feral.org.au/the-economic-impacts-of-vertebrate-pests-in-australia

Hatton J et al (2011) State of the environment 2011 (SoE 2011) Australian State of the Environment Committee, 2011. See also West P (2008) Assessing invasive animals of Australia. National Land & Water Resources Audit. http://www.feral.org.au/assessing-invasive-animals-in-australia-2008

Hewitt L (2009) Major economic costs associated with wild dogs in the Queensland grazing Industry, Blueprint for the Bush, Agforce at http://www.agforceqld.org.au/file.php?id=262&open=yes. Accessed 14 Jan 2015

Hine D, Please P, McLeod L, Driver A (2014) Behaviourally effective communications for invasive animals management: a practical guide. University of New England, Armidale

Hunt R, Brindabella Wee Jasper Wild Dog/Fox Working Group (2005) The Nil Tenure approach to a landscape issue (Wild dogs), Proceedings of the 3rd NSW Pest animal control Conference 4th–7th July 2005, NSW DPI at http://www.feral.org.au/wp-content/uploads/2010/03Hunt2005b.pdf. Accessed 13 Jan 2015. Also Nil Tenure" Approach to Invasive Animal Management in Australia – Extending the Paradigm. Canberra: Invasive Animals CRC. http://www.feral.org.au/nil-tenure-approach-to-invasive-animal-management-in-australia-extending-the-paradigm. Accessed 13 Jan 2015

Invasive Species Council (2011) Barriers to effective climate change adaption: invasive species and biodiversity conservation – a submission to the productivity commission. http://www.pc.gov.au/__data/assets/pdf_file/0015/114522/sub037.pdf

Kruger H (2012) Biosecurity engagement: proposed national action plan for community involvement in plant biosecurity – consultation summary report. ABARES, Canberra

Low Choy D (2012) New settlements on the fringe: understanding contemporary peri-urbanisation. In: Weller R, Bolleter J (eds) Made in Australia: the future of the world's most urbanised nation. UWA Press, Perth

Low Choy D, Buxton M (2012) Farming the city fringe: dilemmas for peri-urban planning. In: Farmer-Bowers Q, Vaughan Higgins V, Joanne Millar J (eds) Food security in Australia: challenges and prospects for the future. Springer, New York

Low Choy DC, Harding J (2010) Exploring agents of change to peri-urban weed management. UMCCC Periurban Weed Management Study, Land & Water Australia, Canberra

Low Choy DC, Sutherland C, Scott S, Rolley K, Gleeson B, Dodson J, Sipe N (2007) Change and continuity in peri-urban Australia – peri-urban case study: south east Queensland, monograph no 3 – change and continuity in peri-urban. Urban research program. Griffith University, Brisbane

Low Choy D, Sutherland C, Gleeson B, Sipe N, Dodson J (2008) Change and continuity in peri-urban Australia: peri-urban futures & sustainable development, monograph 4, urban research program. Griffith University, Brisbane

Majchrzak A (1984) Methods for policy research, vol 1, Applied social research methods. Sage Publications, London

Marin P, Verbeek M (2006) Sustainability strategies. Federation Press, Sydney

Martin P (2008) Cross pollination or cross-contamination? Directions for informing the management of invasives with market-economy concepts (keynote). In: Van Klinken RD, Osten VA, Pancetta FD, Scanlan JC (eds) 16th Australian weeds conference, Brisbane

Martin PV, Shortle J (2010) Transaction costs, risks and policy failure. In: Soares CD (ed) Critical issues in environmental taxation: international and comparative perspectives, vol VIII. Oxford University Press, Oxford

Martin P, Verbeek M (2013) Measuring the impact of managing invasive species. May 13, 2013 for the Australian Government Department of Agriculture Forestry and Fisheries. Unpublished

Martin P, Verbeek M, Riley S, Barel R, Le Gal E (2012) Innovations in institutions to improve weed funding, strategy and outcomes, Proposals for a national weed institutions research agenda May 2012 RIRDC Publication RIRDC 12/091 ISBN: 978-1-74254-433-5

McKenzie-Mohr D, Smith W (1999) Fostering sustainable behavior: an introduction to community-based social marketing. New Society Publishers, New York

Miles RL, Kinnear S, Friedel M, Grice AC, Van Klinken RD, Setterfield S, Herpich M (2009) Policy, institutional and managerial considerations in managing weeds with a commercial value. http://lwa.gov.au/products/pn22362

Morgan G (2006) Unsettled places: aboriginal people and urbanisation in New South Wales. Wakefield Press, Kent Town

Norris A, Low T, Gordon I, Saunders G, Lapidge S, Lapidge K, Peacock T, Pech R (2005) Review of the management of feral animals and their impact on biodiversity in the rangelands – a resource to aid NRM planning. PAC CRC, Canberra

North D (1994) Economic performance through time. Am Econ Rev 84(3):359–360

Ohmae K (1982) The mind of the strategist. McGraw Hill, New York

Oliver J, Walton C (2004) Pests in Queensland baseline survey 2003: a survey of primary producers and residents of regional centres and large country towns. Queensland Department of Natural Resources, Mines and Energy, Brisbane

Pritchard B, Neave M, Hickey D, Troy L (2012) Rural land in Australia: a framework for the measurement and analysis of nationwide patterns of ownership change, aggregation and fragmentation. RIRDC Publication no. 12/038, Canberra

Roberts PD, Diaz-Soltero H, Hemming DJ, Parr MJ, Wakefield NH, Wright HJ (2013) What is the evidence that invasive species are a significant contributor to the decline or loss of threatened species? A systematic review map. Environ Evid 2(1):5

Selman P (2006) Planning at the landscape scale. Routledge, London.

Southwell D, Mccowen S, Mewett O, Hennecke B (2011) Understanding the drivers and barriers towards the adoption of innovative canid control technologies: a review. Invasive Animals CRC, Canberra

Thompson L, Kruger H (2013) Who's involved with weeds? A social network analysis of funding and information networks for weed management. RIRDC, Canberra

United Nations, Department of Economic and Social Affairs, Population Division (2014) World urbanization prospects: the 2014 revision, highlights (ST/ESA/SER.A/352)

Van Ham C, Genovesi P, Scalera R (2013) Invasive alien species: the urban dimension – case studies on strengthening local action in Europe. IUCN European Union Representative Office, Brussels

Weizsacker EV, Lovins AB, Lovins LH (1998) Factor four: doubling wealth, halving resource use. (Earthscan, London) and F. Schmidt-Bleek. The factor 10/MIPS-concept bridging ecological, economic, and social dimensions with sustainability indicators. Wuppertal Institute (2000) http://www.factor10-institute.org/files/MIPS.pdf. Accessed Jan 16 2015

Woinarski JCZ, Burbidge AA, Harrison PL, Milne DJ (2014) The action plan for Australian mammals 2012. CSIRO, Melbourne

World Wildlife Fund Living Planet Report (2014) WWF International, Switzerland.

Chapter 29
Gentrification Versus Territorialisation: The Peri-Urban Agriculture Area in Beirut

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Abstract This chapter is the result of a research project on the peri-urban area in Greater Beirut conducted at the Landscape Design and Ecosystem Management (LDEM) Department at American University of Beirut (AUB), and improved during the fall semester 2013–2014, LDEM design course titled 'Site design in urban context.' The research explores the potentiality of landscape approach using urban agriculture as a sustainable strategy capable of reconstructing brooked identity and territorialised marginalised people. Could the use of urban agriculture in Beirut play a role in the break off gentrification process?

Real estate is a major driver of the economy in many countries of the Middle East, as in other developing nations. It is one of the main barriers to the development or implementation of zoning and planning regulations that would make urban agriculture more than a fortuitous and temporary use of space (Zurayk 2010). Moreover, A-line Raad argues that Lebanese urban society is now undergoing a paradigm shift in social thought and action towards valuing heritage, public space, social cohesion, and accessibility to leisure and cultural activities recognising that these factors can enhance urban liveability. The peri-urban greater Beirut area was chosen in the design course as a case study to explore, while designing, the potentiality of the landscape approach in addressing the multiple features of those areas. The gentrification process in Beirut was identified as one of the drivers of the city development causing de-territorialisation and incongruous land use coexistence.

Keywords Landscape strategy • Nahr Beirut • Lebanon • Urban Agriculture • Real estate • Peri-urban landscape

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29.1 Introduction

29.1.1 Background

Beirut is a cityscape of residues, remains produced by the uncontrolled use of the land; landscape of juxtaposed fragments that have lost value and collective identity. The phenomenon is in part related to the urban sprawl, the unplanned, uncontrolled spread of urban development into areas adjoining the edge of a city, and in part with gentrification, the increase in ground rent and the construction of high-rises for wealthier people. Sprawl and gentrification are, in Beirut, directly linked to the real estate power and the neoliberal politic, whereby land and landscape are conceived as resources to be used for economic profit, 'colonised' for the enjoyment of a few privileged (Makhzoumi 2011). Speculation drove prices upward and land became a commodity and a capital asset, the value of which is determined by its return on investment. Agriculture, traditionally a low-return sector stood no chance. The city invaded its surroundings, both physically and ideologically. Much of the farmland that remains locked into the expanding conurbation is just green space given a reprieve (Zurayk 2010).

Although the real estate market is showing some signs of slowing down, (Salem 2010), more than 350 real estate projects were under construction in May 2011 in municipal Beirut alone, an area that does not exceed 20 km^2 (Alami 2011). Economic liberalism continues to be pushed to the extreme, with no controls on business or profit making, thus intensifying the gentrification process to remain active for decades. The gentrification definition that will be used in this chapter is the one proposed by Neil Smith (1996) who emphasises the production of space, of a supply, thus anticipating a demand. Smith advanced the "Rent-Gap theory" as an explanation for this process, where the "Rent-Gap" is the difference between the actual rent for a piece of land and the potential one, if the land had higher and more profitable use. In line with David Harvey, Smith inserted gentrification in a larger process of uneven development, related to a capitalist system that keeps on reproducing itself on different geographical scales, in order to contain its crisis (Hicham el-Achkar 2011).

The lack of government initiatives and problems with land tenure and market land prices makes urban agriculture uncommon in the city. In the past 30 years most of the urban agriculture area was destroyed along with a healthy urban economical and ecological system. Productive land, in the southern and eastern parts of Greater Beirut, still continues to be replaced with construction. In Choueifat, along the southern suburbs of Beirut, there is an example of integration of food production and processing into residential area – a common practice that is disappearing.

Our question is would it be possible to establish in Beirut a *Productive Urban Landscape* working on the remnant agricultural plots and on unused open spaces to create a productive green infrastructure that includes green spaces, rural areas, open air food markets, educational areas, wetland areas, water harvesting and recycling. It is undeniable that urban agriculture practice has increased dramatically in the world over the past 10 years. City farms, community gardens, schools farms, and allotment projects in Europe and the Detroit urban Agriculture Network, the New York's community garden movement, the vertical city farms, and the rooftop gardens in America, are multiple examples of a wide range of urban agricultural practices that demonstrate the social and cultural benefits and enhancement of the quality of life.

Lebanon presents a totally different situation compared to other parts of the world, where Continuous Productive Urban Landscape (CPLU) is already successfully implemented. The State has, until now, shown little interest in implementing sustainable projects with high impact on the future of the city. The future is so unpredictable in this country that the only logic implemented is today's easy profit. Arab economies continue to unsustainably deplete renewable natural resources, motivated by short-term profits, causing environmental impoverishment of scarce land and water resources while discounting the value of these resources to future generations. The average annual cost of environmental degradation in Arab countries has been estimated at $95 billion, equivalent to 5 % of their combined GDP in 2010.

Nevertheless, things may change. In Iraq the city of Erbil recently completed a plan for the green belt surrounding the city that retains a large proportion of farmland in order to foster local food systems and feed the city (Zurayk 2010). In Beirut, *Studio Invisible* years ago proposed rooftop gardens, with plants in plots for drainage and climate control, applied at the city scale as an improvement to the quality of life by increased oxygen levels and air pollution remediation. The project encountered a high rate of civic support but faced difficulties of financial and municipality support.

29.1.2 Gentrification Versus Territorialisation: The Lebanon Case

After the Lebanese civil war, 1975–1990, the reconstruction priorities were defined according to the neo-liberal concerns of the ruling merchant elite (Harb 2007). This elite was more eager to monopolise administrative positions, a source for profits, rather than to reflect on the living environment of the people it was supposed to govern. On the other hand, Beirut's urban development and expansion can be interpreted as a series of decomposition and territorialisation according to community's spatial dynamics (Davie 1996).

Poor zoning and construction regulations have rendered almost all territories open to construction (coastal, agricultural, natural, historic city centres), knowing that the land is serviced by an access road. A liberal market has invited investors and real estate promoters to build in all corners of the country with lasting impacts on the urban and rural landscape, and with severe implications on energy consumption SOER 2010).

Overtime, the lack of planning and landscape intervention has created an urban landscape in which disintegration, juxtaposition and marginality are among the elements capable of expressing its inherent qualities. Areas in search of identity alternate spaces with prevailing residential and community identity, and abandoned spaces coexist with new residential zones; spaces of old and new infrastructures circumscribe and sometimes contain the remains of ancient agricultural practice. New and traditional land uses coexist, thus creating a complex urban dynamic, difficult to confine in design categories. Projects continue to tackle this intriguing reality; projects that still consider the city as an asset to be exploited, an expression of the economic interests of privileged few. This urbanisation process calls for land-use planning that promotes the positive potentials and shapes the sustainable development of cities over the long term. This is an unprecedented task in its dimension, which assigns to the landscape architecture a unique role in urban development, as it is capable of bringing together diverse needs and creating an integrated plan for the future (Mertens 2010). A plan that not only divides the city into different areas with different rules i.e. zoning, but also focuses on more emergent needs that cities all over the world are facing, such as climate change, poverty and food production, pollution, water scarcity, social inequality.

The Schéma Directeur de la Region Métropolitaine de Beyrouth (SDRMB), which aimed to plan the evolution of metropolitan Beirut after the civil war, was completed in 1986, but was not officially approved. Later, in the early 1990s, it was heavily debated during the beginning of the reconstruction process. The SDRMB was a brilliant intellectual exercise, but the political leaders did not pay attention to it, even when they knew it existed (Verdeil 2003).

Consequently, this area has grown into an overwhelming urbanisation, in addition to the fact that future policies which predict, control, and monitor this urban development are absent. The dominant elite, that reached positions of power and authority during and just after the civil war, continues to control the development process holding or investing, as silent associates in real estate. The main form of investment by this elite is “property speculation [which] raised the price of land and imposed the construction of luxury apartment buildings” (Traboulsi 2007: 160). The concern of most politicians is directed mostly towards their personal interests. This political intervention in the realm of public institutions takes three different forms (Hicham el-Achkar 2011) by:

– Politicising the administration.
– Issuing exceptions to regulations.
– Obstructing the work of some institutions.

The result is the implementation of a gentrification process that in Beirut, as well as in some other cities in developing countries, presents variants from the common norms of gentrification seen in Europe and North America (Hicham el-Achkar 2012).

Gentrification is creating a new wave of delocalisation or displacement, similar to the one that occurred during and after the civil war, making again a *tabula rasa* of local cultural identity and causing the de-territorialisation, which in anthropology refers to a weakening of ties between culture and place. In a simplistic way it can be said that gentrification and globalisation are two faces of the same process that is shaping the cityscape, in a State such as Lebanon where the debate between identities and cultures is nearly continuous and where construction is practically always given priority.

29.1.3 Peri-Urban Agriculture Area in Beirut

The peri-urban landscape is part and parcel of the relationship between the city and the countryside. This was once evident, when the city or town was compact and was easily recognisable as the countryside was heavily cultivated, thanks to the substantial land reclamation and construction work undertaken over the centuries to increase productivity.

Beirut peri-urban landscape is characterised by residual parcels of green land bordered by infrastructure, residential, commercial and industrial settlements unrelated to farming. In such a setting, the city has the greatest environmental impact because of its proximity and because of the lack of an identity. Informally sanctioned by the State, the rapid peri-urbanisation that is unfolding along the edges of Beirut, often in violation of master plans and state norms, (Roy 2003), is part of the expansion of the gentrification process started in Lebanon in the 1960s. This process is closely related to the neoliberal economy adopted by the Lebanese state and to the history and dynamics of Lebanon's sectarian communities.

Nowadays the informalised way of peri-urban construction has led to a new form of territorialised flexibility that enables the self-effacing existence of different type of voids: No-Man's-Land, agricultural plots, parking, informal open market, wild spaces. The differential value attached to what is "formal" and what is "informal" creates the patchwork of valorised and de-valorised spaces that is in turn the frontier of a primitive accumulation and gentrification. Is the real state of built process formally or informally asserted, seeing that it is mostly in deregulations of norms based on corruption and favouritism? How can we define formal and informal in a city where plans are nearly always implemented for the benefit of the rich class and mostly all the land is privately owned? Construction pressure, social and cultural changes, and market globalisation has significantly reduced the city's agricultural area and left it in a state of neglect without development policies or protection. The absence of a national policy to protect agricultural lands from unwanted development and encourage farmers to modernise their production systems is leading to the rampant encroachment of buildings on fertile lands (SOER 2010).

The disappearance of most urban agriculture in the last 30 years brought an end to healthy urban economic and ecological systems. Today, governmental institutions ignore the city's potential to embed agriculture, even organic farming, into its urban framework as was done throughout the 1950s, (Rishani 2011). Previously Beirut's urban agriculture (Fig. 29.1) included (Rishani 2011):

Fig. 29.1 Ancient pictures of the agricultural character of Beirut

1. use of typical urban resources, such as organic waste as compost;
2. use of urban wastewater for irrigation as early as the 1960s;
3. direct links with consumers or vibrant healthy food markets; and
4. urban food systems which decreased urban poverty and increased urban food security.

29.1.4 Political and Cultural Constraints

The discourse of landscape has so far been absent from public discussion, since the concept of landscape is new to the Arabic culture. Thus, planning policies that recognise and protect the cultural landscape are also absent. Landscape architecture is a new profession in the Arab world with its perception generally limited to beautification of contemporary urban settings (Makhzoumi 2011).

Current management of the land attests to the lack of governmental initiatives leading to geographies of injustice and privilege. The city must be reconsidered in terms of quality and wellbeing. Awareness must be raised to the composition and organisation of the city, the quality of public spaces and the urban cultural landscapes. Architecture and urban development play an important role in determining the conditions of life of the urban population. The design project could be considered as a cultural program that not only aims to contest a compartmentalised and elitist attitude towards planning development but to also take civic responsibilities toward public right and domain. There is a need for innovative cultural and economic projects that can succeed in attracting a young workforce and that can present sustainable development alternatives. Some already existing initiatives in Lebanon prove that there is a rise in the health services and claim for better quality of life. 'Bioland', a leading organic food provider in Lebanon, with farmlands located in Batroun, Jbeil and Lassa, demonstrates that there are increasing requests from consumers to ensure the health of their family and there are open windows to change and success.

For too long, quality has been overlooked in favor of the construction of spaces instead of places. The result is a mosaic in which edges are permeable and the boundaries between cities and countryside are in flux. Perhaps, today, it may make sense to talk about a landscape project based on knowledge and rediscovery of values to build sustainable processes of re-signification of territories and giving back dignity and identity to the city. This process must begin by identifying what is valued, rather than what is not and set a generative and dynamic self-adjusting feedback mechanism into motion. Such a mechanism will consider communities as protagonists of the transformation processes and active stakeholders in this planning strategy.

The peculiarities of the landscape are crucial when identifying intervention strategies and guidelines for the surrounding areas that promote awareness and knowledge, protection, management, innovation, and experimentation strategies. What is needed are planning strategies capable of managing transformations, emphasizing the identity and socio-economic values of peri-urban areas and the relationships between urban and rural areas which provide the quality of our landscape. Quality is a territorial capital that is impossible to relocate, but it can be easily trivialised and stripped of its cultural and natural values. Despite the fact that urban agriculture will never be self-sufficient to sustain the food requirements of a city, and its ecological footprint, it allows social interaction within the local environment helping to educate new generations, introducing new sustainable habits (Canbay Türkyılmaz et al. 2013).

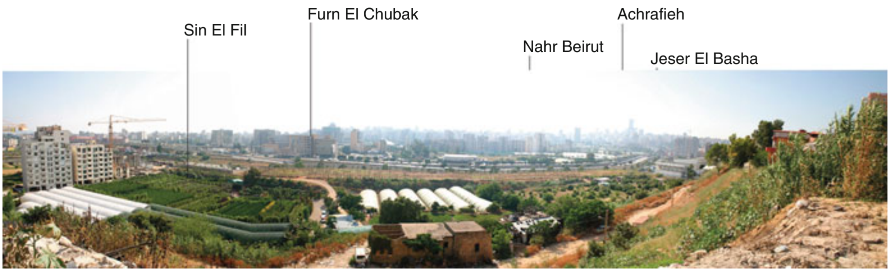

Fig. 29.2 View of the urban agriculture plots along Nahr Beirut River

29.1.5 Urban Agriculture in Beirut: A Research Project

Urban Agriculture is always part of something-some development activity. As a space user, it may be part of more strategic concepts, such as CPLU, City or Agrarian Urbanism, or other development concepts adopted by a municipality. As a food growing activity of individuals or groups, it is part of a network of processes aiming to sustain urban life – either directly by the produce grown or by the commercial exchanges it generates (Bohn and Viljoen 2014).

In 1993/1994, the Italian architect Andrea Branzi conceived *Agronica* as an experimental territory where the differing programs – food production, livestock grazing, and leisure – were all moveable and shifting according to demand. As Susan Carruth (2013) argues 'While Branzi's work is theoretical and highly conceptual, it is critical to the progression of Landscape Urbanism discourse – it suggests radical strategies and tactics for planning a relationship between landscape and infrastructure beyond normative modes and habits. It assumes the intertwinement of nature and culture, and engages directly with, and learns from, the specifics of a specific landscape, moving past pure metaphor or representation, and by doing so suggests a strategic foundation for planning and adapting energy landscapes.'

This research project aims to investigate the design implication of such a practice trying to define a coherent strategy applicable in the Beirut peri-urban area. Beirut's few remaining urban agriculture plots – the NahrBeirut area, Haddat, Hay al Selloum, and Chouifat – are located along the southern and south eastern boundaries of the city. In this part of greater Beirut, open spaces still exist with historical connotations linked to the traditional agricultural activities in the face of advancing settlements that lead to the greatest exploitation of land (Fig. 29.2). This rural-urban landscape represents an important area of transition between the city and the river's ecosystems, and between the river and the future expansion of greater Beirut. It forms an external "greenbelt", a crown that in reality has different gradients of deterioration and fragmentation in relation to the different areas (Fig. 29.3).

Those spaces on the border of the city, no longer countryside, but not yet city, form a landscape which is still defining itself and is characterised by uncertainty, instability, and informality. Uncertain and unstable space potentially ripe for future transformation processes in the form of new building work, such as houses, shop-

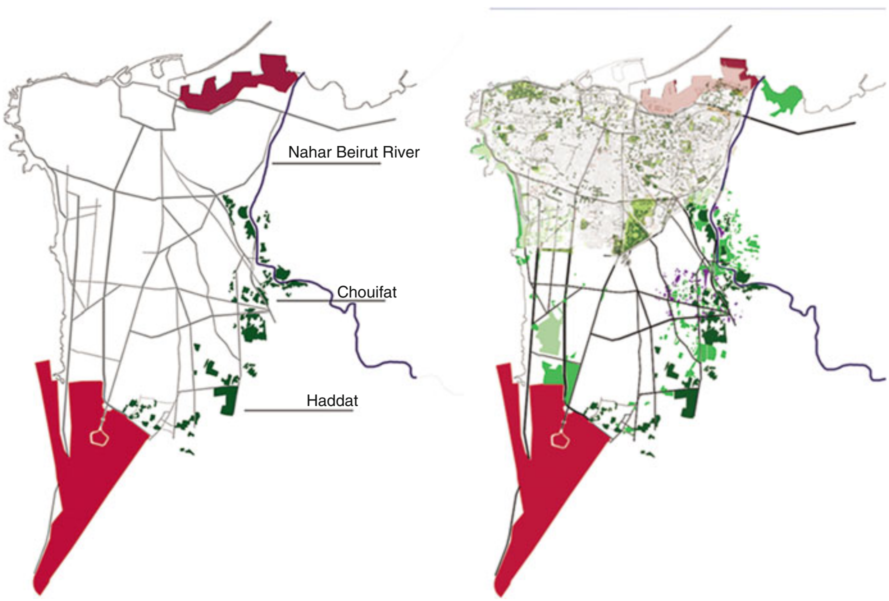

Fig. 29.3 Map of the agriculture plots and the green areas

ping centres with annexed parking lots, industrial or artisan warehouses as well as new roads and motorway junctions and/or other high-impact infrastructure (Pays Med Urban 2011).

This informality produces an uneven geography of spatial value thereby facilitating the urban logic of creative destruction. The self-organized urbanism creates spaces that are the result of misuse, a waste of natural resources; refused landscapes that are reserves of land consumed and abandoned but yet "re-naturalise" with pioneer species and as such a significant reserve for biodiversity.

Despite being subjected to high anthropogenic pressure, those areas have essential functions of environmental compensation and protection which are vital to regaining an eco- systemic equilibrium as a potential for education, recreation and cultural and historical identity.

While waiting to be absorbed by urban development and then developed into more economically valuable forms of land use, they moreover have now acquired an important strategic value for their position in the middle of the in-between places on hold, suspended between urban, suburban and rural. They act as a mitigation buffer by smoothing the transition from the canalised stretch of the Beirut River to the more natural stretch, while preserving the area's environmental integrity. Those areas are the starting point on the creation of a green corridor from the peri-urban towards the inner city, building again an interpenetration of nature and urban. This was already done in Casablanca, Morocco (Casablanca project Urban Agriculture as an Integrative Factor of Climate-Optimised Urban Development) with the German-Moroccan research project of the German Federal Ministry of Education and Research (BMBF) within the megacity research program "Research for the Sustainable Development of Megacities of Tomorrow, Focus: Energy- and climate-efficient structures in urban growth centres"; indeed, a multifunctional green infrastructure will be created integrating existing agricultural use into urban development. It will address the question of how a new green infrastructure can be integrated into an existing and at the same time dynamically expanding city. As Giseke (2011) argues, urban agriculture [will be used] as an integrative factor of urban development, as an example of thinking about a broader approach to open space systems in the sense of multifunctional urban landscapes that react to the specific challenges of the megacities of tomorrow. Moreover, these spaces will represent a starting point in generating public goods through agricultural land management.

The informality created a fully capitalised domain of property and a highly effective "spatial fix" in the production of value and profits. These spaces represent a starting point in generating public goods through agricultural land management. Moreover, they act as a mitigation buffer by smoothing the transition from the canalised stretch of the Beirut River to the more natural stretch, while preserving the area's environmental integrity.

29.2 Strategy of Design Intervention: The Nahr Beirut River Project

The strategy adopted for the Nahr Beirut Rive project aimed to formulate a process that starting from the peri-urban is integrated into the urban structure connecting the existing open spaces, in a game of interaction between small and larger scale, and setting the conditions for the implementation of green infrastructure (Figs. 29.4 and 29.5).

Only 3 % of Beirut's surface area is allocated for parks, a percentage that is far below the World Health Organization's recommendations. This 3 % includes playgrounds and urban forests and represents 0.8 m^2 per resident. In order to reduce marginalised pockets and social disparity and in order to pave the way for new immigrants to integrate more easily, we used the park as a flexible relational device between natural and artificial materials, processes, parts of the city and parts of the campaign.

We divided the peri-urban area into three sections: the Narh Beirut river banks, the residential neighborhood of Haddat and the industrial/airport area of Hay al Selloum and we chose the river land as an area of intervention. The river has become an appetising object of attraction for future development, gentrification, and delocalisation of exiting activities and inhabitants and, we felt, necessary to our contribution in terms of research project. In 1968 the Nahr Beirut River was converted from a perennial river to a concrete canal and eventually mutated into an open sewer. The highway built on its right bank completed this conversion into an infrastructural conduit of sewage and transport (Frem 2009).

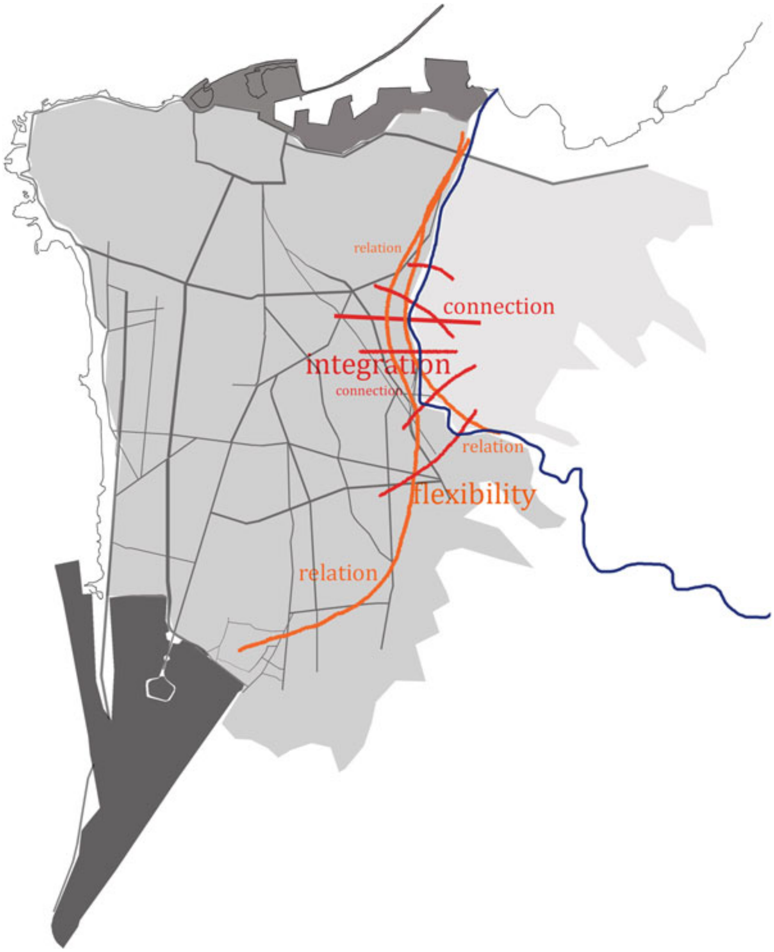

Fig. 29.4 The landscape program

The design intervention not only aimed to weave together exiting infrastructure, agricultural land, neglected areas, sport areas, post-industrial space (old train station and rail tracks), but also to transform the overlooked river banks into a new green/ecological corridor.

The proposal intends to re-give cultural and ecological value at the water/natural element and to anticipate the urban development pressure increasing the percentage of open/public space in Beirut. It is based on:

– Identifying the constituent elements and relations that structure these places;
– Identifying values (economic, ecological; heritage, visual and perceptive);
– Identifying areas of potential; and
– Examining the key dynamics under way with a view to future scenarios.

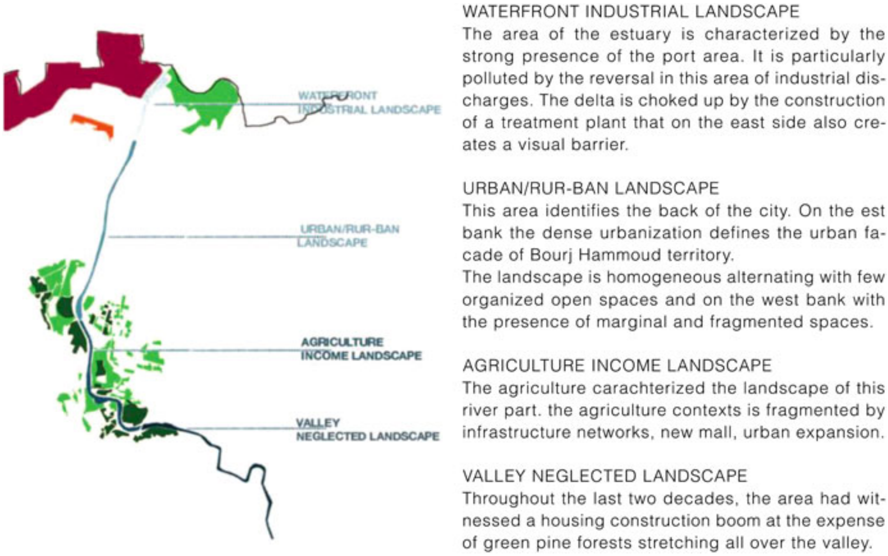

Fig. 29.5 The landscape strategy

29.2.1 Methodology/Process

The study was conducted trying to apply a methodology based on three types of approach:

- The holistic approach in order to embed and encompass the different components of the study area;
- The dynamic approach considering the different spatial and temporal scale and
- The meta design approach.

After an analysis was conducted for all the Nahr Beirut area, we divided it into four stretches (Fig. 29.6):

- The waterfront/industrial
- The urban/rurban
- The agricultural
- The valley

Students defined a topic for each stretch and organized into groups they worked on the design proposal.

At the larger scale, the park was intended as a system to create a healthy and productive environment for the community and the city, to remediate the contaminated sites, to restore the river and generate public spaces. No longer just part of nature, the Park is a driving factor and device through which we choose to re-decline the image of the city and to reinvent and reconnect fragmented sets of urban areas. The park was organized as a system of structures and to direct urban development,

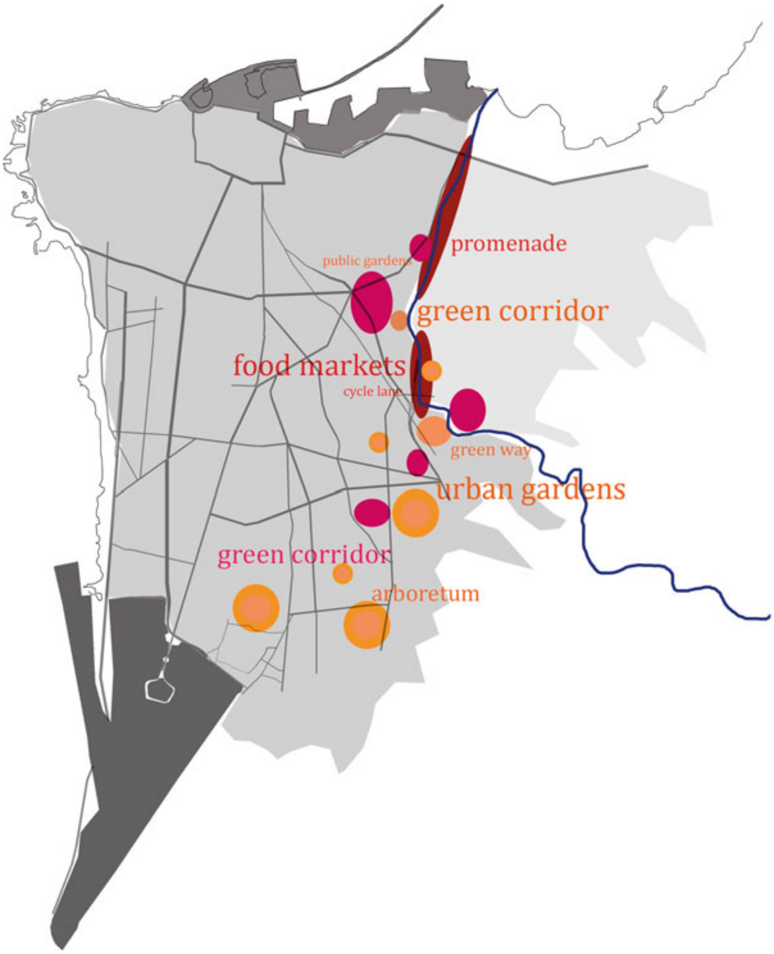

Fig. 29.6 The landscape stretches along the river

from time to time starting from the mouth to reach the valley, a wetland garden, promenade, urban garden, open air food market, bicycle path, forest, sport garden, agricultural garden, parking, orchard, educational garden, botanical garden (Figs. 29.7, 29.8, 29.9, 29.10, and 29.11).

The Park was structured as an infra-park, born and grown in the interstices of spaces, between built and non-built, a connector and zipper of entire portions of the urbanised area. We opted for the creation of a new form of urban agricultural park, considered as a pilot park that combines the conservation and protection of the territory while promoting the economic role of agriculture. It will be a green infrastructure network, which will reorganize all of the green, peri-urban, agricultural, fallow, and structured green areas, through the activation process of recovery, requalification and regeneration. This would allow a greater availability of peri-

Fig. 29.7 The agricultural area (student proposition)

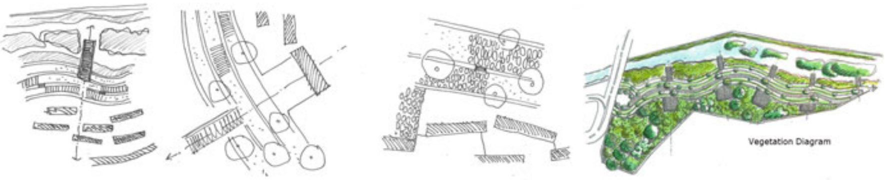

Fig. 29.8 The wetland area (student proposition)

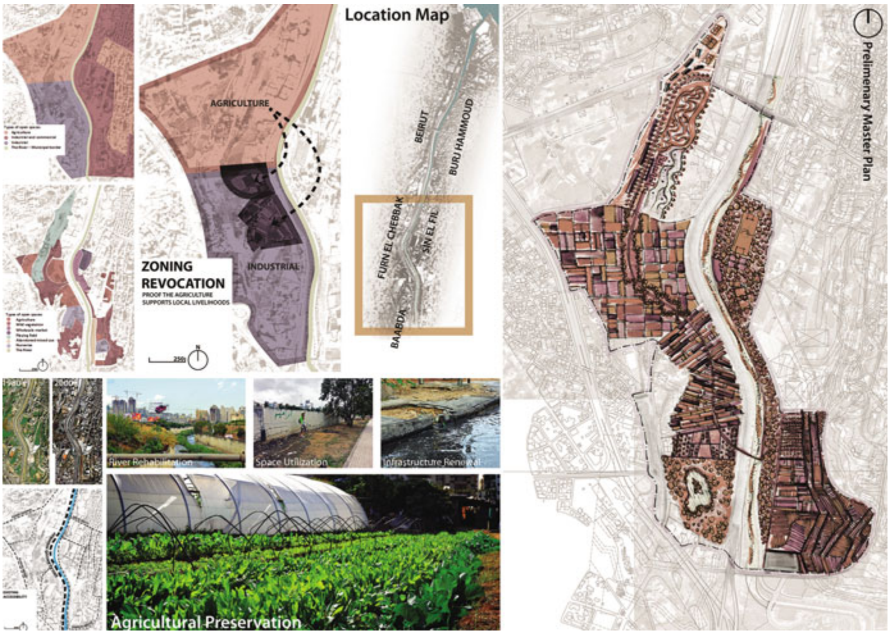

Fig. 29.9 The agricultural park (students proposal)

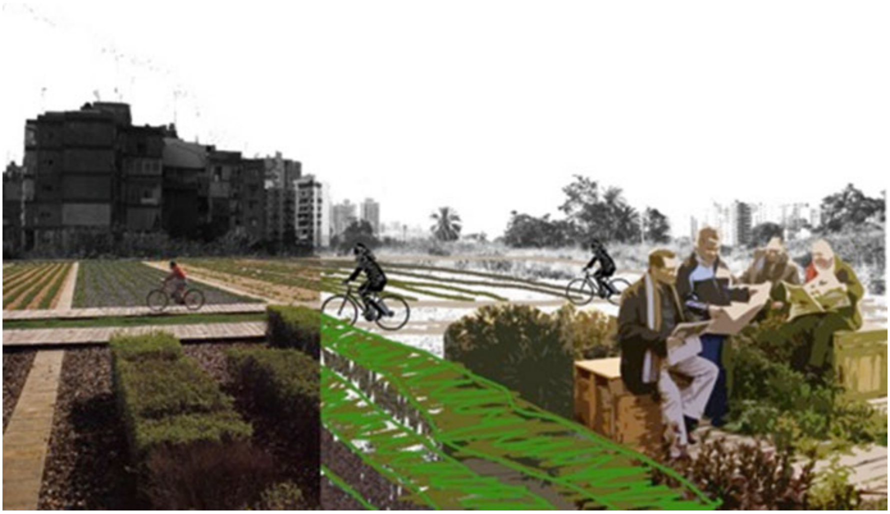

Fig. 29.10 Public goods through agricultural land management

urban open spaces to be achieved, including them as part of a network and hinge system between urban, suburban and rural areas. The goals of this approach are to preserve the integrity and identity of the natural and cultural landscape, to maintain a sustainable, functioning ecosystem, to protect cultural treasures and to provide recreational opportunities.

Furthermore, these combined attributes meet the ever more pressing demands of urban community's for open, usable spaces filled with cultural value.

For this park to become a reality, it is necessary, on the one hand, to change the agricultural policy of the area, and on the other hand to show the economic value of the landscape in terms of future ecological and environmental benefits and of quality of life. Only recently has it been recognised at the international level that peri-urban open spaces are important to citizens who are increasingly searching for "landscapes", for open spaces and places where agriculture plays a renewed role in the local production of goods and food. Such spaces are also educational and multifunctional and represent a balanced relationship between development and sustainability. In the 'Charter on Peri-urban Agriculture' written in 2010 after the Agroterritorial Seminar held in Barcelona by the Consorci del ParcAgrari del BaixLlobregat, the Fundacio Agroterritori and the Red Agroterritorial, it is stated that the concept of agricultural parks or other similar forms of planning and design intervention are significant not only for protection against eventual incorporation into urban development process but as a means to preserve their inherent agricultural functions and foster a type of management that promotes within them the economic development of their land and farms, as well as preserving and disseminating cultural and ecological value. The Lebanese urban planning system does not adequately address sustainability, livability, environmental, spatial, and equity issues. Instead, urban plans focus exclusively on physical planning and lack strategic

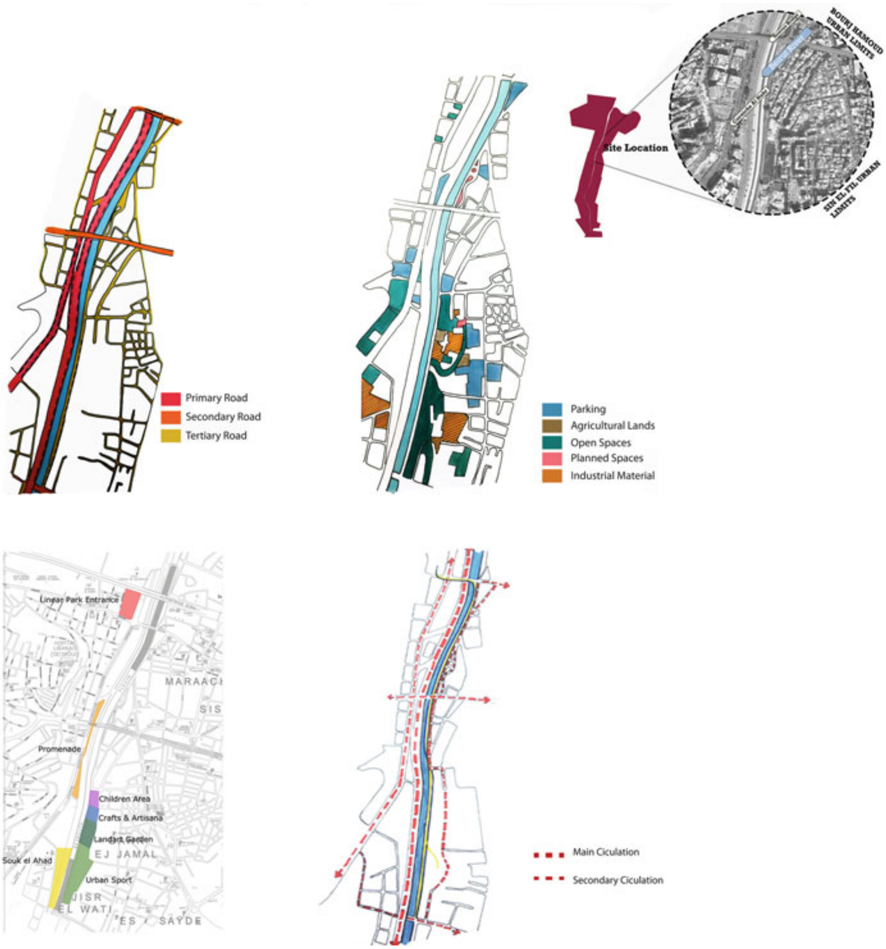

Fig. 29.11 The urban stretch (students proposal)

perspective (United Nations Development Program UNDP 2010). At the same time there is a need for a public and open space that is accessible and usable by different ethnic and religious groups, neutral space to gather, to stay together and to share ideas and identity.

29.3 Conclusion

The significance of this research is to try to demonstrate that landscape knowledge, more inclusive than the urban one, could be an alternative to managing the urban area, because it is flexible, relational, and participatory. We attempted to show that landscape knowledge could represent an alternative to reorganize those territories by creating mediation between the needs of identity and naturalness of places and the needs of the people and those of production and economic activities without neglecting the aesthetic aspects that are the subject of perception and appreciation of local communities. The Nahr Beirut River became a green corridor, structured with green, path, and activities, the connective tissue able to re-establish the lost connections, and create new relations between the existing interstitial opens spaces of the city. This park, conceived as a flexible development process that incorporates multiplicity and mutability, aims to plan the expansion of this peri-urban area by bringing together the physical, economic, cultural, aesthetic, and social components in order to build sustainable processes of re-designation of territories and the restoration of identity and dignity to the landscape. Sewing the relationship between the city and its frayed edges, it will become a hybrid capable of blurring the boundaries between squares, green roads, boulevards, and gardens. It will be a relational device between things, processes, people, and parts of the city. The strategy described here could have significant positive impacts for the local residents and for the metropolitan region improving the quality of life without necessarily consuming new land, constructing new buildings and opening new roads. We will slow down the gentrification and residential densification process creating an access to open and natural spaces. We will structure a system of park and green urban networks so as to integrate food gardens as an ecological lung and source for local food production, self-organised activities and ecological education. This will increase the percentage of city's green areas and respond to the increasing needs of the citizens.

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References

Achkar H (2011) The role of the State in initiating gentrification: the case of the neighborhood of Acrhrafiehin Beirut, Master's thesis. Lebanese University of Beirut Verdeil E, Faour G, Velut S, 2007. Atlas du Liban. Presses de l'Ifpo, CNRS Liban

Achkar H (2012) The Lebanese State as initiator of gentrification in Acrhrafieh. Les Carnet de l'Ifpo. La recherché en train de se faire a' l'Institut Francais du Proche-Orient, Hypotheses. org, 5 juillet 2012
Alami (2011) État des Lieux: Un secteur à double vitesse. In: L'Hebdo Magazine, n° 2794, pp 34–36, 27 May 2011
Bohn K, Viljoen A (2014) Second nature urban agriculture. Designing productive cities, vol 10. Routledge, New York
Canbay Türkyılmaz Ç, MoyaPellitero AM, Türkyılmaz E, Silva Eliziario JD (2013) Urban rehabilitation: reinventing a productive landscape, vol 7/2. Golden Horn Case Study. Archnet-IJAR, Istanbul, pp 282–296
Carruth S (2013) Anthropocenic landscapes: 'Topomimicry' as an approach to energy planning in Greenland, The Northern Research Forum
Cortigiani R, Natali A (2009) Agriregionieuropa19/5. www.agriregionieuropa.it/. Accessed 25 June 2014
Davie MF (1996) Beyrouth-Est Beyrout - Ovest: aux origins du clivage confessionnel de la ville. Les Cahiers d'URBAMA 7:17–50
Giseke U (2011) Urban agriculture Casablanca. Design as an integrative factor of research. Technische Universität Berlin [TUB], Berlin
Harb M (2007) Deconstructing Hizballah and its suburb. In: Middle East Report, No. 242, The Shi'a in the Arab World, pp 12–17
Frem S (2009) Nahr Beirut: projections on an infrastructural landscape. Thesis (S.M.)--Massachusetts Institute of Technology, Dept. of Architecture
Makhzoumi J (2011) Colonizing mountain, paving sea: neoliberal politics and the right to landscape in Lebanon. In: Egoz S, Makhzoumi J, Gloria G (eds) The right to landscape. Contesting landscape and human right. Ashgate, England
Meeus S, Gulinck H (2008) Semi-urban areas in landscape research: a review. Living Rev Landsc Res. www.livingreviews.org/lrlr-2008-3
Mertens E (2010) Visualizing landscape architecture. Functions I concepts I strategies. Birkhauser, Basel/Boston/Berlin
Pays Med Urban (2005), Paesaggi Periurbani, 'Linee guida paesaggistiche per il governo del territorio/Periurban Landscapes. Landscape planning guidelines'. www.paysmed.net/paysurban/pdf/LINEE%20GUIDA%20ITALIANO.pdf. Accessed 25 June 2014
Rishani Richani S (2011) Urban agriculture in Beirut, Beirut the fantastic. www.spatiallyjustenvironmentsbeirut.blogspot.com/2011/06. Accessed 25 June 2014
Roy A (2003) City requiem, Calcutta: gender and the politics of poverty. University of Minnesota Press, Minneapolis
Salem R (2010) Towering profits. Exec Mag 137:82–92
Smith N (1996) The new urban frontier: gentrification and the revanchist city. Routledge, New York
UNDP, State of the Environment report in Lebanon 2010. MOE/UNDP/ECODIT report. Accessed 25 June 2014
Traboulsi F (2007) A history of modern Lebanon. Pluto Press, Ann Arbor
Verdeil E (2003) Methodological and political issues in the Lebanese planning experiences. In City Debates 2003 Proceedings. American University of Beirut. pp 16–22. www.test.moe.gov.lb/Documents/Cover%20and%20Front%20Matter.pdf
Zurayk R (2010) From incidental to essential: urban agriculture in the Middle East. J Agric Food Syst Commun Dev 1(2):13–16

Chapter 30
Reimagining the "Peri-Urban" in the Mega-Urban Regions of Southeast Asia

T.G. Mc Gee and I. Shaharudin

> *The very notion of urban ecology has become multi-scalar, extending from individual urban systems to systems of cities and towns, and from ecosystems within urban settlements to urban settlements as ecosystems, to the way in which cities and towns shape ecosystems beyond as well as within urban boundaries*
>
> (Haughton and McGranahan 2006).

Abstract Defining urban spatial expansion, this chapter examines the role of mega urban regions (MURs) in Southeast Asia. These MURs can be regarded as economic integration regions. Globalization is integrating the MURs into global economy. Globalism is embraced at the national level but functions at the local level. Hence, urbanisation is made up of the interaction between national scale, provincial scale, urban scale and individual scale of individuals and households. Urbanisation in the MURs is driven by a complex array of social, economic and political processes.

Keywords Mega-urban areas • Globalism • Global economy • Economic integration • Southeast Asia

30.1 Introduction

This chapter explores the major challenges posed by the spatial expansion of urban areas in Southeast Asia. For the purposes of this presentation we define "urban spatial expansion" as having two general features. First, it refers to the territorial expansion of urban activities outside the cores of urban areas. Secondly urban expansion

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also includes all the changes that occur in the urban system defined on the basis of population both within urban areas and in the national urban system. An example of changes in the urban system is the ongoing increase in the population and spatial expansion of the secondary cities in the urban hierarchy. This chapter analyses changes in the one component of the urban system in Southeast Asia within the selected Mega Urban Regions (MUR's) of Manila, Jakarta, Bangkok and Kuala Lumpur. For the purposes of this chapter MURs are defined as urban agglomerations of more than five million in size that function as an integrated economic region.

In the contemporary era the interpretation of urban expansion is influenced by the following arguments. Firstly, is the argument that globalisation processes are bringing about the increasing integration of these MURs into the global economy. This is leading to an increasing convergence in governmental policy responses among nations. On the face of it this argument seems strong as governments react to the integration imperatives of the global economy with policies that are designed to create more efficient and productive MURs. This enables them to position these MURs so as to capture income from investment industrial production, improvements in the built environment and higher-order services. For this they need increasingly efficient MURs that can compete with other MURs in the Southeast Asian region. Many of these policies focus on 'investment' in improving the transactional flows of MURs such as transportation systems, digital networks, providing services such as sanitation, energy and the amenity spaces orientated to globally influenced activities.

A second argument emphasises that at the same time of this convergence of urban policy responses local populations located in urban local spaces are adapting, accommodating and resisting to the environmental, economic and social consequences of these globally influenced processes. It is central to the argument of this chapter that this reshaping of urban space driven by globalisation processes should be positioned in a more interactive and local paradigm that emphasises the contextual setting on which these global processes impact. This is because the contemporary processes have different dimensions from the early phases of urbanisation in the developed countries and because the reshaping of urban space is occurring at a much faster rate than in earlier periods of the urban transition in developed countries. In support of this position Marcotullio and Lee have argued with respect to this urban transition that the "…unique feature of the present era is the compression of the time frame in which the transitions are occurring" (Marcotullio and Lee 2003: 331) For example Indonesia achieved a level of urbanisation of almost 50 % in 2010 from 25 % in 1950 in almost half the time that it took England and Wales starting from a similar low level of urbanisation. Marcotullio and Lee further argue that transitions are now overlapping "in a telescoping of the transition process in a much shorter time-frame than earlier." (Ibid. 331).

A third argument is that these telescoping transitions are being driven by accelerated transactional flows of people, commodities, capital and information between, and within, countries. The international components of this transactional revolution are generally referred to as part of a new era of globalisation in which foreign investment, encouraged by national states, is an important component. Fourthly it is argued that this transition is best seen in a dynamic sense as a process of transformation of national and urban space in which interaction, networks and linkages reflect a new urban reality and permeates both rural and urban areas. This is leading to a rapid change in the conventional polarising between rural and urban space. In contemporary Southeast Asia a network of international, national, regional and local linkages provide a dynamic spatial framework in which flows of people, commodities, information and capital drives both the rural-urban transformation and changes within the urban system.

The acceptance of the reality of "transcending networks" means that the restructuring rural and urban space is occurring simultaneously particularly in the intense transaction networks focused on mega-urban regions and corridors that link the urban system (Martin 2000).

So "globalism" is embraced at the national level but acted on at the local level, In this way the urbanisation process is made up of the interaction between national scale, provincial scale, urban scale and at the individual scale of individuals and households of which they are a part (Kelly 2000). This idea is captured well by Forbes. "Macro-representations of globalisation subsume the internal dynamics of urban development, the subtleties of local politics, the resilience of urban patterns of life, the tensions embedded in fractured social structures, the multiple strands of modernity and the resistance to the imposition to change" (Forbes 1997: 462).

It is therefore important to stress that the urbanisation process as it works its way out in the mega-urban region is driven by a complex array of social, economic and political processes. Rather than simply reflecting the imprint of global capital what we see are processes of both "articulation" with global flows in certain urban spaces and "disarticulation" in others. Thus "global spaces" are intertwined with "local spaces". For example as the mega-urban regions of Southeast Asia urban space has been reconfigured into articulated networks of interaction between middle and upper class dwellers while excluding "much of the intervening or peripheral spaces from accessing networks, because the networks pass through the spaces without allowing local access" (Graham 1997: 112).

Finally it is important to emphasise the importance of the Asia region in the processes of global urban change in the twenty-first century.

For a chapter that is focused on urbanisation in Southeast Asia it is important to recognise that a major part of this global urban increase will occur in Asia. Thus between 2000 and 2030 58 % (1.3 billion) of all global urban population increase will occur in this region most of it in the population giants of China, India, Pakistan, Indonesia and Bangladesh. It might be argued that since Southeast Asia will account for only for 16 % of the Asian urban increase in this period that it is less important at a global level but this does not detract from its importance in the regional and national contexts (UNO 2002, 2008)'.

The chapter is organised into three parts. Part One; The Spatiality of Southeast Asian MURs, Repositioning the Peri-Urban Region. Part Two; The Spatial Analysis of Southeast Asian MURs 1990–2010. Part Three; Policy Challenges of the Urban Expansion of Southeast Asian Cities.

30.2 Part One: The Spatiality of MURs in Southeast Asia, Repositioning the Peri-Urban Region

The understanding of these processes of urban growth described in the introduction has implications for the definitions that are adopted for mega-urban regions and their analysis. This also affects the definition and delineation of the zonal analysis of the growth of population approach most frequently used to analyse population change in mega-urban regions. This conventional analysis using the concept of three zones stretching from the core of the mega-urban region, to an inner ring of increasing urban activity and a outer zone region of mixed urban and rural activity under-estimates the intra-zonal changes that occur within zones particularly as they are affected by the transactional system of mega-urban region (Fig. 30.1).

There are many debates concerning how the term "peri-urban" fits into these zonal models of MUR space (Adel 1999) including an interpretation that focuses on the "peri-urban interface" (Atkinson 1999). In this chapter we have used a broader definition to the zones within the MUR that lie outside the MUR city core. Defining peri-urban in this way thus encompasses what are often described as the peri-urban fringes of the MUR and the inner zone of urban activity that abuts the core of the

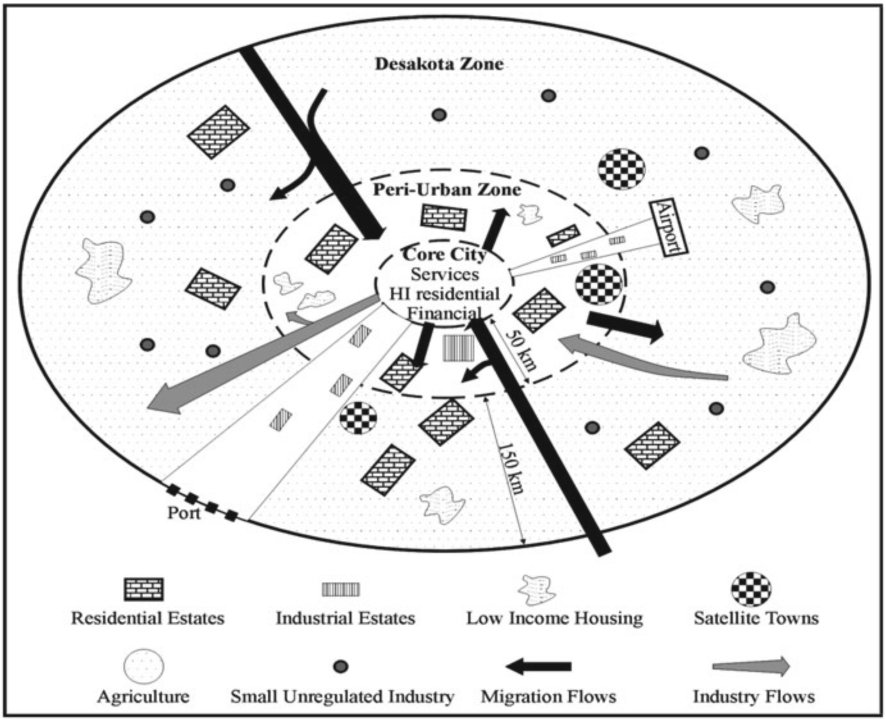

Fig. 30.1 Zonal Model of Southeast Asian Mega-Urban Region C2000

city (Hudallah et al. 2013). The outer zone approximates to an earlier definition of the "desakota" region in Asian mega-urban regions in which urban activity is expanding into rural areas often referred to as the "rural-urban fringe" or "rural-urban interface".

Three points need to be made with respect to this definition. First the idea of "peri-urban" is conceptual. Thus more precise definitions of the peri-urban will have to be worked out in the case of each MUR particularly as the inner zone expands. Secondly implicit in this definition is the idea of the peri-urban as part of the functional space of the MUR. The peri-urban zone plays an important role in the transactional flows of the urban eco-system as well as the information, communication and demographic and economic flows within MURs.

This suggests research on the peri-urban zones of Southeast Asia's mega-urban regions needs constant updating of information that can be fed into policy formation process. For, as we have argued this is an area where the environmental, jurisdictional, social and economic challenges are most marked. It can be further argued that this repositioning of urban policy is made even more urgent because of the vulnerability of many of these mega-urban regions to the effects of global change and fluctuations in the global, energy and food prices.

This emphasis on urban policy needs to be based upon an understanding of the key components of the urban transition in Southeast Asia over the last 50 years.

Firstly most MUR's have expanded outwards very rapidly beyond the limits of the city core but this is also a process that is occurring throughout the urban system at the level of secondary cities. Secondly, the pace of development and features of the peri-urban areas show considerable variation between MURs which reflect the different ecosystems land use practices and urban and national policies of at various scales of government and the level and pace of integration into the global system Thirdly, there are universal driving forces that are leading to the expansion of these peri-urban zones. Perhaps most important is that this expansion has been driven by transport systems that have encouraged the increasing use of auto-centered transport systems including private motor cars and motor bikes. Barter (1999) has shown that while most Southeast Asian countries still have lower vehicle/population ratios than the developed countries their ratios have been increasing rapidly. Most countries have embarked on what may be labelled auto-dependent trajectories which will lead to an increase in the number of motor vehicles over the next 20 years. This development will be further reinforced by the growth of national road systems and ongoing mega-urban based policies of freeway and railway development. What distinguishes these transportation modes from others such as walking is that they require a great deal of space. These transportation activities include "an extensive material infrastructure of roadways, service and repair facilities, storage spaces and an extensive social infrastructure of elaborate bureaucracies" (Freud and Martin 1999). The development strategy of the more rapidly industrialising countries of Southeast Asia is supporting the concept of automobility though the fostering of growth of national automobile industries often in joint ventures with foreign companies.

Another common feature of this expansion has involved these urban "hinterlands" acting as a resource frontier providing, inputs such as water, food, building materials, labour for the urban core and inner ring as well as land to be used for urban activities such as industry, commerce, residential and recreational activities. Atkinson points out that this "functional analysis of cities and their hinterlands focuses attention on resources which is significant as a serious issue in ecological sustainability" (Atkinson 1999).

This urban expansion is also characterised by extensive land conversion that in the Southeast Asian region ranges from state monopoly over the process (Myanmar) to unregulated private sector conversion. In between these two extremes are situations in which the operation of the private sector is regulated and dual land markets operate, as is the case in Vietnam. These land conversion practices lead to rapid changes in land-use from agriculture to non-agricultural activities. They may be described as most intense at the local level where the urban landscapes become increasingly fragmented into a mosaic of different land uses. Particularly in the context of urban expansion where there is an ongoing unregulated growth of urban activity occurring in the rural areas which can take the form of "invisible urbanisation" or "urbanisation by stealth".

This process of urban expansion has also involved an uneven allocation of both government and private capital to different zones in the MURs. The major part of government and private investment has been directed to investments in infrastructure and the built environment that is being constructed to facilitate the growth of industry, residential complexes, new towns, freeways, international airports and container ports. These constructions are designed to integrate the mega-urban region and make it more attractive to global capital. Much of this investment (public and private) is focused on the core cities and inner zones of the mega-urban regions thus causing contradictory processes of greater involvement of the city cores with global transactions and at the same time separating many parts of the urban fringe from this process.

Finally, in the Southeast Asia context this process of expansion varies greatly according to the ecological features, history and political economy of the local region into which the urban expansion is occurring. Broadly we would suggest in the Southeast Asia there are three types of mega-urban regions defined in terms of core hinterland interaction.

Those mega-urban regions in which urban expansion has been primarily into high density rice growing areas characterised by high rural densities such as Bangkok, Manila, Jakarta and Hanoi.

Those mega-urban regions that were expanding into areas where agriculture was more mixed including the production of non-food crops where population densities were much lower. Examples are Kuala Lumpur and Ho Chi- Minh (Mc Gee 1991).

Finally there is the example of the Sijori mega-urban region in which the expansion of the core area has occurred over international boundaries into parts of South Johor (Malaysia) and Batam and Bintang in the Riau Province of Indonesia that ecologically has some similarities to type 2, but has been involved international collaboration.

Thus the creation of peri-urban zones while it is directly associated with processes of urban expansion it is developing in diverse ways and presents a mix of policy challenges that vary from country to country. However the urban fringes still remain places of intense competition for resources and threats to ecosystems. Thus the peri-urban region becomes a significant element of the local-global nexus and the rejigging of regional urban space in which policy interventions are urgently needed (Webster et al. 2003).

30.3 Part Two: The Spatial Analysis of the Mega-Urban Regions of Southeast Asia 1990–2010

It would be incorrect to suggest that the emergence of large urban centres in Southeast Asia is a recent event. Historically Southeast Asia has a long urban history during which large urban settlements emerged from the pre-western period which had different ecological, functional and spatial features. They ranged from low density spread out urban areas such as Angkor in twelfth century Cambodia, to densely populated spatially concentrated cities such as Singapore in the nineteenth century. These large urban centres had extensive trading and cultural interaction with other parts of Asia which increased their populations from the fifteenth century with the large urban centres, such as Malaka, Manila, Batavia, Singapore, Rangoon, Saigon-Cholon and Bangkok that were the urban gateways in the colonial period (McGee 1967; Askew and Logan 1994).

In the post-war period after 1945 the urbanisation patterns began to change radically with the growth of nationalism and the creation of independent states. This period was characterised by the grafting of national administrative functions to most of the primate cities as well as significant structural changes in the temporal shift from agriculture to industry and services.

By 1960 only two countries, Singapore and Brunei, had reached levels of urbanisation similar to that of developed countries and both can be labelled city-states. During this decade the levels of urbanisation in the rest of Southeast Asia remained low as the rural populations continued to grow in size. The economic structures of the cities changed little and the growing influx of rural migrants placed pressures on the existing infrastructure of housing, roads, water and power, many of the migrants moved in to squatter settlements on the fringes or empty spaces of the inner cities and crowded inner tenements. At the same time new housing for the emerging national elites was being built in suburban estates such as Kenny Hill in Kuala Lumpur and Makati City in the Philippines. Residential settlement began to develop in new towns on the outskirts of the cities at this time such as Petaling Jaya in Kuala Lumpur and Kebayoran Baru on the edge of the cities at that time.

This pattern began to change radically in the period between 1960 and 2000 and the levels of urbanisation exhibited sharp variations that reflected different trajectories of urbanisation. There were three main conditions that contributed to these developments. First the geo-political conditions of Southeast Asia where the intensification of the Cold War established clear lines between the socialist states of the region (Vietnam, Laos,) and the states of Cambodia and Myanmar and the remaining capitalist states; Singapore, Thailand, Malaysia, the Philippines, Indonesia and Brunei.

A second factor was the growth of foreign investment as the developed economies began to accelerate the restructuring of their economies from the 1970s. Singapore, the Philippines, Malaysia, Thailand and Indonesia became important sites for foreign investment in industrial activity either for internal consumption or export. This process led to an acceleration of manufacturing and higher order services focused on the major mega-urban regions which accelerated urban expansion. This process was characterised by the creation of industrial estates, free-export zones, air and container ports and other infrastructure facilities focused on the main mega-urban regions of these countries. Increased income also created consumer demand for housing increasingly in low-density housing estates in the peri-urban regions.

The consequence of these trends was to produce a threefold pattern of urbanisation in Southeast Asia in the late 1980s (Mc Gee and Robinson 1995; Mc Gee 1997). First, Singapore emerged as the regional centre as the Singapore government embarked upon on an ambitious programme to make their country the first post-industrial city in the region. Labor-intensive industry was rapidly restructured and moved offshore to South Johor in Malaysia and Batam Island in the Riau province of Indonesia in a project designed to create a regional growth triangle utilising the economic advantages of the different parts of the triangle such as cheaper labour, capital availability and technology (Macleod and Mc Gee 1996).

Thus by 1990 the processes of urbanisation and economic development were beginning to create the conditions for an accelerated movement of many of the mega-urban regions of Southeast Asia towards increasing global integration particularly reflected in the creation of new "globally-orientated spaces" such as tourist zones, export zones, multiple commercial centres and middle class housing estates. In the cores structural changes occurred as space for the growth of tertiary services such as finance increased which led to urban renewal and high rise building booms. These internal transactional environment of these mega-urban regions began to change and were increasingly linked by road systems responding to the fact that these mega-urban regions were becoming increasing auto-dependent. These developments fuelled a rapid expansion into peri-urban zones throughout the urban hierarchy but particularly in the mega urban regions (Kelly and McGee 2003; Mc Gee 2011).

Many of these processes which have been identified in the preceding paragraph continued and intensified into the 1990s and the first decade of the twenty-first century. A major feature has been the accelerated incorporation of capital flows into the region primarily into equity markets, financial institutions, manufacturing industries and property sectors focused on the mega-urban regions. At a policy level this encouraged effort by national and city governments to market their cities as sites for international investment. This encouraged a major part of infrastructure investment in the MURs resulting in public investment disproportionately concentrated in these regions. However, one of the more important consequences of this global integration has been the exposure of Southeast Asian countries to the volatility of global financial and commodity markets. The 1997 collapse of equity markets slowed down many of these trends particularly in the property market. Secondly as the financial crisis deepened it opened up long-standing discontent with the existing governments among the poor, the students and even the middle class. In Indonesia it created the conditions that led to the collapse of the Suharto government in 1998 and added further elements of volatility (Mc Gee and Scott 2001). But the first decade of the twenty-first century has seen a rapid economic recovery in the region particularly in the more rapidly developing countries of the Malaysia, Indonesia, Thailand and the Philippines. This has accelerated the pace of urbanisation particularly in the MUR's of Manila, Kuala Lumpur, Bangkok and Jakarta. Some indication of the dimensions of this increase are shown by the fact three of the selected MURs in Southeast Asia were ranked as the 2nd (Jakarta) 6th (Manila) and 19th (Bangkok) of the 30 mega-urban regions in the world over a population of 10,000,000. Kuala Lumpur is ranked as 49th in the list of more than 500 agglomerations over 100,000 population in size. This trend emphasises the importance of Southeast Asia particularly in relation to its proportion of total population within Asia.

These have led to significant changes in the urban form and internal population distribution of the leading Southeast Asian mega-urban regions listed above. In order to establish the importance of MURs in the Southeast Asian context we will focus on the demographic aspects of their growth that involves constructing a longitudinal picture of their demographic growth focused on the four selected MURs of Kuala Lumpur, Manila, Jakarta and Bangkok.

We conclude this discussion of the general features of the growth of mega-urban regions with a summary of the preliminary findings with respect to demographic changes over the last 20 years drawn from data based on data analysis of the 1990, 2000 and 2010 censuses in Jones and Douglass (2008). For Kuala Lumpur see Rostan (2006, 2010, 2011).

This analysis is divided into two parts using population data organised on the basis of (a) spatial zones and (b) the urban system of the mega-urban region.

30.3.1 Zonal Analysis of Population Change in Selected Southeast Asian Mega-Urban Region 1990–2010

The major findings of this zonal analysis are shown in discussion below.

(i) Eleven of the selected MURs increased their populations in the decades between 1990 and 2010. The increase is most marked in the period 2000–2010 when all the selected cities increased the size of their population at rates above 25 % for the decade. Jakarta and Kuala Lumpur had the most rapid increase. The MURs continued to hold their share of their country's population in the two decades between 1990 and 2010 except in the case of Manila.

This reinforces Jones comments on the earlier decade that "contrary to the conclusions reached by some observers who have used the population of the officially designated metropolitan area to conclude that many mega-cities have passed their period of rapid growth and are holding a declining share of national population".

(ii) With respect to density there is a sharp difference between the two high density mega-urban regions of Manila and Jakarta and the lower density mega-urban regions of Bangkok and Kuala Lumpur. Kuala Lumpur has a significantly lower density of population than the other three mega-urban regions.

(iii) The zonal analysis shows that all the four Southeast Asian MURSs have experienced a slowing of population growth in the core areas but still retain a significant proportion of the population of their MUR. In general the rates of increase in the inner zones and the proportion of their population in their MURs have increased as the built-up environment has extended from the core zones. Part of this increase is the consequence of the restructuring of urban cores that has led to out-migration of population and industry to the inner and outer zones. The outer zones have continued to grow at a faster rate with the exception of Jakarta where they have the lowest proportion of population in the four MURs outer zones from outside the MUR. From the point of view of the central arguments of this chapter the most important findings are that the analysis shows the core and inner zones of these MURs while experiencing slower rates of increase have still increased their population size while declining in their population share of the MUR population. Secondly the inner zones have been responsible for absorbing the largest growth of population in Kuala Lumpur unlike the other MUR's. If the core and inner zones are combined then the regions have shown an increased share of the population suggesting that the four Southeast Asian mega-urban regions are exhibiting ongoing "centrality" of the core and inner zones in the mega-urban regions.

(iv) However, in all mega-urban regions and particularly in Jakarta the outer zones are increasing their population and if present trends continue they will attract more population as these mega-urban regions continue to grow. The implications of this analysis suggests the future of mega-urban regions will involve a continuation of the thickening-up of population in core and inner zone areas but that the outer zones will attract a considerable proportion of the increase of population in the MURs over the next decades (Mc Gee 2011).

30.3.2 The Changing Urban System of Jakarta and Kuala Lumpur 2000–2010

This section uses census data analysed on the basis of the administrative units and presents data for the decade 2000–2010 in the MURs of Jakarta and Kuala Lumpur (KL). This analysis enables a probing of the urban system that is emerging at the intra-mega-urban region and presents different spatial ordering of the population data analysed zonally in the preceding section. In the case of the Jakarta MUR the kabupatens that form the hinterland of Jakarta core are separated from their urban centres (regencies/kotas) of Bekasi, Tangerang (North and South) and Bogor in the Jakarta MUR. In the KL MUR there has been a rapid expansion of urban activity in surrounding areas creating areas of mixed rural and urban activity that we have labelled urban clusters. The main urban concentrations represented by the Federal Territories of Kuala Lumpur and Putra Jaya, and other Municipalities and Cities that have the status of Local Administrative Areas have expanded their urban areas boundaries to accommodate almost 90 % of the population of the KLMU.

In both the Jakarta and Kuala Lumpur MURS this administrative difference between Kota and LAA reflects contrasting administrative approaches to the challenges of urban expansion. In the Kuala Lumpur MUR case the challenges of urban expansion are led at the Federal Level with the overall development of the main communication systems, major infrastructure investment, e.g. water systems, the broad environmental policies and social and other investment. The State is responsible for much of the local level service and local level administration through the governance of appointed Councils. Finally at the local level there is a threefold layering of administrative territories. Firstly Local Administrative areas that "usually include consolidation of towns and gazetted administrative areas" (Malaysian Census 2010: 402) that have been taken over by cities and municipalities that have expanded their responsibilities to include parts of the districts in which they have located. In the case of Indonesia the administrative structure is at the local level consisting of special status cities such as Jakarta and Kabupatens which are further divided into kota (urban areas) and non urban areas which are administered by the kabupatens.

The results of this analysis indicate two main trends:-

(i) The core areas of K.L and Jakarta MURs are the central hubs of the MURs increasing their population over the last 20 years although decreasing their proportion of the total MUR population.
(ii) In the case of both the Kuala Lumpur and Jakarta MURs a polycentric urban system is emerging based on the urban clusters centered on secondary cities. In the outer zone of Bogor in the case of the Jakarta MUR and Seremban and Sepang in the KL MUR are the only urban clusters The largest urban clusters are located in the inner ring that makes up a rapidly urbanising inner zone of the wider peri-urban region of Kuala Lumpur and Jakarta MURs stretching along the main north-south and east-west highways. In both MURs these urban

clusters are forming an urban network that is being linked by road and rail connections and developing some functional differentiation particularly between the core and the surrounding LAAs (Firman 2011).

30.4 Part Three: Policy Challenges of the Urban Expansion of Southeast Asian MURs

The implications of this research into the emerging spatial patterns of Southeast Asia MURs indicate that there are many policy challenges that have to be faced.

Firstly new systems of data collection are needed that can measure the impact of changes that are occurring in MURs at different territorial scales within the MURs. These will involve spatial measures of population change as our main approach but it must be recognised that it is only one of many measures that could be used. Other approaches include the analysis of migration, employment. land use, population change flows of people, information, capital and satellite imagery (Sui and Zeng 2001).

Secondly the analysis using the concept of "urban clusters" in the Jakarta and Kuala Lumpur MURs raises questions concerning an approach that only uses zonal analysis defined in relation to the spatial positioning to the core of the mega-urban region. Using the urban cluster approach suggests that there is a formation of an incipient poly-nucleated urban system that exhibits increasing differentiation between these urban clusters in terms of economic activity, commuter patterns and labour force formation. While further research is necessary it suggests that the analysis using urban concentric zones is becoming less suitable for studying the evolving urban form as the population is increasingly living in clusters of urbanising space where these urban nodes are surrounded by a growth of urban activities including industrial and residential estates and smaller scale industry and residential settlement which we have labelled "urban clusters" (Choe and Laquian 2008).

Thirdly these spatial developments suggest that the concept of mega-urban regions as transactional environments that are driving the creation of a network of multiple urban clusters is important to the understanding that is important for formulation of urban policies. These urban clusters spread outwards from the urban core forming secondary urban clusters creating a pattern of highly mixed urban activity that presents its own challenges to urban management, transportation systems, the environment, the provision of physical infrastructure and social services. This means that debates about urban sprawl are sidetracking more research into the new urban systems that are directly influenced by the changing transactional environment.

Fourthly, the implications of these findings are important to policy debates concerning urbanisation in Southeast Asia and particularly for peri-urban regions. Increasingly evidence supports the view that MURs should be regarded as crucial areas for policy formation because of their economic importance and the challenges they pose to sustainability and liveability. An understanding of these needs is necessary because it is the mega-urban regions and particularly peri-urban regions that will be the focus of most urban-orientated growth absorbing a large portion of all urban increases over the next decades. At the same time there is restructuring in urban cores and inner zones creating a more densely populated and expanded built-up environment which is experiencing increasing prices of land and housing that encourages decentralisation of office services, industry and residential housing. These developments will pose challenges because the increasing integration to the global economy is creating an economic environment in which more investment is directed to the core and inner zones thus creating fiscal imbalances between the core and inner zones and outer peri-urban zones (Mc Gee 2008).

The policy solutions for these latter regions are not easy for many Southeast Asia mega-urban regions that are governed by several layers of national, provincial and local government which is often highly fragmented. Sub-regional variations in the eco-systems, densities and urban morphology thus create great difficulty for policy makers. These developments create a complex managerial environment in which a myriad of decisions at the local level come into conflict with the transformative elements of higher level government, and firm decisions, often resulting in a decisional congestion of management in these outer zones. This is exacerbated by the mixed urban developments that occur as outwards expansion in urban clusters as the MURs expand.

This will involve rethinking the governance and management systems of MURs to reflect the inevitability of the ongoing expansion of these mega-urban regions (Asian Development Bank 2008) and particularly the growth of urban clusters that leads to policy responses that recognise the growing diversity of MURs.

Fifthly, as part of these institutional changes the management of these mega-urban regions need to be directed to ensuring liveability and sustainability. Rapid mega-urban growth poses environmental challenges particularly where national environmental policies that operate at the various levels of government inhibit reducing the environmental impact of rapid urbanisation. Many of the policies that are being adopted at present are too broad to effectively cope with the diversity of urban eco-systems. There are also ongoing tensions between the requirements of development and eco-system protection. One way to respond to these challenges is to build the concept of the "spatiality of eco-systems" into the policy process that will lead to recognition of the importance of peri-urban regions to the sustainability of MURs.

This is particularly significant in the delivery of services such as water provision, public transportation, public and private utilities including sewerage and power, housing and social services including education and health. This is challenging in the less densely populated zones and peri-urban zones of Southeast Asian mega-urban regions that have mixed land-use, much lower incomes and both environmental and health challenges. The cost of installation is extremely expensive. An alternative approach would be to introduce "eco-services" which would be make greater use of the ecological infrastructure of urban agriculture, water systems wetlands and urban forests that are present in the peri-urban zones that can reduce the costs of engineered large scale service provision. In a broader approach the encouragement of local level community associations to manage the ecological infrastructure could create employment and reduce the costs of services by macro-level engineered solutions (De Groot et al. 2005). This mega-urban visioning does not exclude the possibility of city region, public-private partnerships, and government-civil society coalitions being formed but the privatisation of services such as water has proven very difficult.

There must be a commitment to the preservation of the eco-systems of which these MURs are a part. In this discussion we want to emphasise first that the local features of the eco-system must be taken into account particularly in Southeast Asia where the diversity of mega-urban eco-systems demands locally- derived responses. The policy implications of regarding the MURs as an integral part of national eco-systems does demand acceptance of the idea of extended eco-systems that reach far beyond urban boundaries. This vision of ecosystems sees large urban places functioning as partial ecosystems that are generally supported by biophysical resources from peri-urban regions beyond their administrative boundaries. Generally these mega-urban regions, because they are significant users of energy, material transformation and consumption are more demanding of local and non-local energy systems than non-urban places.

These demands that the mega-urban regions place upon peri-urban often affect the quality of air, the availability of water, the production of local food, waste disposal and other aspects of the ambient environment and are well documented in the Southeast Asian context.

The crucial part of this approach is to recognise not only the importance of protecting eco-systems as part of policy but to build the concept of "spatiality" into the policy process. In 1995 McGee and Robinson had argued that the central imperative for the large mega-urban regions of Southeast Asia was the need to create a response at a regional level that was discussed earlier in this section. But in the decade since this argument was presented the idea that regional planning can provide some rational response to the policy requirements of MURs has become less popular as neo-liberal thinking has developed an agenda of deregulation, privatisation and decentralisation. These neo-liberal ideas have become part of the policy agenda of developing Southeast Asian counties and often made the prerequisite of loans by international agencies. In some cases these agendas clash with the top-down agendas of the states of Southeast Asia and there is a fragmentation of policy responses particularly in the peri-urban areas of the mega-urban regions of Southeast Asia. Thus policy solutions for the mega-urban regions of Southeast Asia will need some way to combine regional vision that is needed to preserve the ecosystems and sub-regional intervention particularly in the peri-urban zones which are contingent on solutions at the local level (Shaharudin et al. 2011).

As various policies are introduced for mega-urban regions it is important to respond to the issues of vulnerability that are being created by global warming (De Sherbinin et al. 2007) and what seems to be increasing volatility in the prices of fossil fuel and food that have major effects on large urban areas. As we have already indicated the mega-urban regions of Southeast Asia have been shaped by the ready access to fossil fuel as the major source of transportation and are becoming increasingly dependent on imported food. Many are also located on low lying coastal plains that could be vulnerable to projected sea-level rises that is likely to affect the cores cities much more than the urban fringes. The effects of such developments have already begun to be seen in riots that occurred in Jakarta as a result of increasing oil prices but they have the potential to create even greater social discontent and as the competition for scarce resources increases. One policy response being advocated in developed countries is to plan for higher density cores (compact cities) that that penalise the use of the automobile and develop public transport systems. But in the Southeast Asian context many of the mega-urban regions already have high-density cores that are well in excess of western cities (where the idea has developed most traction) so that the possibilities for this type of policy response are limited. Another response might be the capture of "land value" in peri-urban areas as land use is changed from urban to rural (Angel 2011; Angel et al. 2012). This captured capital could then be used to fund the preservation of the local ecosystem and ecosystem services. Other responses could involve efforts to increase the use of alternative energy sources, water conservation and public transportation. Although many planners do not regard it as a viable policy another approach would be to increase the production of food for these mega-urban regions in the peripheral areas. At least in the case of the densely populated rice growing hinterlands of Manila, Jakarta and Bangkok this would be a return to a historical relationship between these cities and their hinterland that has existed for centuries. But it would also involve a sustained investment in the peri-urban regions that at present is in conflict with the priorities of creating internationally competitive urban regions. Obviously these policies will have to be embedded in the local context of each mega-urban region but they should contain the following components:

1. effectiveness in contributing to economic growth;
2. effectiveness in contributing to local and global sustainability;
3. effectiveness in promoting eco-systems approach;
4. effectiveness in contributing to social inclusion, increasing employment and reducing urban poverty; and
5. effectiveness in producing a liveable environment by increasing the provision of services such as health, education, access to housing and, care for the aged.

30.5 Conclusion

In this chapter we have tried to present the major challenges that the current growth of the peri-urban regions Southeast Asia pose for the future sustainability of Southeast Asian societies. We have been concerned to emphasise the challenges that are posed by the recent evolution of the large mega-urban regions, the importance of using a multi-scalar approach to the analysis of the processes that have created them and from the perspective of this chapter the need to spatially deconstruct the internal spatial features of these regions. The task ahead, then, is to incorporate these ideas into planning for the future so as to ensure that the changing spaces of the mega-urban regions of Southeast Asia are liveable and sustainable. To return to the introductory quote of this paper most solutions to the challenges of mega-urbanisation will have to be based on the policies that place emphasis on the importance of the eco-system (Curtis 2004) as well as adopting a multi scalar approach and "reimagining" the concept of urban expansion.

References

Adel G (1999) Theories and models of the peri-urban interface: a changing conceptual landscape. Development Planning Unit, London

Angel S (2011) Making room for a planet of cities. Policy focus report. Lincoln Institute of Land Policy, Cambridge, MA

Angel S et al (2012) Atlas of urban expansion. Lincoln Institute of Land Policy, Cambridge, MA

Asian Development Bank (2008) Managing Asian cities. Asian Development Bank, Manila

Askew M, Logan WS (eds) (1994) Cultural identity and urban change in southeast Asia. Interpretative essays. Deakin University Press, Geelong

Atkinson A (1999) Principles and components of strategic environmental planning and management for the peri-urban interface. Discussion paper of the Peri-Urban Research Project Team. London. Development Planning Unit, University College, London

Barter T (1999) An international comparative perspective on urban transport and urban form in Pacific Asia. Challenges of rapid modernization in dense cities. Institute for Sustainability and Technology Policy. Murdoch University Perth, Australia

Choe K, Laquian A (2008) Toward an urban-led strategy for Asia. Asian Development Bank, Manila

Curtis F (2004) Eco-localism and sustainability. Ecol Econ 46:83–102

De Groot R et al (2005) A typology for the classification. A description valuation of ecosystem function, goods and services. Ecol Econ 41:393–408

De Sherbinin A et al (2007) The vulnerability of global cities to climate hazards. Environ Urban 19:39–64

Firman T (2011) Post-suburban elements in an Asian extended metropolitan region: the case of Jabodetabek (Jakarta metropolitan area). In: Phelps NA, Wu F (eds) International perspectives on suburbanization: a post-suburban world. Palgrave Macmillan, New York, pp 195–209

Forbes D (1997) Metropolis and mega urban region in Pacific Asia. Tijdschr Econ Soc Geogr 88(5):457–468

Freud P, Martin G (1999) Driving South. The globalization of auto-consumption and its social organization of space. http://www.montclair.edu/hadish/drivessouthhtml. Accessed 14 Sept 2004

Graham S (1997) Cities in the real time age: the paradigm challenge of telecommunications to the conception and planning of urban space. Environ Plan A 29(1):105–127

Haughton G, McGranahan (2006) Editorial urban ecologies. Environ Urban 18:3–8

Hudalah D, Winarso D, Woltjer J (2013) Industrial land development and manufacturing deconcentration in greater Jakarta. Urban Geogr 34:950–971

Jones GW, Douglass M (eds) (2008) The rise of mega-urban regions in pacific Asia – urban dynamics in a global Era. Singapore University Press, Singapore

Kelly PF (2000) Landscapes of globalization. Human geographies of economic change in the Philippines. Routledge, London

Kelly PF, Mc Gee TG (2003) Changing spaces: southeast Asian urbanization in an era of Volatile Globalization. In: Chia LS (ed) Southeast Asia transformed. A geography of change. Institute of Southeast Asian Studies, Singapore, pp 257–286

Macleod S, Mc Gee TG (1996) The Singapore- Johor-Riau growth triangle: an emerging extended metropolitan region. In: Lo F-C, Yeung Y-M (eds) Emerging world cities in Pacific Asia. Tokyo United Nations University Press, Tokyo

Malaysia (2010) Malaysia. Population distribution by local authority Areas and Mukims 2010. Department of Statistics Malaysia Putrajaya. http://www.statistics.gov.my/portal/index.php?option=com_content&view=article&id=1354&Itemid=111&lang=en

Marcotullio PJ, Lee YS (2003) Environmental transitions and urban transportation systems. A comparison of Asian and North American experience. Int Dev Rev 25(4):325–354

Martin AM (2000) China’s spatial economic development: restless landscapes in the lower Yangzi Delta. Routledge, London

Mc Gee TG (1967) The southeast Asian City. A social geography of the primate cities of Southeast Asia. G Bell & Sons, London

Mc Gee TG (1991) The emergence of Desakota regions in Asia. Expanding a hypothesis. In: Ginsburg NJ, Koppel B, Mc Gee TG (eds) The extended metropolis. Settlement transition in Asia. University of Hawaii Press, Honolulu, pp 3–26

Mc Gee TG (1997) Five decades of urbanization in Southeast Asia. Institute of Asia-Pacific Studies, Chinese University of Hong Kong, Hong Kong

Mc Gee TG (2008) Managing the rural-urban transition in Asia in the 21st century. Sustain Sci 3(1):155–167

Mc Gee TG (2011) Revisiting the Urban Fringe: reassessing the challenges of the mega-urbanization process in Southeast Asia. In: Ton Nu Quynh et al (eds) Trends in urbanization and suburbanization in southeast Asia. CEFURDS Centre for Urban Studies Ho Chi Minh City and UMR 151IRD University of Province General Publishing House. Ho Chi Minh, pp 21–52

Mc Gee TG, Robinson (eds) (1995) The mega-urban regions of southeast Asia. UBC Press, Vancouver

Mc Gee TG, Scott S (eds) (2001) The poor at risk. Surviving the economic crisis in southeast Asia. Final report on social safety net programmes in selected southeast Asian Countries 1997–2000 submitted to CIDA, Canada

Mc Gee TG, Lin GCS, Marton AM, Wang MY, Wu W (2007) China’s urban space. Development under market socialism. Routledge, London

Rostan K (2006) Pembandaran dan pekembangan Wilayah metropolitan lembah Kuala Lumpur-Langat, Malaysia. J e-Bangi 1(1). http://pkukmweb.ukm.my/e-bangi

Rostan K (2010) Perubahan Pendudok Wilayah Metropolitan Lanjutan Klang-Langat, Malaysia 1957–2000 (Population Changes of the Kuala Langat Extended Metropolitan Region 1957–2000). Akademika 79:1–18

Rostan K (2011) Pembandran di Pingger Wilayah Metropolitan Lanjutan: Beberapa Iimplikasi terhadap Corek dan Kualiti Kejiranan (Urbanization at the Fringe of the Klang-Langat Extended Metropolitan Region. Some Implications on the Patterns and Qualities of Neigbourhoods). Akademika 81(3):19–29

Shaharudin I, Samad H, Abdul HFM (2011) Viewing urban expansion from below: the complexity of sustainable urban growth. Academika 81(2):49–58

Sui DZ, Zeng H (2001) Modeling the dynamics of landscape structure in Asia’s emerging desakota regions: a case study of Shenzhen. Landsc Urban Plan 53:37–52

Sutiprapa J et al (2008) Bangkok-globalizing the City of Angels. In: Jones GW, Douglass M (eds) (2008), pp 62–108

UNO Department of Economic and Social Affairs (2008) World Urbanization Prospects 2007. United Nations, New York

UNO Department of Economic and Social Affairs, Population Division (2002) World Urbanization Prospects. The 2001 Revision. United Nations, New York

Webster D et al (2003) Emerging third stage peri-urbanization. Functional specialization in the Hang Zhou Peri-Urban Region. Asia Pacific Research Center, Stanford University

Part X
Integrated Urban Development

Chapter 31
Sustainability of Water Resources in Peri-Urban Landscapes: Learning from the Journey of Engagement

Kevin Rozzoli and Basant Maheshwari

Abstract Water is vital to sustainability and liveability of cities and the peri-urban river systems play an important role in the supply of water for domestic use, agriculture, commerce, industry and the environment. It is therefore essential that peri-urban river systems are properly used and managed, especially under the pressure of urbanisation. Using the Hawkesbury-Nepean River system as an example, in this Chapter we discuss how management of the river system evolves under changing circumstances. We then examine the complexity of managing peri-urban river system and discuss a multitude of challenges and issues that have to be resolved to achieve sustainability of water resources in peri-urban landscapes. We also identify actions, engagement strategies and governance mechanisms that influence the outcomes of water resources management in a peri-urban context. Genuine engagement of community, government agencies and other stakeholders is an important vehicle to establish dialogue and achieve effective and long-term water resources planning at a regional scale. However, the engagement and programs for securing water futures in peri-urban landscapes is made more difficult due to a large number of stakeholders, agencies and interests involved and the changing roles of participants as government policy changes.

Keywords Sustainability • Liveable city • River system • Urbanization • Governance • Stakeholder

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31.1 Introduction

It is now increasingly being realised that peri-urban areas surrounding metropolitan cities and regional towns in Australia and internationally are highly dynamic regions characterised by unique social, environmental and economic changes. A peri-urban region is a diffused territory existing between the urban and rural townships, and river systems in such regions are often used as source of urban water supplies resulting in the construction of major dams. Urban regions extract significant supplies of water for domestic, industrial and agricultural purposes while the river system is also used to receive discharge of treated, and sometimes untreated, municipal effluent originating from urban townships (Ford 1999; Buxton et al. 2006).

Peri-urban landscapes are continuously expanding to accommodate the communities who migrate into these diffused territories in search of a better lifestyle and mostly work in nearby townships, thereby creating a range of competing and conflicting land use issues (Nelson and Dueker 1990; Barr 2003; Buxton et al. 2006). As a result, the health of many peri-urban river systems in Australia and other parts of the world has gradually deteriorated over the last decade (De La Torre et al. 2005; Zhang et al. 2007; Simon 2008; Pinto et al. 2010). Being key river users, the life cycles of aquatic species and social activities of humans are severely impacted by the deterioration of water quality in peri-urban river systems.

The main aim of this Chapter is to examine the challenges and issues faced in managing and sustaining peri-urban river systems in the context of competing water users and urbanisation. We use the Hawkesbury-Nepean River system in the Sydney Basin as an example to understand how the management of river systems evolved since the European settlement and the role played by government agencies, community and other stakeholders in the sustainability of the river system.

31.2 The Hawkesbury-Nepean River System

This Hawkesbury-Nepean River (HNR) system is the main source of water supply for the Sydney Metropolitan area. The main stem of HNR system is about 300 km long, known in the upper catchment as the Nepean River (155 km) and the Hawkesbury River (145 km) (Markich and Brown 1998). The Nepean River becomes the Hawkesbury River at the Grose River confluence near a rural town of Yarramundi, New South Wales (NSW) (Fig. 31.1). A total of two million people live in the catchment suburbs and the catchment covers approximately 21,710 km^2. Due to a large number of urban and peri-urban activities the HNR catchment presents some particular challenges in terms of water quality and health of the HNR system. Currently land use in the catchment includes heavily urbanised, industrial, recreational, agricultural and scenically attractive regions (Baginska et al. 2003). There are numerous point and diffuse sources of anthropogenic pollution which primarily originate from peri-urban agriculture, sewerage treatment plants, sand and gravel

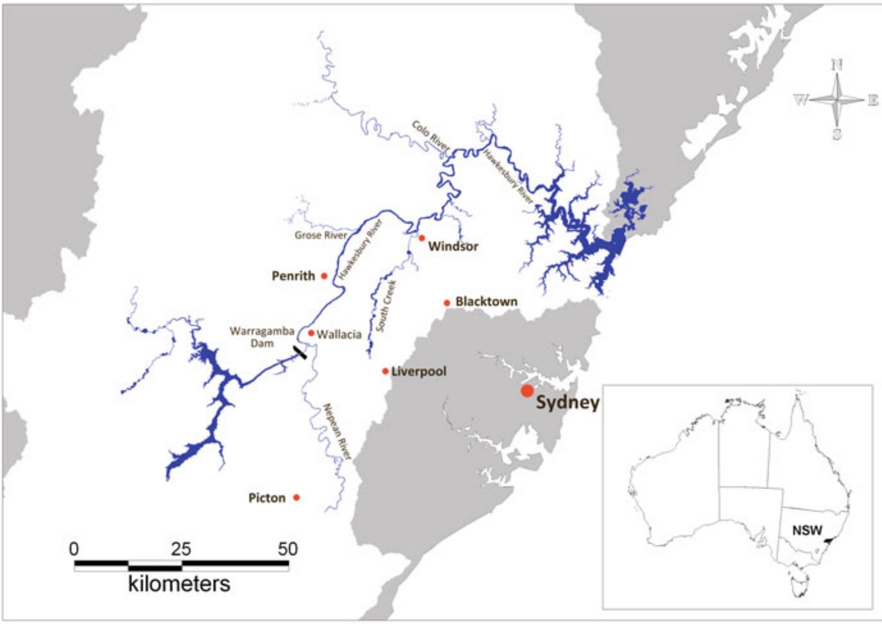

Fig. 31.1 Map of Hawkesbury-Nepean river system

mining and industrial activities. The HNR system supports a variety of recreational activities for both residents and tourists in Western Sydney. As a result of land use changes and modifications of physical habitats over the last 50 years, the river has been profoundly altered from its pristine state (Gavin et al. 1998). Thus, this river system and the catchment provide an ideal case study to investigate the meaning of river health from a range of community perspectives.

31.3 Water Sustainability in Sydney: Thinking from the Past

31.3.1 Settlement of the Five Macquarie Towns

The first conscious move towards sustainable living after post white settlement came under the stewardship of Governor Lachlan Macquarie (1810–1822). Before white settlement it may be said that the aborigines practised a high level of sustainable living in that their way of life may well have continued but for the intrusion of a more 'advanced' culture. That same 'advanced' culture brought with it the elements that have led to our current need to look for a sustainable living system. Large populations, divorced from the land that sustains it, show little regard for the future as it consumes finite resources at an ever accelerating rate.

On his arrival on 31 December 1809 Macquarie observed a colony filled with "dissensions and jealousies". As recorded in Sydney Gazette of 7 January 1810, in his address on taking command the following day he said he hoped to bring a "Spirit of Conciliation, Harmony, and Unanimity, among all classes and descriptions of the Inhabitants of it". He concluded with the assurance that "the honest, sober, and industrious inhabitant, whether Free Settler or convict, will ever find in me a Friend and Protector".

In matters of civic administration he ordered the construction of a new hospital, part of which was to become the home of the New South Wales Parliament. He established a post office, laid out planned streets, dedicated open spaces, introduced the first building regulations and registered carters and bullock-wagoners. Soon the populace looked with pride on the newly ordered town which had risen in place of what had been little more than a military encampment.

Of paramount concern to Macquarie was the urgent need for the colony to be self-supporting in food, thus lessening its reliance on shipments from England. It was not long therefore before Macquarie, in his quest for farming land, turned his attention to the hinterland and the towns of Parramatta and Green Hills. On 6th December 1810 he renamed the latter Windsor at the same time establishing the location of four new towns, Richmond, Wilberforce, Pitt Town and Castlereagh.

31.3.2 Governor Macquarie's Vision of Sustainability

Macquarie on his first visit to the lands immediately to the west of Sydney was informed of the devastating floods in the months before his arrival. His diary notes, 6th December 1810, that he specifically located and established each township on high ground "for the security and accommodation of the Settlers and others inhabiting the Cultivated Country, on the Banks of the Rivers Hawkesbury and Nepean", adding, " I recommended to the Gentlemen present to exert their influence with the Settlers in stimulating them to lose no time in removing their Habitations, Flocks and Herds to these Places of safety and security and thereby fulfil my intentions and plans in establishing them."

Land grants in the Hawkesbury were relatively small, many being taken up by emancipated convicts who, recognising that their prosperity was thanks to Macquarie's efforts, worked hard. In contrast to the richer, more ambitious settlers who took up large grants of grazing land to the south west upon which to build their fortunes, the settlers of the Hawkesbury were less troublesome to Macquarie. In recognition of their industry and contribution he reserved land for them in areas most suited for intensive cultivation. By 1821 there were about 1000 small settlers producing fruit, vegetables, grain and meat for the local market.

Macquarie was a hands-on, industrious administrator making frequent expeditions to the interior to familiarise himself with the territory under his control. His decision to curb expansion, following the crossing of the Blue Mountains, the discovery of a route from Windsor to Newcastle, and the exploration of land to the southwest as far as Lake George and the Goulburn Plains, meant for better administration of law and order and more assured access by settlers to markets and labour supply. Macquarie was the first of our great planners and in every way the Hawkesbury was a beneficiary of these decisions.

31.4 The Problems of the Hawkesbury-Nepean System

The Hawkesbury-Nepean is a very old river. It commenced as an upland area dissected by a juvenile river with a formation of rounded water-worn pebbles. By the time it reached its senile stage it meandered over a level surface of Wianamatta shale with the pebbles still present in its bed. These pebbles are the rich blue metal deposits of today. Later the more northerly regions were uplifted. This warping, however, was sufficiently slow to preserve the river's meandering course. The shale became gradually eroded to expose the Hawkesbury sandstone.

During this period, a lake formed and it was the sediment in this lake which created the original alluvial deposits. The build-up of sediment finally forced the water level in the lake higher until it found an opening to the sea at Brooklyn. The subsequent out flow eroded the valley to the base level of the opening, dissecting the lake alluvial in the process. The numerous tributaries now attacked the softer uplifted areas and eroded juvenile gorges.

The next significant aspect was an invasion from the sea which affected all parts of the valley and tributaries at base level and caused a heavy deposition of sediment. A secondary uplift exposed this silt and created the final scenario for the present process of erosion and deposition upon which modern-day human activity has wrought its own changes.

There is another picture of the river which is useful and for which we are indebted to the Metropolitan Water Board. They use for comparison a bath tub filled from a number of taps of varying size, about seven. During periods of heavy rainfall these taps flow at different rates and for different periods of time. The Warragamba catchment for example, is the biggest tap and is turned on most frequently. The bath has one plug-hole, that is, the mouth of the river at Brooklyn. It is not difficult to visualise that with the taps turned on the plug-hole cannot empty the bath fast enough or, in real terms, the river floods.

The very nature of its geological origins created the complex matrix of positives and negatives that shaped its evolution over the last 200 years of European influence. On the positive side it has provided, and still provides, a valuable food source, has given up millions of tonnes of gravel and sand to build a modern, sophisticated city, provided until recently a seemingly inexhaustible source of potable water and made Western Sydney one of the economic powerhouses of Australia. On the negative side this cornucopia of resources has produced a dangerous level of self-indulgence and an indifference to the cumulative impact of unrestricted growth. This had led to the sacrifice of agricultural land, indeed some of the best in Australia, an over reliance on low price building material, an unrealistic view of the balance between supply and demand in the water cycle, high levels of pollution and a vast peri-urban area with needs and dynamics little understood by planners acquiescent to the alluring cash cow of urban development. With Sydney's population nearing five million, and Western Sydney nearing two million of that, pressures are emerging that seem little understood by government decision makers.

31.5 The Complexity of the Peri-Urban Regions

Peri-urban regions are those areas on the urban periphery into which cities expand or which cities influence (peri: around, about or beyond). Peri-urban land can be seen simply as land adjacent to the edge of an urban area into which the urban area expands (Burnley and Murphy 1995). Peri-urban areas have been defined in relation to a nearby metropolitan area on its inner boundary, a rural area on its outer boundary, or as the land in between (Buxton et al. 2007). Peri-urban areas need to be understood in relation to both the urban area it surrounds and the rural lands beyond. Invariably they contain important natural resources, biodiversity and significant landscapes, and are very important for local fresh food supply and recreation. Generally they attract a diverse population of people because of the wide range of employment skills generated by the landscape.

An estimated four million people live in Australia's peri-urban areas which are major areas for food production. They are significant in size and will be expected to absorb much of the country's growing population. Paradoxically this could result in an unsustainable additional demand on water supply from traditional sources. Research supports the premise that for some peri-urban areas it will be highly unlikely, within 20 years, that it will not be able to meet the demand for water from potable supplies. Research has also revealed that, for much of that demand, water of potable quality is not necessary. This suggests new directions for science-informed policy and decision-making to improve social, economic and environmental outcomes in peri-urban areas.

Typically peri-urban areas significantly contribute to economic, social and environmental functions in the regions and provide fresh fruits, vegetables, cut flowers, nurseries, turf etc. to cater for the needs of urban and rural communities. They are the fastest growing areas as the location for the majority of new housing developments in all the big cities in Australia. Water and Irrigation Strategy Enhancement through Regional Partnership (WISER) research has indicated that the water cycle and water management issues which concern peri-urban zones differ greatly from urban and rural areas and that planning processes are mostly based on criteria relevant to urban and rural needs. These are rarely applicable in peri-urban areas.

31.6 National Water Initiative

In 2004, the Australian Government established the National Water Commission (NWC) as the lead Australian Government agency for driving national water reform under the National Water Initiative (NWI). The overall objective of the NWI is to achieve a nationally compatible market, regulatory and planning system of managing surface water and groundwater resources for both rural and urban use which optimises economic, social and environmental outcomes (Smith et al. 2014).

Under the NWI, governments have made commitments to the preparation of water plans with provision for the environment, dealing with over-allocated or stressed water systems, the introduction of registers of water rights and standards for water accounting, the expansion of trade in water, the improvement of pricing for water storage and delivery, while meeting and managing urban and rural water demands.

In 2008, the Government announced the nation's new water plan 'Water for the Future'. The plan aims to develop a single, coherent, national framework that integrates rural and urban water issues. Programs have been developed for rural, urban and environmental sectors and components including sustainable water use, urban water and desalination planning and river health.

Until now such initiatives have been guided by extensive research into rural and urban water as separate sectors. A research project 'Change and Continuity in Peri-urban Australia' (Buxton et al. 2008) undertaken by Land and Water Australia in 2008, investigated the complexity of peri-urban regions, the interface between urban and rural areas. This research highlighted particular competing uses and conflicting demands for water and reported that in regards to water use and management, the increasing recognition of the importance of peri-urban regions is yet to be fully reflected in research.

Peri-urban zones have special needs, problems and opportunities. The particular conditions and circumstances of this zone provide a range of possibilities for water and land management that do not exist in denser urbanised areas or sparsely populated rural environments. It is also becoming apparent that if these zones are not well managed the quality of life in increasingly urbanised environments could be put at risk.

To date water research has been conducted by a wide range of institutions driven by agendas particular to the briefs they have been given. As yet, no research centre has been given a holistic brief to tackle the most complex of water supply and demand management issues, that is, those which occur in Australian peri-urban areas. Institutions have to date concentrated on either urban or rural water issues, but an estimated four million people live in Australia's peri-urban areas and these are the major areas for food production. These areas are significant and will, in future, be expected to absorb the country's growing population, which, paradoxically, could result in an unsustainable additional demand on water supply from traditional sources and a major impact on the availability of fresh fruit and vegetables.

The Western Sydney region is the largest peri-urban area in Australia. It typifies the complex range of land and water management issues faced by peri-urban zones. As such, it has proved an ideal laboratory for research that is applicable across the nation and overseas. Challenges solved within Western Sydney can inform solutions to similar problems elsewhere.

31.7 The Birth and Demise of the Hawkesbury-Nepean Catchment Management Trust (HNCMT)

In the 1960s and 1970s Harry Scholer, then a Supervising Engineer with the Department of Public Works working on the State's river systems, sounded early warning bells for the future welfare of the Hawkesbury River. In 1973 the National Trust held a symposium entitled "Planning the Future of the Hawkesbury River Valley" and later held further conferences to discuss the problems of the Hawkesbury. In 1974 the first summary of known information on the Hawkesbury was produced by the Askin Government. This coincided with their appointment of the first environment minister in Australia although the portfolio was entitled Minister for Conservation. In 1974 Kevin Rozzoli by then the Member for Hawkesbury in the State Parliament began quietly working on an administrative model for the river system based on cohesive management of the whole of the catchment. He finally presented his work in the form of a draft Hawkesbury River Authority Bill which he unsuccessfully tried to bring to the attention of parliament.

Numerous studies on the Hawkesbury-Nepean system were conducted by the Departments of Public Works, Water Resources and Planning as well as the Water Board, the State Pollution Control Commission and the Soil Conservation Service. The Department of Planning, under its numerous titles, produced a significant number of documents culminating in Regional Environmental Plan No. 20, gazetted on 12th December, 1986. This was a broad spectrum and largely ineffectual document.

By the early 1990s with public concern over the deterioration of water quality in the Hawkesbury having grown to such an extent that a large coalition of environmental groups was formed to bring pressure on the government to take action to stop the degradation. This group, Coalition of Hawkesbury and Nepean Groups for the Environment (CHANGE) met with Mr. Kevin Rozzoli and, after detailed consideration, agreed to back his model. In response to the public pressure they generated the Government established a Hawkesbury Nepean Task Force to examine his proposal and in 1993 set up the Hawkesbury Nepean Catchment Management Trust by regulation. Under this regulation its work was restricted to that part of the river system below Warragamba Dam. The government, then functioning without a majority in either the Legislative Assembly or the Legislative Council, wanted to establish the Trust without amendment to the structure it had decided on even though the initiative had in-principle support from both sides of parliament and the independents. The decision to set up the Trust by regulation was later to prove fatal.

The Trust was hugely successful. Funded to the extent of $3.56 m. a year from consolidated revenue it managed to lever a further $8.5 m in its latter years towards catchment improvement. It also achieved outstanding results in government agency cooperation, was highly successful in community engagement with over 7000 volunteers working on rehabilitation projects, instigated State of the Environment reporting for the whole of its area and supported Councils within its areas to produce their own State of the Environment reports. During the 7 years of its operation it became internationally recognised for its success in cooperative engagement, particularly with the community.

The Trust was uniquely structured. Firstly it had a clearly defined charter which was to make such surveys and general plans for the region and its hydrological catchment as may be necessary to guide and control the extent, sequence and nature of development that would be equitable and economically sound and which would advance the orderly and proper physical, environmental, economic and social management of the designated region.

It was relatively small and streamlined in its working processes. It had an executive arm comprised of five full-time persons, a Chief Executive Officer with strong managerial, communication and people skills and four Program Leaders possessing special knowledge of, and experience in, each of four disciplines of major significance to the catchment, viz. Planning, Public Works, Bio-diversity and Community Engagement. Each executive member appointed had such expertise and carried a full practical workload. This leadership ensured strong capability, and a high level of professional integrity.

Its board, drawn from government agencies, industry and resident groups, environmental groups and local government performed their role as individuals rather than as representatives of their parent organisation. This ensured a loyalty to the Trust rather than the background they came from. In addition each person had an interest in and commitment to the region.

Whilst nobody expected the new Trust to perform miracles in the short term the long-range thinker, the long-term planner had found little support in the previous 20 years. It was obvious to those who led the Trust that the cultural attitude towards nurturing the environment would have to change in a way that would embrace the concept of long range planning and management, casting aside the populist call for "instant" solutions. This problem remains today.

The proponents of the Trust wanted to vest the organisation with some perceivable authority believing the community would not accept a management organisation that was seen to be another 'toothless tiger'. What was established was a lean and efficient organisation which, to the greatest possible extent, used existing structures. This provided three major advantages; it was more cost effective, integrated and better utilised the pool of knowledge and expertise already existing within the catchment and, most importantly, it was less threatening to existing agencies.

It was also intended that a major function of the organisation would involve planning strategies and outcomes. It would therefore be necessary to provide within the regional framework of the Department of Planning a mechanism by which the Trust could exercise a limited but important authority, not so much as a deliverer of services but as a co-ordinator, manager and watchdog for the region. These were functions that did not then exist.

It was this vacuum in regional management that had been the single greatest contributor to failure in solving regional problems. Yet at this hurdle the government baulked. The Trust instead would work within existing planning structures in developing a catchment strategy and Regional Environmental Plan REP.

REPs under the Environmental Planning and Assessment Act, 1979 had until this time been mostly statements of general principle, short on fine detail. In recognition of this and arising from the work of the Task Force the Department of Planning decided to revisit Sydney Regional Environmental Plan number 20 A (SREP 20. A) Section 22 committee (set up under S.22 of the Environmental Planning and Assessment Act 1979) with very broad representation was established. A much more comprehensive SREP 20 (No. 2) was gazette in 1997. The revised SREP 20 (No. 2) together with the Greater Metropolitan Regional Environmental Plan No 2 – Georges River Catchment, and the Sydney Drinking Water Catchment REP (2006) tried to break new ground but in many instances fell short of important elements such as cumulative impact and water supply and demand management.

Historically the fine detail of planning is contained in Local Environmental Plans (LEPs). This has led to fragmented standards reflecting different attitudes, at different times, by different councils. In recent years government has also grappled with this lack of standardisation but at this level of detail the task is difficult. The Trust hoped to fill the need for a comprehensive regional plan that articulated planning goals on a whole of catchment basis giving guidance to councils as to what was expected of them. The regional plan would attempt to get ahead of the difficult problems by identifying both problems and the resources required as a basis for designing regional solutions. Progressively the strategy and the plan would provide an accurate, cohesive and informative base upon which developers could design their developments in conformity with known requirements. This would expedite the development approval process without jeopardy to critical standards. Ultimately the regional plan was to be developed by NSW Planning in accordance with normal procedures but taking into account the research, design elements and evaluation of the Trust.

To achieve uniformity between planning instruments it was advocated that the regional plan would, with the exception of State Environmental Planning Policies, take precedence over all other planning instruments. Existing and future REPs would be brought within the regional plan and LEPs amended as necessary to achieve conformity. The Trust also believed it could make a significant contribution to the efficacy of the regional plan if it were to be given a concurrence role for development of an especially sensitive nature. Although this was opposed under government policy which sought to strictly limit concurrence powers the government, in the Sydney Water Catchment Management Act, 1998, later vested the Sydney Catchment Authority with quite extensive concurrence powers.

The Trust also believed an essential ingredient of transparency and integrity of function was access to data. It proposed a 'one stop shop' for all factual data available on the catchment with universal availability to data. Thus government agencies, councils, developers, consultants, government agencies, academics and the general public would all have the same access to the same data.

The strongly independent position it took was founded on the belief that its role was to give honest, well researched advice to government, local government and the community on problems facing the river system. In furtherance of this policy it produced a major strategic planning document with long, medium and short term goals, together with defined key responsibilities for State agencies, local government and the community, linked to costings and time lines on a scale of priorities based on catchment health and the interests of the community. Its achievements however were its downfall. Panicked by the increased level of expectation within the community and presumably the daunting prospect of allocating real money to Western Sydney the government took the extraordinary decision to axe the Trust, virtually overnight. Before the Trust could muster a defence the regulation was repealed. Despite a valiant rear guard action and a Legislative Council inquiry that condemned the government's action the Trust passed into history.

31.8 Engagement of Agencies and Community

During 1997, 1998 and 1999 the NSW Healthy Rivers Commission (HRC), an independent public inquiry body, established under the Pollution Control Act, 1970, conducted a public inquiry into the health of the Hawkesbury Nepean River system. It published a Final Report in August 1998 and a Supplementary Report in April 1999. In his foreword to the Final report the Commissioner, Peter J. Crawford said, "The Commission has been able to capitalise on the wealth of knowledge and understanding of the river in the community at large, in councils and in agencies as well as the Hawkesbury Nepean Catchment Management Trust and in the extensive studies and research on technical and policy issues." The Report did not restate technical research and policy detail except where directly relevant to the Commission's findings but instead referred the reader to original documents listed in the bibliography published in the Report.

Crawford further stated that the inquiry had, "revealed that the way we manage sewage, stormwater, extractive industry, agricultural production and so on must change if river health is to be protected and enhanced. Some of the many excellent recommendations in the report have been progressed; unfortunately however the majority of recommendations for a whole-of-government approach have not been implemented. In March 2001 a Statement of Joint Intent for the Hawkesbury Nepean River System was signed off by a number of NSW Government agencies. The Statement of Joint Intent outlined the recommendations from the HRC and the approvals put into place by Government.

Despite Cabinet approval of many of the recommendations implementation was the underlying weakness of this inquiry. Responsibility for implementation of the Statement of Joint Intent was placed in the hands of a Water CEOs Committee which comprised CEOs of Environment Protection Agency, Department of Land

and Water Conservation, Department of Urban Affairs and Planning and NSW Agriculture. A principal failing was that a lead agency was not appointed from among the Committee members. Although some actions followed the CEOs generally allowed it to die on the vine. For example an independent review to be undertaken within 2 year of the signing of the Statement of Joint Intent was never carried out. The opportunity to implement a holistic planning and management system for the catchment was once again allowed to slip away.

It did however lead to the establishment of the Hawkesbury Nepean River Management Forum which, in its final report, recommended inter alia environmental flows, aquatic weed management, weir modification, effluent re-use, demand management, water sensitive urban design, community engagement and an adaptive management approach.

Implementation of the Forum's recommendations has been excellent. Some improvements are still available in utilisation of the full range of the statutes available for "Water Management Plans" under the Water Management Act 2000. Integration across government and community of monitoring and modelling remain as outstanding options for real benefit with major efficiency returns to natural resource management that would in turn lead to significant savings in total expenditure.

During the passage of these events Sydney's water supply suffered a suspected outbreak of contamination from giardia and cryptosporidium which led to a judicial inquiry chaired by (now) Justice Peter McClellan which made a series of 91 recommendations including: changing Sydney Water and Hunter Water to 'statutory' state owned Corporations; establishing the Sydney Catchment Authority (SCA); defining NSW Health's powers and roles including the ability of the Chief Health Officer to issue alerts to boil water; and improving research, monitoring, treatment, incident reporting and strategies for drinking water. Another important recommendation was the drafting of a Regional Environmental Plan (REP) for Sydney's drinking water catchment to establish protocols for the Environmental Protection Authority, NSW Health Department of Planning, councils and other relevant agencies. The recommendations led to the splitting of Sydney Water functions. Sydney Water retained control over distribution while the capture, storage and supply of quality raw water from well-managed catchments were vested in the new Sydney Catchment Authority.

Despite this attempt to streamline water management including catchment management there is still extensive duplication and the REP is a watered down version of the concepts enunciated by the Section 22 committee, established under the Environmental Planning and Assessment Act, 1976 which endeavoured to drive the process. The bodies which influence decision making are at the very least Department of Planning and Infrastructure, Sydney Water, Sydney Catchment Authority, Hawkesbury Nepean Catchment Management Authority, Office of Environment and Heritage with the responsibility for water now with the NSW Office of Water in Department of Primary Industries, each overlapping in their roles. There is still a major opportunity for increased efficiency and substantial cost saving for natural resource management particularly within the Hawkesbury- Nepean River system.

The relative strengths of the operators and regulators within the Sydney Basin also need close examination. The tail is still wagging the dog to some degree albeit to a lesser extent than say 5 years ago.

Finally in addition to these complexities one cannot ignore the role of the Independent Pricing and Regulatory Tribunal (IPART). The terms of reference for IPART do not reflect the real cost of water extraction in the river system. The current terms of reference reflect the costs of storage, treatment and reticulation of water but do not recognise the costs to the Hawkesbury-Nepean and Shoalhaven River systems of having significant amounts of water withdrawn and stored by the dams and weirs within the river system, or the cost of maintaining a healthy river system.

An important aspect of stakeholder engagement is that engagement needs to be ongoing by the partners involved to allow development of formal relationship among themselves, e.g., by forming an entity through a Memorandum of Understanding. Our experience suggests that such relationships, although they may seem symbolic, greatly benefit the region in building social capital emanating from regular sharing of ideas, debunking engrained prejudices and urban myths about each other, and providing confidence and positive interactions.

31.9 The Life After the HNCMT

Predictably the advances made by the Trust soon evaporated. Its main legacy was the body of information it had developed, now preserved in the Penrith City Council Library, and a small group of people with a continuing passion for and considerable knowledge of the Hawkesbury Nepean River system. The call for a single river authority to develop a strategic direction, avoid duplication and implement cohesive planning for the Western Sydney region and the upper catchment continues.

In 2003 the government established the Hawkesbury-Nepean Catchment Management Authority (HNCMA). The HNCMA describes its primary role as “to fund environmental projects on private land in areas of critical importance. The HNCMA website states “We are a statutory authority with a board that reports directly to the Minister for Environment and Climate Change. Our programs and projects are largely funded by the New South Wales and Australian Governments, as well as our partners and corporate supporters. We work closely with landholders, councils, landcare groups and other government agencies to plan, fund and carry out practical environmental improvements in the Hawkesbury-Nepean Catchment.”

This is a far more limited brief than that given to the Trust. Within its brief it has done some excellent work but failed to satisfy the call for a single river authority.

Continuing public agitation for a “one stop shop” authority led to the establishment of the Office of the Hawkesbury-Nepean to “improve the health of the Hawkesbury-Nepean river system”. The Office was established under the provisions of the Hawkesbury-Nepean River Act, 2009. The Office is responsible for “coordinating the river management activities of relevant NSW Government agencies, including the Office of Environment and Heritage, Sydney Catchment

Authority, Department of Planning and Infrastructure, Department of Primary Industries and Sydney Water." Another "key function of the Office of the Hawkesbury-Nepean is to provide better access for the community to information and advice about the river and its management. Many stakeholders have expressed their confusion about the myriad of State Government agencies, programs and initiatives that address or influence river health."

The Office of Hawkesbury Nepean has no decision making powers and no power to direct agencies or shape departmental policies. Although a step forward it fell far short of Western Sydney demands for a single river authority. Defending its action to repeal the Trust the Government identified the high cost of the Trust (despite the fact that in 7 years its budget had not increased) and its failure to deliver sufficient on-ground outcomes (although this was never its main purpose) as its main concerns. Ironically the budget of the HNCMA, $14.4 million considerably exceeds the budget of the Trust, even allowing for inflation, and yet still does not provide the scope of work undertaken by the Trust.

31.10 The WISER Project

While water scarcity and climate change are considered a driving issue for the management of the Hawkesbury-Nepean River System, the use of water from different sources in peri-urban landscapes is highly fragmented and uncoordinated. As such, this has limited the use of water for irrigation and environmental purposes and made the scarcity of water in the Sydney region much worse than it should be. The Water and Irrigation Strategy Enhancement through Regional Partnership – WISER Project was developed to address these vital issues. It was one of the four multidisciplinary projects established by the Cooperative Research Centre for Irrigation Futures (CRC IF) under the System Harmonisation Program. The challenge the WISER Project, along with CRC IF accepted was to undertake and deliver research, education and training that would give confidence to local government, government agencies, growers, industry, and communities to invest in better water future and better environment in both urban and peri-urban landscapes.

The WISER project focussed on developing a strategy to improve cross-organisational communication and system-wide management to improve production and environmental outcomes in the context of a whole catchment (Khan et al. 2008). The objective of this strategy is to achieve such co-ordination by establishing a regional business plan with the various stakeholders of the region. Although set in the broad categories of 'hydrology', 'production and environmental outcomes' and 'mechanisms and process for change', the work through system harmonisation required understanding the needs of, and close collaboration with, stakeholders associated with irrigation and other water uses of the region.

The project involved the analyses of the region's water cycle components, water productivity, and environmental, social, cultural, institutional and policy issues and challenges. The analyses helped, in consultation with key stakeholders and government agencies, in identifying and evaluating scenarios, strategies and opportunities for sustainable use of the region's water resources in the longer-term. The project was also designed to facilitate the formation of a regional partnership that continues beyond the life of this project. The partnership thus formed will provide key input into implementation of actions identified through this project.

The project encompassed three major activities: stakeholder engagement; modelling and analysis of hydrologic, environmental, economic, social, institutional and policy aspects and visualisation; leading to the facilitation of regional business and environmental partnerships. These activities helped to understand the current water policies and institutional barriers and identify changes that may improve water use and governance. Importantly, the project assisted the stakeholders and agencies to initiate the development of a Regional Water Resources Planning and Management Framework integrating options for water use, future infrastructure development and cost-benefit analysis (Fig. 31.2).

The engagement tasks that were pursued to develop collaboration with stakeholders have included undertaking workshops to determine values and needs of irrigation in the area. They have also involved developing committees to progress and guide the development of regional irrigation business partnerships. Stakeholders considered for such workshops were water users and agencies associated with water management.

Research conducted in the WISER project highlighted the difficulties which Western Sydney, the largest peri-urban region of Australia, will face over the next 20 years in meeting the demand for water. In trying to come to terms with the problem of supplying water for the environment, irrigated agriculture, playing fields and reserves, researchers found that competition for water involved not only farmers, councils and the river system, as with rural environments, but highly urbanised

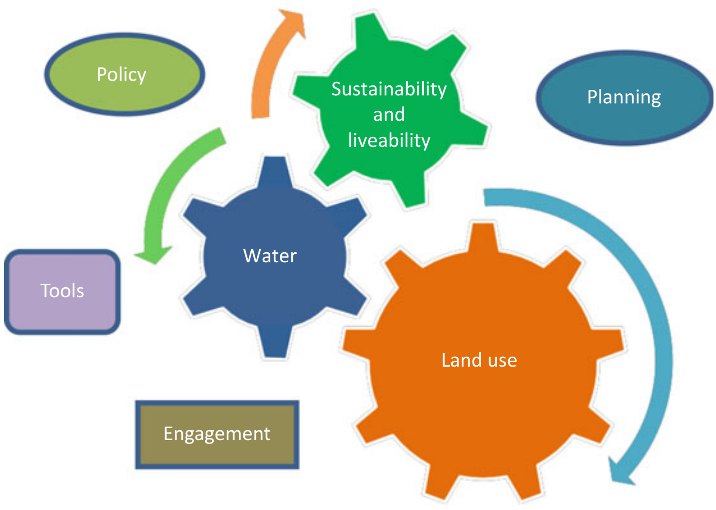

Fig. 31.2 The peri-urban change cycle

domestic, commercial and industrial consumers as well. Potential solutions for some of the challenges were identified, and some have already been adopted by local and state government.

Research indicated that within 20 years it is likely that some peri-urban areas will be unable to meet the demand for water from potable supplies. Research also revealed that, for much of the current demand, water of potable quality is not necessary. This suggests new directions for science-informed policy and decision making to improve social, economic and environmental outcomes in peri-urban areas.

31.11 The Journey of Stakeholder Engagement

In the WISER project, we had extensive engagement with a range of stakeholders directly or indirectly connected with water in the Western Sydney region. Through the engagement process we learnt that it is unrealistic to expect all stakeholders to come to the table at the beginning of the project. This may be related to the lack of clear understanding of the issues and differences in power and authority. Due to the complexity of the peri-urban water management, conflicts among the various parties involved is part and parcel of stakeholder engagement processes and in fact it can even be helpful in stating openly the perceptions and interests that need to be considered in arriving at practical and acceptable solutions (Leeuwis 2000). Stakeholder engagement processes therefore become a mix of 'learning and fighting' (Butterworth et al. 2007).

Often government agencies are the initiator of the stakeholder process but there is always a possibility of confusion, as stakeholders do not usually see authorities as neutral facilitators. On the other hand, the researchers in the WISER project were able to play the role of facilitator between government agencies and stakeholder effectively and eventually were able to bring all the parties together to the table. The engagement in the WISER project has given stakeholders a broader perspective of the region's problems, enabling them to be more integrative in their approach to seeking solutions.

For effective stakeholder engagement it is important to trust the views of stakeholders and provide sympathetic facilitation. Any manipulation in the process should be avoided. The people who represent agencies and stakeholders are only human and on many occasions they may propose seemingly unsustainable or impracticable decisions. However, water issues in peri-urban regions are so complex that we cannot expect everyone to think the same and agree at the beginning of the dialogue. The role of an effective stakeholder engagement process is then to work in a spirit of co-operation and mutual respect, and to lead vision building and solutions that are jointly owned by agencies, stakeholders, researchers and community at large.

31.12 Looking into Future

While the CRC IF was established "to undertake and deliver research, education and training that gives confidence to growers, industry, government, and communities to invest in better irrigation, a better environment and a better future", as indicated at the beginning of this paper this challenge was far more complex in Western Sydney than in the rural communities in which the other centres were located, not the least being that it was researching irrigation problems in the peri-urban area of Australia's largest city.

In recent years NSW has faced the prospect of water shortages with the government spending many millions of dollars in an effort to drought-proof its capital city. This is however a problem facing every major Australian city and many regional centres. The Australian Government has endeavoured to tackle the problem under its National Water Initiative. To date water research has been conducted by a wide range of institutions driven largely by agendas that reflect their particular briefs. As a result, effort has focussed largely on urban and rural water issues, with little attention given to peri-urban needs where some four million Australians currently live. Even the National Water Commission's latest report, 'Urban Water in Australia: future directions' while timely, shows the decision makers are not looking at the bigger picture of water planning and management for Australian cities. The future direction for urban water cannot be properly achieved without integrating peri-urban water in the water planning equation.

There is not a sufficiently on-going, integrated approach to bring together, holistically, hydrologic, social, economic, environmental, cultural, policy, legal and institutional aspects of long-term water planning of urban and peri-urban areas. While the debate on the Murray-Darling Basin plans and the need to develop new regional cities (rather than mega cities) continues, there will be increasing demand on policy makers and agencies such as National Water Commission to deal with precious water resources and city environs holistically rather than the current piecemeal approach. The report also fails to recognise the value of sustaining food production in peri-urban areas.

It is a fact however that these peri-urban regions are expected to absorb the majority of the country's growing population, which, paradoxically, could result in unsustainable additional demands on water supply from traditional sources. This interface between urban and rural areas, the peri-urban zone, has special needs, problems and opportunities that are unique, but also presents a range of possibilities for water management that do not exist in denser urbanised areas or sparsely populated rural environments. A recommended approach is to tackle the future peri-urban water challenges nationally through a co-ordinated and transdisciplinary initiative. It is most desirable that this takes place in one of the important peri-urban regions, Western Sydney, not the least reason being that it is Australia's largest peri-urban zone and faces some of the most complex land and water management challenges imaginable. Such an initiative will help identify potential solutions to practical outcomes and will close the knowledge gap that currently limits planning and management of water in peri-urban regions. In summary, such a national initiative could help in enhancing improved understanding of peri-urban zones as well as developing generic models, tools and processes that integrate ecological, hydrological, economic, social, cultural, institutional and policy aspects into water resource policy, planning, governance, strategy development and management of peri-urban landscapes throughout Australia. In can assist stakeholders and agencies in the analysis of options for sustainable peri-urban water use, infrastructure development and cost-benefit analysis. Further, such initiative can ground a point of quick access to concise and reliable information on peri-urban water matters thus helping agencies and stakeholders develop a shared vision for peri-urban zones and build practical strategies to secure water for social amenities, local food production and river health that will underpin vibrant and resilient communities.

31.13 Conclusions

The Hawkesbury-Nepean River system, like many peri-urban river system around the world, is under constant pressure due to urbanisation. Effective engagement of government agencies and other stakeholders could, and should, be an important vehicle to establish dialogue and achieve effective and long-term water resources planning at a regional scale. However, the engagement and programs for securing water futures in peri-urban landscapes is difficult due to the complexity of issues and the range of stakeholders, agencies and interests involved. The most important issues for peri-urban landscapes inextricably include maintenance of the water cycle for agriculture, recreation and environment in the face of expanding urban needs. For achieving long-term regional water security in peri-urban landscapes, we need effective engagement of stakeholders, regional water managers and land-use use planners in the development of a common vision and successful long-term planning. In addition, we need to treat the regional water cycle as one unit rather than the present practice of managing water within local government boundaries.

References

Baginska B, Pritchard T, Krogh M (2003) Roles of land use resolution and unit-area load rates in assessment of diffuse nutrient emissions. J Environ Manage 69:39–46

Barr N (2003) Future agricultural landscapes. Aust Plan 40:123–127

Burnley IH, Murphy PA (1995) Exurban development in Australia and the United States: through a glass darkly. J Plan Educ Res 14:245–254

Butterworth J, Ducrot R, Faysse N, Janakarajan S (eds) (2007) Peri-urban water conflicts: supporting dialogue and negotiation, Technical Paper Series No. 50. IRC International Water and Sanitation Centre, Delft, 128p

Buxton M, Tieman G, Bekessy S, Budge T, Mercer D, Coote M, Morcombe J (2006) Change and continuity in peri-urban Australia – state of the peri-urban regions: a review of the literature. RMIT University, Melbourne

Buxton M, Tieman G, Bekessy S, Budge T, Butt A, Coote M, Lechner A, Mercer D, O'Neill D, Riddington C (2007) Change and continuity in peri-urban Australia. Peri-urban case study: Bendigo Corridor, Monograph 2. RMIT University, Melbourne

Buxton M, Alvarez A, Butt A, Farrell S, O'Neill D (2008) Planning sustainable futures for Melbourne's peri-urban region. RMIT University, Melbourne. ISBN 978-1-921426-23-0

De La Torre FR, Ferrari L, Salibian A (2005) Biomarkers of a native fish species (Cnesterodon decemmaculatus) application to the water toxicity assessment of a peri-urban polluted river of Argentina. Chemosphere 59:577–583

Ford T (1999) Understanding population growth in the peri-urban region. Int J Popul Geogr 5:297–311

Gavin B, Nicole S, Pieter S (1998) The environmental status of Hawkesbury river sediments. Aust Geogr Stud 36:37–57

Khan S, Malano HM, Davidson BM (2008) System harmonisation: a framework for applied regional irrigation business planning. Irrig Drain 57(5):493–506

Leeuwis C (2000) Reconceptualizing participation for sustainable rural development: towards a negotiation approach. Dev Change 31(5):931–959

Markich SJ, Brown PL (1998) Relative importance of natural and anthropogenic influences on the fresh surface water chemistry of the Hawkesbury–Nepean River, south-eastern Australia. Sci Total Environ 217(3):201–230

Nelson AC, Dueker KJ (1990) The exurbanization of America and its planning policy implications. J Plan Educ Res 9:91–100

Pinto U, Maheshwari B, Ollerton R (2010) Analysing variation in water quality for effective river health monitoring in peri-urban landscapes – a case study of the Hawkesbury-Nepean River system in NSW, Australia (Unpublished). University Of Western Sydney

Simon D (2008) Urban environments: issues on the peri-urban fringe. Annu Rev Environ Resour 33:167–185

Smith P, Maheshwari B, Simmons B (2014) Urban water reform in Australia: lessons from 2003–2013. Water Sci Technol Water Supply 14(6):951–960

Zhang Q, Shi X, Huang B, Yu D, Öborn I, Blombäck K, Wang H, Pagella T, Sinclair F (2007) Surface water quality of factory-based and vegetable-based peri-urban areas in the Yangtze River Delta region, China. Catena 69:57–64

Chapter 32
Development of Future Management Options for the Hawkesbury River

Bruce Simmons, Uthpala Pinto, Jennifer Scott, and Basant Maheshwari

Abstract The Hawkesbury River is a valuable community asset. In the last 200 years there have been continuous and significant changes which have resulted in declining river health and impacts on community values. Management processes which purport to arrest this decline and provide protection or improvements to the quality of the Hawkesbury River were reviewed in light of community concerns and available water quality analysis data. Clear responses in waterway condition can be linked to catchment activities and some management processes to improve river health. It appears however, many such management practices have not been assessed or are not capable of assessment. The development of a framework to assess future management proposals for protection and remediation of the Hawkesbury River is proposed.

Keywords Management options • Hawkesbury River • River health • Community concern • Water quality

32.1 Introduction

While ever there have been communities living along the Hawkesbury River it has provided a source of food, a transport system, water for drinking and irrigation, a habitat for plants and animals and a spiritual and regional setting. Indigenous Australian populations lived in balance with the Hawkesbury for more than 13,000 years according to the earliest evidence, while the nearby east coast of Australia bears testimony to over 30,000 years of occupation (Kohen 1998). For the last 220 years, however, the river has supported European settlement in the Sydney region

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from its early established role as the ‘granary’ of the colony to potable water, agricultural products and building materials for most of the cities development. The catchment is now being invaded by urban development as an area of expansion for burgeoning Sydney, and the river is providing new ways to service the needs of the region. The latest is the growth of recreational and tourism needs of Western Sydney.

There have been many plans developed to manage impacts on the river system. There are concerns however, that the effectiveness of many past and current management practices has not been assessed or understood. As a result cost benefit analysis cannot be undertaken and significant time and funds may have been wasted. As well, there has been little regard of cumulative impacts to put many management plans into perspective and understand the effects of management practices on the river system over time and as a whole.

A review was undertaken in 2013 of past and present management processes which purport to provide protection or improvements to the quality of the Hawkesbury River’s aquatic ecology and to provide an assessment of their effectiveness on the quality of the waterway. It is proposed that the outcomes of this review will have planning significance for river systems in rapidly developing areas surrounding cities (peri-urban areas) such as in Australia and Asia. Given this is the longest settled river catchment in Australia it gives lessons regarding river management options for future decision makers. The purpose of this chapter is to provide an outline of this review.

32.2 The Hawkesbury River System

The Hawkesbury River forms the western boundary of the Sydney Basin, and flows through environments ranging from upland wetlands in the higher altitudes to the main river channels draining the Hawkesbury-Nepean river catchment. The river channel varies from deep sandstone gorges to wide floodplains and includes ponds, sinuous channels and straight reaches. The river provides a wide range of habitats and landscapes in the region as well as venues for recreation and a necessary supply of water to households, industry and agriculture. The Hawkesbury-Nepean River (HNR) catchment covers approximately 22,000 km^2 and is bounded by the Great Dividing Range to the west, the Illawarra Range to the south, the hills of the Cumberland Plain to the east, and the Broken Bay Plateau to the north. It would appear that, as a normal pattern, the river is subject to alternating flood and drought dominated regimes (Warner 1994). The flooding patterns are supported by the rainfall patterns for New South Wales (NSW) since 1900 (Wiles 2007).

32.3 European Development Patterns

Whilst development of the Sydney region has had a direct impact upon the condition of the Hawkesbury River due to the urbanisation and building of impoundments and extraction of water supply in the twentieth century it was the land use changes within the catchment from the time of settlement which began the process of deterioration.

The first settlers initially cleared land along the banks of the Hawkesbury River between Wilberforce and the confluence with Rickaby's Creek. From there land was rapidly cleared from the flood plain of the Hawkesbury River and upstream Nepean River. This prompted further exploration and development of the southern highlands hence that much of this area was settled by the 1850s. Along the river and elsewhere agricultural activities involved the clearing of land, felling of trees and clearing of vegetation from riverbanks. This practice from the time of the earliest settlement caused soil loss and river bank slumping and exacerbated flooding (Atkins 1826). Land clearance and grazing resulted in erosion and sedimentation of waterways in the catchment.

From around the 1850s NSW's population began a steep upwards trajectory. This was spurred on by an influx of free settlers and, led by the discovery of gold at Bathurst to Sydney's west, by mining activities. In this period, coal and kerosene shale mines and smelting industries and primary production industries such as milling, wool spinning and weaving were developed. Activities included land clearing and road and rail construction and particularly in the rugged catchment resulted in significant soil and rock disturbance and instability and sediment transport to waterways in rain periods. The period (1850–1900) was one of intense flooding which resulted in large quantities of sand and gravel transported down the river system. Large steamers could no longer navigate to Windsor and the tidal limit moved downstream from the junction of the Grose River to just above Windsor (Rosen 1995).

By 1990, due to the expansion of Sydney the 'Upper Nepean Water Supply Scheme', a series of weirs, canals and reservoirs was competed. This scheme has since developed into five major dams the last of which was completed in 1962 with the construction of the Warragamba Dam. Prior to this the population serviced from 1888 to the completion of the Nepean Dam in 1939 had grown from approximately 300,000 to 1.5 million (Henry 1939). The impact from the Nepean Scheme is apparent in both flow patterns and sediment transport. In dry times the dams shut off water from 41 % of the catchment (Warner 1981). Dams also block the transport of coarse sediment resulting in sediment starved flows scouring channels and eroding riverbanks as was evident for long distances downstream of the dams (Warner 1983). Sand and gravel extraction to provide building materials for the expansion of Sydney has been undertaken since 1930 from flood plains and in-stream of the Hawkesbury and Nepean rivers causing further in-stream instability.

Sydney's population has continued to steadily grow over the last 200 years. After settlement and from about 1850 it appears to follow migration patterns to Australia stimulated by the gold rush from the 1850s and two world wars in the twentieth century. In 2010 the population was 4.6 million (ABS 2008). This is expected to grow to about six million by 2031 (NSW Govt. 2013a).

Sydney's urban development has largely followed a trajectory from Sydney Harbour/Parramatta River to the first known crossing point of the Blue Mountains to the west. From this line urban development has spread north and south until restricted by geographical features such as the mountains, waterways and rugged bush land. Urban development is now to spread from the trajectory in Greater Western Sydney across the Cumberland Plain, particularly in the areas known as the Northwest and Southwest Growth Centres (NSW Govt. 2013a).

In order to service extensive urban development sand and gravel extraction in the Hawkesbury/Nepean River and flood plain increased in this period. From 1952 to 1981 approximately 22 million cubic metres of sand and gravel had been removed between Penrith and Windsor. Since 1987 the Penrith Lakes Scheme has supplied approximately 50 % of the sand and gravel required by the Sydney building industry (NSW Government 2013b).

From 1950 urban development has influenced the regions hydrology in the following ways. Demand for potable supplies has grown with the population growth from 300,000 in the 1880s to approximately 4.6 million (2010). Increasing volumes of sewage effluent are being discharged to the river system. By 1980 there were approximately 34 sewage treatment works discharging to the river system servicing a population of approximately 300,000 (Approx., 72 million litres per day) predicted to grow to approximately to 1,000,000 (Approx., 240 million litres per day) by 2000 (SPCC 1983). Increasing urban development runoff also exacerbates current impacts on the river. The hardened catchment increases stormwater flows to the river, increasing flooding potential, reducing groundwater ingress and carrying pollutants into the river and tributaries. Pollutants include silts, nutrients, metals and pesticides and cause increased turbidity and increases aquatic plant growth.

32.4 Community Perceptions of the Health of the Hawkesbury River

The contemporary community perception on the health o4erf the HNR is that it is degraded and has not improved significantly over the past few decades (Jennifeer Scott et al. 2010; Tucker et al. 2006; Intergrated Catchment and Environmental Management Research Group 2003; Pinto et al. 2012; Pinto and Maheshwari 2015). Community perception analysis on river health was based on a number of river health indicators that are related to maintaining hydrologic balance (i.e., flow, water quality, depth), visual appeal (i.e., floating debris, river clarity, weeds), water-fit for-purpose (i.e., recreation, resilience, drinkable) and sustaining ecological integrity (i.e., flora and fauna, bank stability) (Pinto et al. 2012). In other words, for the community a healthy river must have a considerable degree of clarity, free from

Table 32.1 The condition of the Hawkesbury River, issues of concern

Issue/concern	Earliest date
Flooding	1789
River bank clearance	1803
Virtues of Hawkesbury River	1829
Sydney water supply needs	1838
Calls for irrigation	1881
Hawkesbury River conservancy	1884
Silting and navigation issues	1881
Pollution by sewage concerns	1903
Conflict of uses	1924
Conditions of mining leases	1928
River discoloration	1936
Noxious weeds	1941

anthropogenic pollutants, must support potable uses and must be able to sustain ecological interactions. The community is also deeply concerned about the declining river clarity and visual appeal.

How the community has related to the Hawkesbury River and expressed any concerns about the quality over time can be demonstrated by a search of Australia's newspapers. Using the TROVE research engine a search was conducted between 1803 and 1950 (the current digitised limit). Preliminary analysis indicates when general patterns of concerns have been expressed (Table 32.1), many were consistent with later analysis by Pinto et al. (2012).

The exacerbation of flooding and loss of navigation due to tree clearance and casting into the waterway was of great local concern at least up to October 1803 when a 'General Order' forbidding the practice was issued by Governor King (Chapman 1803). The impact on river banks was apparent in paintings of Windsor at that time (Simmons and Scott 2006).

During the 1890s river traffic had almost ceased because of the deposition of silt and other materials blocking the river channels. Between 1872 and 1882 more than 60 boats (many of them steamers) were trading as far as Windsor but by the year 1890 the river traffic had all but ceased because of silting (Jack 1980). This was also illustrated in paintings of Freemans Reach by Arthur Streeton in the 1890s (Simmons and Scott 2006).

Various reports of shallowing of the river were made around this time. In an attempt to solve this problem a public meeting in 1886 called for a dredge to operate on the river. This was the first dredge to operate on the river and in 1882 it commenced removing sand downstream of Windsor (Bowd 1969). After flooding continually replenished the sand in the channel the idea was abandoned and dredges were not to operate again till the need for building sand and aggregate was realised in the 1930s.

32.5 Legal and Public Decision Making Impacts on the Hawkesbury Nepean River System

In the early days the colony, including those settlements near the river, was controlled by a Governor who represented the British monarch or ‘the Crown’. The Crown owned and controlled the land, water, plants and animals. However, these institutional arrangements established in the early days of the colony set in train a decision making approach and attitudes to land use that it may be argued ignored any need to control impacts on the river. In 1862 the Real Property Act introduced the system of Torrens Title for land ownership guaranteed by government (Riley 2012). Land ownership rights traditionally permit the right’ to exploit natural resources found upon the land’ (Bates 2006). This system of exploitation of the land appears to have not only influenced private land owners but also managers of public lands (Bates 2006).

The intrinsic commodification of natural resources as a key priority directing government decision making and private venture may explain why community assets such as the river were exclusively managed for the maintenance of their direct utility to the colony. This commodification failed to recognise the land and river as part of an inter-dependent system, rather it appears to have parcelled up the land, water body and forests and regarded them as isolated resources for successive exploitation. The Torrens title system of apportioning blocks of land effectively disrupted the flow of the natural systems existent in the river catchment. The extent of this disruption appears proportional to the population density and level of human impact on the natural systems of the river (Simmons and Scott 2006). By 1900 environmental impacts were becoming evident, these impacts included introduced species outcompeting native species, a reduction in species targeted for building and furniture making and soil erosion (Pain and Wright 2003).

Patterns of land development in the Sydney Basin operated on a principle of ‘Path’ development which focused on pursuing development where communities could be most easily connected to other population centres. The early townships established around the Hawkesbury had the benefit of the river to connect them to the port of Sydney, a destination for their market goods and a general source of services and supplies. The path development pattern continues today putting development in areas most easily connected by roads and some cases rail. Sydney’s ridge top development pattern is a legacy of the historical use of the path development pattern (Troy 2004).

Separating people from the noxious effects of industry was a wise strategy. In the early years of the twentieth century public health legislation attempted to fill the void created by the ignorance of the effects of environmental degradation. Bates (2006) notes the connection between human and environmental health was a largely piecemeal approach. Pollution was initially regarded as little more than a discomfort and incidental to public health. Although the evidence mounted that there was a connection it took the better part of 100 years to recognise the cost of neglecting the impacts of pollution (Bates 2006).

After 1945 post-war activity in the Hawkesbury area was quickly intensified with the introduction of new technology. The development of agricultural technology including irrigation enabled farmers to increase the productivity of their land. Agricultural activities, less dependent on land quality, but highly polluting such as poultry and pig farming emerged in the Hawkesbury region. In the 1960s and 1970s the community was forced to take notice of the growing environmental costs bequeathed by unfettered resource acquisition, manufacture and disposal of goods on an ever increasing scale. According to Pain and Wright (2003) this period also saw the rise of organisations such as the Australian Conservation Foundation and the development of specific legislation designed to protect the environment and combat the growing number of pollution problems. Such Acts included the (NSW) Clean Air Act 1961, the (NSW) Clean Waters Act 1970, the (NSW) Pollution Control Act 1970, (NSW) the Waste Disposal Act 1970 and the (NSW) Noise Control Act, 1975. Pain and Wright (2003) also note it was during this period that government watchdog agencies such as the (NSW) State Pollution Control Commission and the (NSW) Metropolitan Waste Authority were commissioned. This legislation served to separate land use planning from environmental impact and formalise the introduction of environmental impact assessments under the (NSW) Environmental Planning and Assessment Act introduced in 1979.

There have been a number of government agencies commissioned since the 1990s to manage the health of the HNR and its catchment, viz., State Pollution Control Commission, Healthy Rivers Commission, River Management Forum, Hawkesbury-Nepean Catchment Management Trust (HNCMT), Hawkesbury-Nepean Management Authority (HNCMA) and The Office of the Hawkesbury-Nepean (OHN). The HNCMT was established in 1993 as a result of widespread community concern over the health of the HNR system and its catchment. It was considered an independent and well-coordinated government body whose programs had shown considerable improvements of river health management programs (Jennifeer Scott et al. 2010; Pinto and Maheshwari 2013). Until HNCMT was dissolved in 2001, this authority was majorly responsible for planning and management actions conducted in the catchment.

The HNCMA, now amalgamated with the Sydney Catchment Management Authority, stands as the only authority that has a direct say on the river catchment. The OHN was established in 2009 and decommissioned in 2011. The tasks conducted previously by the OHN is now distributed among a number of government agencies viz., NSW Office of Water, Office of Environment and Heritage, Metropolitan Water Directorate, HNCMA and Hawkesbury River Country Council.

32.6 River Health Improvement Programs

Over the last 30 years, the government of New South Wales has implemented a range of investigations (Tables 32.2 and 32.3) and initiatives to improve river health of the HNR. However, the effectiveness of such programs has not been evaluated

Table 32.2 Major investigations on river health

Year	Organisation	Investigations
1994	Hawkesbury-Nepean Catchment Management Trust	Hawkesbury-Nepean Task Force
1998	Healthy Rivers Committee	Independent Inquiry into the Hawkesbury Nepean River System
1999	NSW Office of Water	Stressed Rivers Assessment Report – Hawkesbury-Nepean
2005	Hawkesbury-Nepean Catchment Management Authority	Hawkesbury-Nepean River Management Forum
2008	Hornsby city council	Lower Hawkesbury-Estuary Management Plan

Table 32.3 Major river health improvement programs over the last few decades

Year	Organisation	Program
1986	MWS & DB	Nutrient Removal Program
1996	Hawkesbury-Nepean Catchment Management Trust	Phosphorus Action Program
1995	Hawkesbury-Nepean Catchment Management Trust	Erosion and Sediment Control Policy and program
2001	Hawkesbury-Nepean Catchment Management Trust	Strategic Plan for the Management of the Hawkesbury-Nepean Catchment and River System
2006	Hawkesbury-Nepean Catchment Management Authority	River Restoration Project
2007	HNCMA, NSW-DPI, Natural Heritage Trust	Hawkesbury-Nepean Catchment Weed Management Strategy
2009	Office of the Hawkesbury-Nepean	Hawkesbury-Nepean River Recovery Program
2010	Sydney Water	Replacement flows project
2007–2016	HNCMA	Hawkesbury-Nepean Catchment Action Plan 2007–2016
2012–2023	Hawkesbury-Nepean Catchment Management Authority	Hawkesbury-Nepean Catchment Action Plan 2012–2023

against the value of resources invested (i.e., River Restoration project; 2006 1.99 million dollars, Hawkesbury-Nepean River Recovery Program in 2009; 77.4 million dollars), nor has assessable or measurable improvements in river health after the program been completed. In reality, many government initiatives were restricted to short term due to limited funds. As a result most river health improvement programs have a short life span and are not conducted vigorously enough to obtain significant improvements in the river system (Pinto and Maheshwari 2013).

All of these programs have purported to offer improvement of the Hawkesbury River but only two appear to have had or could have a measurable effect on the health of the Hawkesbury River. These are Nutrient Removal from Sewage effluent and Environmental Flows.

From 1986 Sydney Water began progressive tertiary treatment of sewage effluent discharging into the Hawkesbury River System. This involved reducing ammonia concentration and nitrogen and phosphorus removal. There has been a measurable progressive reduction in plant nutrient and suspended algae (phytoplankton) concentrations in the river since this time (see next section).

The flows of the HNR are majorly influenced by water extraction for potable and industrial uses (i.e., 22 dams, 15 weirs) in Sydney, Blue Mountains and Illawarra regions, water extraction for irrigated agriculture, effluent discharged by STPs (i.e., 18 STPs) and water transfers into the Nepean and Wingecarribee Rivers from Shoalhaven River (Varley 2002). In 2005, Hawkesbury-Nepean River Management Forum decided that the provisional environmental flows that were designated in SCA's Water Management Licence were inadequate to maintain the sustainability of the river. Thus, the forum recommended the release of 'all inflows into the dam at low flow periods and release of a proportion of the inflows during medium and high flow' (Diamond 2004). The aim of his recommendation was to keep the flows in HNR similar to that of natural flows. At present, the Metropolitan Water Directorate is conducting an Environmental Flow Option Assessment to investigate whether the further release of water into the HNR from the dam could help maintain or improve the river's health.

32.7 River Health Over the Last 20 Years

Over the last few decades, the river management agencies have conducted a large number of river health improvement programs targeting the water quality and catchment health. In theory, the overall river health should be improved proportionately to the funds which had been allocated. In this section, we broadly look at water quality trends of the HNR system over the past few decades, present patterns in aquatic floral communities and highlight different flow regimes attempted by river management authorities.

32.7.1 Water Quality

There are two key documents that describe the long-term water quality data of the entire HNR System for the past 20–30 years (Krogh et al. 2008; Pinto et al. 2013). The study by Krogh et al. (2008) holistically investigated the long-term changes in water quality, quantity and range of biological variables between 1980 and 2000 using data collected for Hawkesbury-Nepean River Environmental Monitoring Program. Pinto et al. (2013) used a range of multivariate analytical techniques on six selected water quality parameters, viz., temperature, chlorophyll-a, dissolved

Table 32.4 Some long term water quality trends in the HNR

Krogh et al. (2008)	Pinto et al. (2013)
Increased water quality in many sites (e.g. indicated by decreases in filterable and total phosphorus)	River has two major zones, the polluted (middle section with a length of approximately 98 km) and clean (upper and lower sections of the river accounted for approximately 158 km of the river)
Increased electrical conductivity (indicates increased salt levels)	Increased trend in water temperature
Declined water quality in some sites (e.g. total and inorganic nitrogen downstream of West Camden Sewage Treatment Plant)	Decreased trend in suspended solids
Declined chlorophyll-*a* levels and little change in blue-green algal cell counts at many sites	There are peaks visible for NOx near STP discharge points

oxygen, oxides of nitrogen, suspended solids and reactive silicates, measured at weekly intervals between 1985 and 2008. Some key findings from studies by Krogh et al. (2008) and Pinto et al. (2013) are summarised in Table 32.4.

Figure 32.1 represents changes in z-scale standardised annual median values of four water quality variables viz., Chlorophyll-a, suspended solids, total phosphorus and total nitrogen at three locations on the Hawkesbury River.. These sites were chosen to cover the Hawkesbury river system. The North Richmond is the most upstream site. Lower Portland is in the tidal reach of the river system. In general, Total Phosphorus and Chlorophyll-a declined over the 1986–1990 period and then remained stable. This is in line with the Sydney Water's nutrient removal program, 'Water Plan 21' started in 1994. However, Total Nitrogen and suspended solids fluctuated over time. Further, all parameters fluctuated considerably at Lower Portland compared to North Richmond and Wilberforce.

Overall, the water quality of the HNR has been fluctuating on a spatio-temporal scale over the last few decades. The major reasons include changes to flow regimes, reduced loads of nutrients in STP effluent, extensive land use changes, effects of climate change and river health improvement strategies initiated by government agencies. These factors influenced at varying levels along the river resulting in relatively improved water quality in some parts of the river system while declining water quality in other parts of the river.

In the estuarine section of the river (i.e., Lower Portland), the tidal exchange plays a crucial role in determining the water quality. However, the water quality of the middle section of the river is influenced by the quality and quantity of STP discharge and surface runoff.

In general, describing the river health improvement in relation to the river health improvement strategies is a challenging task. What is evident from past river quality trends is that the river system has responded intermittently to the short-term river health improvement initiatives but failed to leave a lasting impact on the river health after the lifetime of such programs. The trend of river health improvement, in

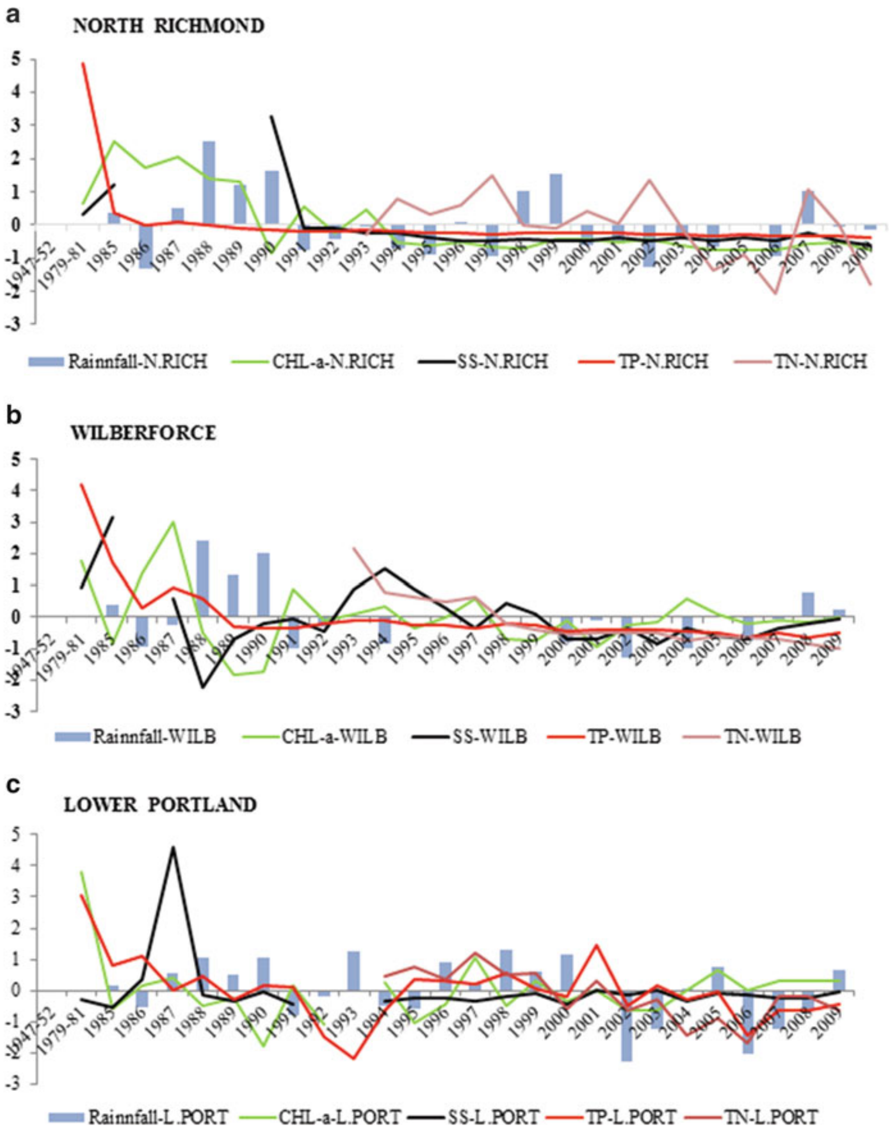

Fig. 32.1 Annual median water quality trends of Chlorophyll-a (CHL-a), Suspended solids (*SS*), Total Phosphorus (*TP*), Total Nitrogen (*TN*) and Rainfall at four sites between 1947 and 2009. Y-axis represents the z-scores of water quality variables (This data was obtained from various sources CSIRO, SPCC and Pinto et al. 2013)

relation to the number of river health improvement strategies and amount spent is not clear. The improvements we see in the river system are 'improvement in water quality from what was a relatively poor condition' and the river system has a 'long way to go before meeting water quality objectives' such as ANZECC/ARMCANZ guidelines (Krogh et al. 2008).

32.7.2 Aquatic Plants

The algae problem in the river system has been an ongoing issue viz., large algal blooms reported in 1983, 1985, 1988 and 1991 (Hawkins et al. 1994; Saunders and White 1993). However, the intensity (i.e., distribution) and the frequency of blooms has reduced over the last 5–10 years. The prime reason for phytoplankton blooms in the river system is the presence of plant nutrients in excessive levels. These nutrients are added to the river system mainly through diffuse-source pollution from urban and agricultural runoff (during high flow periods) and treated effluent from STPs (during low flow periods) (Bishop et al. 2002; Krogh et al. 2008). The reduction in intensity and frequency of large algal blooms are consistent with nutrient reduction strategies undertaken at STPs and catchment.

In 2007, the NSW Department of Agriculture conducted a survey on the abundance and distribution of submerged, emergent and floating macrophytes of the HNR (Thiebaud and Williams 2007). The major submerged genera reported were Vallisneria gigantean, Hydrilla verticillata and Egeria densa. The abundance of Vallisneria gigantean and Hydrilla verticillata was consistent with earlier studies (SPCC 1983). The extent of Egeria densa growth was viewed with concern by Roberts et al. (1999). In the past the widespread introduced species of Egeria densa, Elodea canadensis, Alternanthera philoxeroides, Eichhornia crassipes and Salvinia molesta have been considered as a considerable threat to the recreational activities and visual amenity of the river system (Thiebaud and Williams 2007).

The accumulation of nutrients and frequency of phytoplankton blooms has reduced over the last 30 years. Nevertheless, the distribution and abundance of exotic macrophytes has reduced the recreational and visual amenity of the river.

32.8 Conclusions and Recommendations

The Hawkesbury River has been a valuable community asset while ever there have communities living along the river. In the last 200 years, however, there have been continuous and significant changes which have resulted in declining river health and impacts on community values.

There are a significant number of Government acts, regulations and programs concerning protection, remediation and management of the Hawkesbury River. Issues of community and agency concerns have included river bank clearance, silting and navigation issues, turbidity, algal blooms and noxious weeds. Water quality analysis undertaken around 1980 indicated high nutrient levels and responding algal blooms. From 1986, however, there appeared to a significant response due to progressive nutrient reduction in sewage effluent. This is the only program that can be linked to the multitude of management programs developed to protect or improve the quality of the Hawkesbury River.

It can be demonstrated that clear responses in waterway condition can be linked to catchment activities and some actions to improve river health. It appears however, many such actions or management practices have not been assessed or are not capable of assessment. The development of protocols or a framework to assess future management proposals for protection and remediation of the Hawkesbury River is recommended. It is suggested that this include investigation of legal river status with recognised values and rights of its own, as has been undertaken in New Zealand and Canada.

References

Archer J (2014) Rivers, rights & reconciliation in British Columbia: lessons learned from New Zealand's Whanganui River agreement (January 3, 2014). SSRN: http://ssrn.com/abstract=2374454 or http://dx.doi.org/10.2139/ssrn.2374454

Atkins J (1826) An account of the state of agriculture and grazing in New South Wales. Sydney University Press, London, UK, Reprint 1975

Australian Bureau of Statistics (2008) Population projections, Australia, 2006 to 2101 Issue Released) 4 Sept 2008 Canberra. http://www.abs.gov.au/Ausstats/abs@.nsf/mf/3222.0. 17 Nov 2013

Bates G (2006) Environmental law in Australia, 6th edn. Lexis Nexis Butterworths, Sydney, Australia

Bishop K, Growns I, Church T, Warner R, Taylor E (2002) Status of the health of the Hawkesbury Nepean River. Independent expert panel on environmental flows, for the Hawkesbury Nepean, Shoalhaven and Woronora Catchments

Bowd DG (1969) A history of the Hawkesbury. Library of Australian History Publication, Macquarie Country

Chapman WN (1803) Sec. Government House, Sydney, Oct 4. 1803. The Sydney Gazette and New South Wales Advertiser. 1803. 'General Orders' Sunday 9 October 1803

Diamond R (2004) Water and Sydney's future- balancing the value of our rivers and economy. Final report of the Hawkesbury-Nepean River Management Forum. Department of Infrastructure, Planning and Natural Resources, Sydney

Hawkins P, Hill B, Saunders J, Kobayashi T, Winder J (1994) Algal bloom dynamics in the Hawkesbury-Nepean River (October 1992–March 1993). Australian Water Technologies, West Ryde
Henry FJJ (1939) The water supply and sewerage of Sydney. Halsted, Sydney
Intergrated Catchment and Environmental Management Research Group (2003) Values, attitudes and issues around creeks, rivers and waterways: a community survey within the Hawkesbury Local Government Area. University Of Western Sydney, Sydney, Australia
Jack RI (1980) A colonial scene – the Hawkesbury Nepean Valley. Department of Adult Education, Sydney University, Sydney, Australia
Kohen JL (1998) Aboriginal environmental impacts in the Hawkesbury River area', in the improvers legacy – environmental studies of the Hawkesbury. Deerubbin Press, Berowra Heights, NSW Australia
Krogh M, Wright A, Miller J (2008) Hawkesbury Nepean River environmental monitoring program: final technical report [online]. Department of Environment and Climate Change NSW and Sydney Catchment Authority, Sydney. Available: http://www.environment.nsw.gov.au/resources/water/09112hnrempfintechrpt.pdf. Accessed 16 Feb 2012
NSW Government (2013a) Draft metropolitan strategy for Sydney to 2031. Mar 2013 © Crown Copyright 2013 ISBN 978-0-7313-3570-1
NSW Government (2013b) A premium Western Sydney destination for Waterside recreation, working and living [Online]. Office of Communities. Available: http://www.opl.nsw.gov.au. Accessed 31 Dec 2013
Pain N, Wright S (2003) The rise of environmental law in New South Wales and federally: perspectives from the past and issues for the future. National Environmental Law Association Annual Conference. Broken Hill
Pinto U, Maheshwari B (2013) Sustaining the river health in peri-urban fringes: a multi-perspective analysis through key informant interviews. J Hydrol Eng 19(6):1060–1068
Pinto U, Maheshwari BL (2015) Community perspectives on managing health of peri-urban river system: evidence from the Hawkesbury-Nepean river catchment, Australia. J Environ Plan Manag:1–20
Pinto U, Maheshwari BL, Ollerton RL (2013) Analysis of long-term water quality for effective river health monitoring in peri-urban landscapes – a case study of the Hawkesbury–Nepean river system in NSW, Australia. Environ Monit Assess 185(6):4551–4569
Pinto U, Maheshwari BL, Shrestha S, Morris C (2012) Understanding the meaning of river health for a community: perspectives from the peri-urban region of the Hawkesbury–Nepean catchment, Australia. Water Policy 14(5):766–783
Riley C (2012) Land ownership timeline in New South Wales, Genealogy in New South Wales blog [Online]. Available: http://heritagegenealogy.com.au/blog/land-ownership-timeline/. Accessed 14 Oct 2013
Roberts D, Church A, Cummins S (1999) Invasion of Egeria into the Hawkesbury-Nepean River, Australia. J Aquat Plant Manag 37:1999
Rosen S (1995) Losing ground: an environmental history of the Hawkesbury-Nepean catchment area. Hale and Ironmonger PL, Sydney
Saunders J, White B (1993) The blue-green algal bloom in the Hawkesbury River at the Sackville Ferry during the summer of 1991/2. Wetlands (Australia) 12:30–38
Scott J, Simmons B, Parissi C (2010) River keeper feasibility study. University Of Western Sydney, Richmond
Simmons B, Scott J (2006) The river has recorded the story, living with the Hawkesbury River, Sydney, NSW, Australia. In: Tvedt T, Jakobsson E (eds) A history of water: water control and river biographies. IB Tauris, London/New York, p 253
SPCC (1983) Water quality in the Hawkesbury-Nepean River: a study and recommendations. State pollution control commission, Sydney, 207 p
Thiebaud I, Williams R (2007) Distribution of freshwater macrophytes in the Hawkesbury Nepean River from Warragamba Dam to Wisemans Ferry. NSW Department of Primary Industries Port Stephens Fisheries Centre, Nelson Bay

Troy P (2004) The structure and form of the Australian City: prospects for improved urban planning issues. Urban Policy Program. Griffith University, Brisbane, Australia

Tucker D, Jorgensen BS, Nancarrow BE, Leviston Z, Johnston CS (2006) Sense of place: towards a methodology to value externalities associated with urban water systems: the Hawkesbury-Nepean case study

Varley I (2002) Water balance for the Hawkesbury Nepean River System. Independent expert panel on environmental flows for the Hawkesbury Nepean, Shoalhaven and Woronora Catchments

Warner R (1981) The impacts of Dams and Weirs on the Hawkesbury-Nepean River System, NSW, Australia. Second international fluvial conference, 1981 Keele, UK. Keele University

Warner R (1983) Channel changes in the Nepean River, NSW. In: Proceedings of the 53rd ANZAAS Congress, 1983 Perth

Warner R (1994) A theory of channel and floodplain responses to alternating regimes and its application to actual adjustments in the Hawkesbury River, Australia. In: Kirby M (ed) Process models and theoretical geomorphology. Wiley, Chichester

Wiles P (2007) Climate change and variability: observed trends for Australia, NSW and the Namoi. NSW Climate Services Centre, Climate Change and Agriculture

Chapter 33
Planning Development to Reduce Mosquito Hazard in Coastal Peri-Urban Areas: Case Studies in NSW, Australia

P.G. Dwyer, J.M. Knight, and P.E.R. Dale

Abstract In this chapter we take a multidisciplinary approach to evaluating planning for coastal development, particularly in peri-urban areas. We consider ecosystem services and disservices and how, in the past, much development was at the expense of coastal wetlands. We then focus on mosquito production as a wetland related disservice that affects residents and imposes costs on individuals and government from both a health and management perspective. Most coastal peri-urban areas including adjacent wetland sites retain legacy infrastructures and landforms that degrade wetland function and often exacerbate the mosquito hazard. Rehabilitating coastal wetlands can improve wetland function while also reducing the mosquito hazard. Yet examination of rehabilitation and mosquito management within the existing planning framework found deficiencies and complexity. In particular, coastal wetlands are almost always overlaid with a number of different zone and ownership boundaries that increase complexity of both mosquito management and wetland rehabilitation actions. We illustrate the issues with two case studies from northern New South Wales (NSW), Australia: a greenfield development located in Ballina and a retrofitted site at Banora Point near Tweed Heads. We recommend land use planning frameworks incorporate a trigger for both assessment of adjacent coastal wetland ecosystem function and restoration of wetland ecological processes that includes provision for habitat based source control of mosquito hazard and coastal wetland rehabilitation.

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33.1 Introduction

Population growth in Australia is concentrated in the coastal zone, and especially along the south east of the continent (ABS 2014) where enjoyment of the coastal environment is a strong attraction for many people. Growth pressure has produced increasingly rapid coastal zone development and has been termed the 'sea change' phenomenon (Gurran et al. 2006). However, the geography of the coastal zone, including rivers, wetlands and floodplains, is a constraint on urban development that has led to peri-urban development close to the coast. Coastal peri-urban areas are a temporal and spatial mosaic of agricultural land and open spaces being gradually converted to housing with some natural areas being retained for green space.

In this chapter we take a multidisciplinary approach to examining planning issues for coastal development in peri-urban areas. Initially we look at coastal wetlands, and the incumbent mosquito hazard, in the context of ecosystem service. The issue of mosquito production receives little consideration in planning even though mosquito borne diseases and mosquito control incur considerable cost for individuals and government. We also consider the legacy of past impacts on coastal wetlands and issues around rehabilitation that are rarely incorporated into planning, though the impacted wetland can be a constraint for development and future residents. Through two case studies, a 'greenfield' and a 'retrofit' development, we explore some options to address these impacts on coastal wetlands.

Greenfield developments often involve the subdivision of agricultural or open space land and the provision of urban infrastructure such as roads, green space and other services. Retrofit developments occur at already developed sites and involve modifying infrastructure to minimise unintended environmental impact, for example, incorporating water sensitive urban design features into an existing stormwater network. Replacement, technological improvement or additional information can be retrofit triggers. Retrofit works are often costly, involving design and outcome compromises because of constraints imposed by the existing infrastructure setting. Consequently, there is little commercial incentive to undertake retrofit works which are therefore generally undertaken by public authorities often in response to regulatory risk. By contrast greenfield developments are generally undertaken for commercial profit. Both development types can require approvals from relevant authorities.

33.2 Ecosystem Services: A Context for Development

The ecosystem services concept provides a common language for ecologists, planners, resource users, decision makers and the broader community to contribute and evaluate technical and experiential information about the links between human and ecological systems (Granek et al. 2010). Ecosystem services are the 'products of nature that directly benefit humans' (Schmidt et al. 2014, p. 57) and where these products have a negative impact or cost there can be an ecosystem disservice (Lyytimaki and Sipila 2009). Coastal wetland services include fish and bird habitat and coastline protection and have economic value, while disservices, such as mosquito production, can have social, economic and health costs (Dale and Knight 2012). Without effective safeguards peri-urban development in coastal environments can reduce delivery of ecosystem services and increase delivery of ecosystem disservices (Niemelä et al. 2010).

33.2.1 Coastal Wetlands in Peri-Urban Areas

Intertidal coastal wetlands are dynamic systems that are habitat for mangrove and saltmarsh plant communities. They deliver a wide range of ecosystem services (Perillo et al. 2009) providing a range of value and non-value uses (see Barbier et al. 2010 for a detailed review) including nursery habitat for commercially and recreationally important fish species (Sheaves et al. 2014), habitat for migratory birds (Visser and Baltz 2009) and aesthetic green spaces. Coastal wetlands improve water quality by stripping nutrients and intercepting sediments, and they reduce erosion by protecting the foreshore from waves and currents (Costanza et al. 2006). In addition, mangrove and saltmarsh are amongst the most efficient ecosystems in the world at sequestering carbon (Saintilan et al. 2013) and are being investigated for future Blue Carbon opportunities (e.g., Mcleod et al. 2011; Irving et al. 2011).

However loss of coastal wetlands is a major concern globally (Irving et al. 2011) with urbanisation and development identified as the most common cause of mangrove loss (Dale et al. 2014). Losses in New South Wales (NSW) Australia have been estimated at 60 % for the period from European settlement (1788) to 1970 (Goodrick 1970) with losses continuing to occur (Pressey and Middleton 1982). More recently loss of saltmarsh (Saintilan et al. 2014) has resulted in its listing as an endangered ecological community within NSW and nationally.

The high conservation value of coastal wetlands is now better recognised with many protected by legislation and sometimes via land use zonings. However, even when there is protection via zoning or other means, coastal wetlands often retain legacies of past land uses that pre-date the zoning. Clearing, draining and construction of roads associated with agricultural and urban development are major contributors to loss, fragmentation and degradation of coastal wetlands (Williams and Watford 1997). In the NSW coastal zone several thousand structures that could

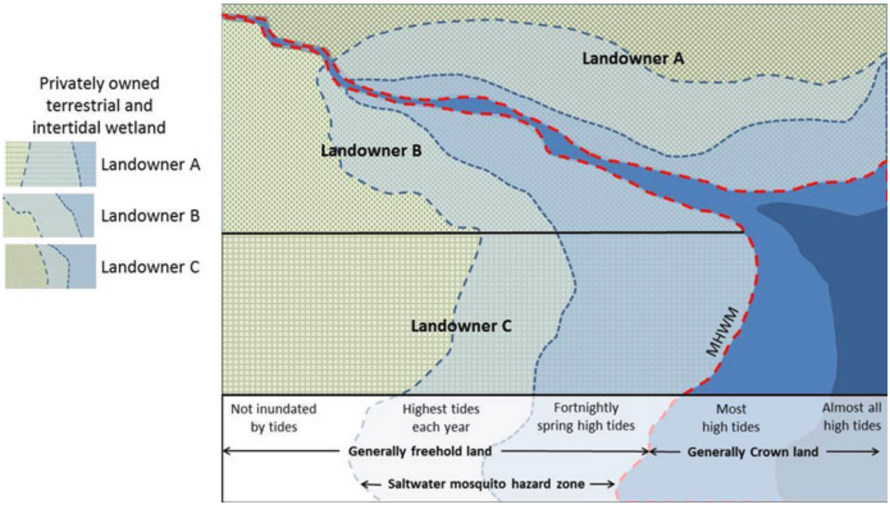

Fig. 33.1 Coastal wetlands and jurisdictional boundaries in NSW

affect wetland hydrology leading to wetland damage and loss were identified by Williams and Watford (1997). Structures identified included field drains, floodgates, culverts and levees that were originally installed to alter tidal hydrology and improve agricultural potential. However in a post agricultural peri-urban landscape, such infrastructure is often redundant or orphaned due to the land use change. Yet, even in a deteriorated state, they often continue to operate suppressing tidal processes, fracturing ecological function and impacting on wetland ecosystem service delivery. Underpinning these changes is alteration of two key ecosystem functions: hydrology and sedimentation (Lee et al. 2006). Disservices that can result include poor water quality resulting from exposure of acid sulfate soils leading to fish kills and reduced oyster aquaculture production, loss of coastal wetland vegetation and weed incursion, unpleasant odour from rotting vegetation and increased mosquito hazard (Knight et al. 2012). Also soil compaction and subsidence resulting from long term desiccation can occur due to altered tidal function (Rogers et al. 2006).

Land tenure and jurisdictional boundaries influence the response to ecosystem disservice. In NSW the Mean High Water Mark (MHWM), a statistically derived conceptual line, is used as both a natural feature boundary and a zoning and property boundary. Consequently, coastal wetlands, which almost always extend landward beyond the MHWM, are often intersected by arbitrary boundaries (Fig. 33.1). Generally, Crown land (public land owned by the State) occurs below the MHWM. Freehold land generally extends landward from the MHWM across tidal and supratidal wetland areas (inundated by only the highest tides of the year) into terrestrial environments. Tidal and supratidal areas above the MHWM, are however, both an integral component of the coastal wetland environment and the areas with the greatest risk for saltwater mosquito production (Knight 2011). Furthermore, multiple private owners are often co-located within a single coastal wetland and this can increase the complexity of saltwater mosquito management and more broadly, coastal planning.

33.2.2 Mosquito Hazard: An Ecosystem Disservice

Saltwater mosquitoes, *Aedes vigilax* and *Ae. camptorhynchus*, breed prolifically in mangrove and saltmarsh areas where their lifecycle is tuned to tidal cycle inundations such as fortnightly spring tides (Knight 2011). Apart from a blood meal, the main prerequisites for saltwater mosquito breeding success are: moist substrate on which eggs are laid, flooding to trigger egg hatch, and, standing water to provide a habitat for larval development. The whole process can take as few as 11 days in summer. But when conditions are unsuitable saltwater mosquito eggs can survive both desiccation and multiple wetting-drying cycles before hatching. Consequently, a store of viable eggs can build up ready to hatch when conditions are suitable (Knight 2011).

Apart from breeding in natural habitats, large populations of saltwater mosquitoes are often a symptom of degraded coastal wetlands (Webb and Russell 2009; Webb 2013). Tidal inundation, water quality and mosquito production are influenced by a site's microtopography. Differences in relative elevation of the ground surface within the wetland as little as 0.1 m may be sufficient to facilitate mosquito production (Knight et al. 2009, 2013a; Griffin et al. 2010). Consequently, even small depressions, vehicle tracks and mounds of sediment incidentally left in tidal areas from development or agricultural activity can unwittingly increase the saltwater mosquito hazard. Also, disturbed wetlands, artificial drains and artificial drainage areas have been found to produce some of the highest densities of saltwater mosquito larvae (Gislason and Russell 1997; Jacups et al. 2009).

Saltwater mosquitoes are a significant health hazard because they are vectors for the two main mosquito borne viruses affecting people in coastal Australia: Ross River virus (RRv), and Barmah Forest virus (BFv) (Naish et al. 2006; Russell 2002). These diseases bear significant cost for both society and the individuals affected (Harley et al. 2001; Ratnayake 2006). RRv is the most common and important (Lyth et al. 2005) with close to 5000 cases reported each year in Australia (NNDSS 2014). It causes polyarthritis with debilitating arthritic symptoms that may persist for several months incapacitating some adults for 5–6 weeks. For some people recovery may take longer and chronic fatigue type syndrome persists in ~10 % of patients (Gilbert et al. 2013). BFv has similar symptoms to RRv but is less prevalent with an average of 1868 notification annually (NNDSS 2014). Mosquito control is also costly. Data for Queensland show that costs, for the State, rose from AUD7 million in 1993 to AUD11 million in 2004 (Tomerini 2007) and may have exceeded AUD20 million in 2014.

Kangaroos and wallabies are a major natural reservoir of RRv, causing the disease to be thought of as a rural one, but it is increasingly prevalent in peri-urban environments (Webb 2014; Tong et al. 2008). In addition, saltwater mosquitoes can disperse widely in their search to find a blood meal and, with wind assistance, can range up to 50 km from larval habitats in coastal wetlands (Naish et al. 2012). This has consequences for the 80 % of Australians who live within 50 km of the coast (ABS 2014).

33.2.3 Managing Mosquitoes

Integrated mosquito control programs (IMCPs) use a variety of chemical products and methods to control mosquitoes while minimising cost and resistance issues. Currently IMCPs focus on treatment of larval habitats using chemical larvicides (such as *Bacillus thuringiensis* var *israelensis*) or insect growth regulators (such as S-methoprene). Generally, chemical control is achieved by aerial application but in areas with dense vegetation (e.g., sedge *Juncus* sp.) the canopy can reduce the amount of larvicide reaching the pools where the larvae reside (McGinn and Sullivan 2013). Mangrove canopy is likely to cause a similar limitation. Pelletised and briquette formulations of chemicals can overcome the problem of dense canopies but often require more time consuming direct application. In NSW mosquito control is not mandatory and only a limited amount of aerial spraying occurs, mainly in the Tweed local government area just south of the Queensland border.

Another method used in IMCPs is source reduction. This involves modifying the environment to minimise conditions suitable for mosquitoes. In Australia this is usually achieved by runnelling, a process that involves construction and maintenance of shallow channels that connect saltmarsh pools to the tide source to modify the tidal inundation regime to one less suited to saltwater mosquitoes (Hulsman et al. 1989; Dale and Knight 2012). LiDAR data has been used to detail the micro-topography within mangrove systems enabling runnel-like techniques to be tested in mangrove environments (Knight et al. 2009).

33.2.4 Development Buffers: An Indirect Approach

Planning decisions can complement IMCPs by providing for buffers between mosquito habitats and urban settlement. The buffers are cleared areas between housing developments and known mosquito habitats. They can reduce the hazard from some mosquito species (such as *Verrallina funerea*) that disperse only relatively short distances (<1 km). Maintenance is needed to prevent establishment of understorey or continuous vegetation that provide harbourage or flight corridors. Mosquito buffers can also serve as bushfire asset protection zones and contribute to open space within a development. When bounded by a single fronted road defining the urban edge, they also assist in delineation of public and private space.

33.2.5 Rehabilitation

To mitigate adverse effects of past development rehabilitation has the potential to restore some coastal wetland function and minimise mosquito issues. Rehabilitation has been defined by Elliott et al. (2007, p. 354) as 'the act of partially or, more rarely, fully replacing structural or functional characteristics of an ecosystem that have been reduced or lost…'. Elliott et al. (2007) goes on to note that: '…the rehabilitated state is not expected to be the same as the original state or as healthy, but an improvement on the degraded state.' The intent is to provide more ecosystem services and fewer disservices, (i.e., positive not negative outcomes).

Identifying and rehabilitating the ecological functions that drive ecosystem service provision should be a focus of rehabilitation efforts (Simenstad et al. 2006). Key to rehabilitation success is a thorough understanding of the issues and options followed by restoration of the appropriate hydrologic conditions (Lewis 2005; Turner and Lewis 1996; Dale et al. 2014). In practice, this can become complicated where unintended/unforeseen outcomes can occur. For instance, Turner and Streever (1999) increased tidal flows in a coastal wetland by removing two small culverts in a road crossing, replacing them with a channel and bridge. They found that reconnecting tidal flushing significantly reduced mosquito production in the immediate vicinity. However, increased tidal connectivity into the rehabilitated marsh also enhanced flushing to the high marsh areas and, in one area, this actually enabled mosquito production. Webb (2015) recommends judicious use of chemical larvicides to limit the potential for mosquito hazard during the initial response phases of wetland rehabilitation as ecological functions re-establish.

Many coastal greenfield development sites within NSW occur in a peri-urban landscape with agricultural or post agricultural features. Well planned greenfield developments, in addition to minimising impacts can undertake actions to rehabilitate the adverse effects of previous land uses. Such rehabilitation has the potential to not only restore some wetland function, but also to minimise mosquito issues.

33.3 Planning Framework for Coastal Development in NSW

Within the state of NSW there are policies for wetland management. These include three state-wide policies that support protection and rehabilitation of wetlands: NSW Wetlands Policy (NSW Govt 2010), NSW Fish Habitat Conservation and Management Policy and Guidelines (NSW Govt 2013), and NSW Biodiversity Offsets Policy (NSW Govt 2014). The three policies are intended to work together to outline where development impacts on wetlands should be avoided, mitigated or offset with rehabilitation works at another site. In addition to consideration of these policies, some development proposals may trigger approval requirements under other NSW legislation such as the *Water Management Act* 2000 or the *Fisheries Management Act* 1994. Conditions for approvals under these Acts are generally determined at the development assessment stage via referral to relevant state agencies.

Within NSW there is also a state based planning and zoning regulation framework that establish how land can be used and how that use can be changed. The principal planning statute in NSW is the *Environmental Planning and Assessment Act* 1979. State Environment Planning Policy 14 Coastal Wetlands (SEPP14), gazetted in 1984, is a planning instrument that influences management of mosquito hazard. It prescribes that within mapped SEPP 14 wetlands clearing of vegetation, levee bank construction, draining and filling activities require assessment by an environmental impact statement. Consent authorities such as local councils must apply state planning instruments when determining a development application. They also consider Local Environmental Plans (LEPs) which are legislative documents that outline permissible land uses within mapped zones. Development Control Plans (DCPs) are non-legal, issue or site specific documents that provide planning and design guidance for development assessment.

DCPs for mosquito hazard have been gazetted by three local authorities in northern NSW (Tweed, Byron and Ballina). Each recommends:

- Provision of general advice for residents and prospective developers;
- Identification of risk zones; and
- That major residential development proposals include a qualified and experienced entomologist in the consultancy team.

The DCPs acknowledge that on-site habitat modification may reduce biting insect breeding. However the opportunity to link rehabilitation of wetland function and delivery of other ecosystem services with mosquito source control is not developed into a recommendation.

Having outlined the planning situation and identified some problems with development that does not take account of ecosystem services and disservices we now present two illustrative case studies. The case studies demonstrate how restoration of ecological function can be a shared objective of both coastal wetland rehabilitation and saltwater mosquito hazard source control. One case study focuses on the development of a greenfield site and the other looks at a retrofit for an existing area adjacent to a degraded coastal wetland. Both are set in coastal peri-urban landscapes. These provide some guidance for new development planning and for retrofitting in established developments.

33.4 Case Studies

The case studies came from the first author's direct experience. In the first case study this was managing the planning approval processes on behalf of DPI Fisheries and in the second case study as a member of a team investigating wetland rehabilitation options at the site. Case study selection was made on the basis that they illustrated the two types of development occurring in the peri-urban coastal zone, new or greenfield site development and retrofitting components of an already developed site.

33.4.1 Case Study 1: Greenfield Site

In 2003 a 43 ha former cattle grazing property (Fig. 33.2) was the subject of a development application for 19 ha to be filled with imported earth, to create a ground level above flood height followed by construction of several hundred self-care dwellings with facilities for housing aged and disabled people (Fig. 33.3). The majority of the site is low lying, with natural ground level elevations measuring <1–2 m Australian Height Datum (AHD). Mean sea level is 0 m AHD, and the highest tides of the year occurring at the site reach 1 m AHD. During the 1970s

Fig. 33.2 The greenfield development site

Fig. 33.3 The proposal for several hundred self-care dwellings (Source: King & Campbell Pty Ltd, 2003)

surface and groundwater hydrology was modified to promote drainage for agricultural use. The natural waterways were deepened and straightened and floodgates were installed to control flow regimes. Floodgates are one-way valves installed across waterways to allow drainage from the site during low tides but preclude re-inundation by higher tides. This fragmented and degraded the coastal wetland. Part of the wetland was listed as a SEPP 14 Coastal Wetland in 1985. Grazing activities, causing periodic discharges of poor quality water with impacts on a nearby oyster farm and the broader estuary, continued until construction of the housing development commenced (Fig. 33.3).

33.4.2 Constraints and Approvals

The local authority responsible for determining the development application, Ballina Shire Council, used the Ballina Mosquito Management DCP (Ballina Shire Council 2003) to guide their assessment of the application. The DCP recommends the proponent use a qualified and experienced entomologist to incorporate relevant guidelines from the DCP into the application and ensure their effective implementation during construction. Recommendations in the DCP that became conditions of the local authority's approval mainly related to infrastructure (Ballina Shire Council 2004) and included:

- community buildings to be fully screened against mosquitoes;
- self-closing doors to be fitted at all points of entry; and
- screening structures to be installed over swimming pool and barbeque areas.

In addition to the DCP guidelines, the local authority mandated that prospective buyers of units within the development be notified and given access to the reports concerning mosquitoes prior to purchase (Ballina Shire Council 2004).

The proposal also triggered provisions within the NSW *Fisheries Management Act* 1994 requiring the application be referred to the fisheries agency for conditions of approval. The fisheries agency imposed additional conditions for better management of the wetland by:

- excluding development from occurring within a 100 m buffer between the mapped SEPP14 Wetland boundary and the development; and
- requiring preparation and implementation of a wetland rehabilitation and buffer management plan involving the removal of floodgate valves to promote tidal flushing.

These conditions aimed to achieve better management of the wetland. Because the mapped SEPP14 Wetland boundary did not encompass the whole wetland, the 100 m buffer circumscribed the wetland and provided an area where manipulations could be made to both rehabilitate wetland function and reduce the source of the mosquito hazard. Implementation of the wetland rehabilitation and buffer management plan had to commence during the early stages of the proposed development.

33.4.3 Lessons

Satisfying the conditions of approval required the developer to prepare and implement a rehabilitation management plan with planned and adaptive elements. Removal of one-way tidal floodgate valves enabled tidal inundation and introduced a more natural tidal hydrology into the wetland. Cessation of stock grazing at the site removed a disturbance stressor that had been degrading the wetland. Grazing in wetlands can exacerbate the mosquito hazard as hoof prints from stock walking in boggy sediments create a rough surface with hummocks for mosquito ovipositing and depressions that can be used as larval habitats.

The effect of site rehabilitation was a reduction in saltwater mosquito habitat (McGinn 2012). Reinstatement of tides partially restored hydrologic and sedimentary function within the wetland allowing silt to be deposited across the saltmarsh surface. Without the disturbance of stock grazing, this process continues to fill the old cattle hoof prints reducing larval habitat, while the increased frequency of tidal inundations reduces egg laying opportunities.

As work at the site progressed the wetland rehabilitation plan was adapted to incorporate installation of six channels for tidal flushing through an old levee to better link isolated pools. Removal of some river oaks (*Casuarina glauca*), a native pioneer plant species that had established on the levee, was required to ensure longevity of flushing channels. Future management of grey mangrove (*Avicennia marina*) and river oaks will be required to ensure flushing continues at a rate sufficient to minimise the mosquito hazard.

Restoration of tidal flushing was the key action that drove rehabilitation and provision of improved ecosystem services. Tidal inundation of saline water forms an additional service for the landowners as it is a cost effective weed suppressant along waterway margins at the site. Tidal inundation is compromised, however, by the small aperture of the culvert through which the tide is flushed. Thus, rehabilitation has been only partial but the site is still expected to provide more sustained delivery of ecosystem services rather than disservices. The system is not self-sustaining, however, and maintaining the improved conditions will require periodic management interventions. Planners and decision makers should appreciate that only achieving a portion of the total possible ecosystem service is a common outcome in urban areas (Bolund and Hunhammar 1999).

33.4.4 Case Study 2: Retrofitting Existing Development

A coastal mangrove wetland was directly impacted by urbanisation and the development of a nearby canal estate during the early 1980s (Fig. 33.4). With no buffer between the coastal wetlands and residential housing, degradation of coastal wetland habitat occurred. Today's residents experienced mosquito hazard and other disservices including odour, poor water quality, degraded vegetation and weed

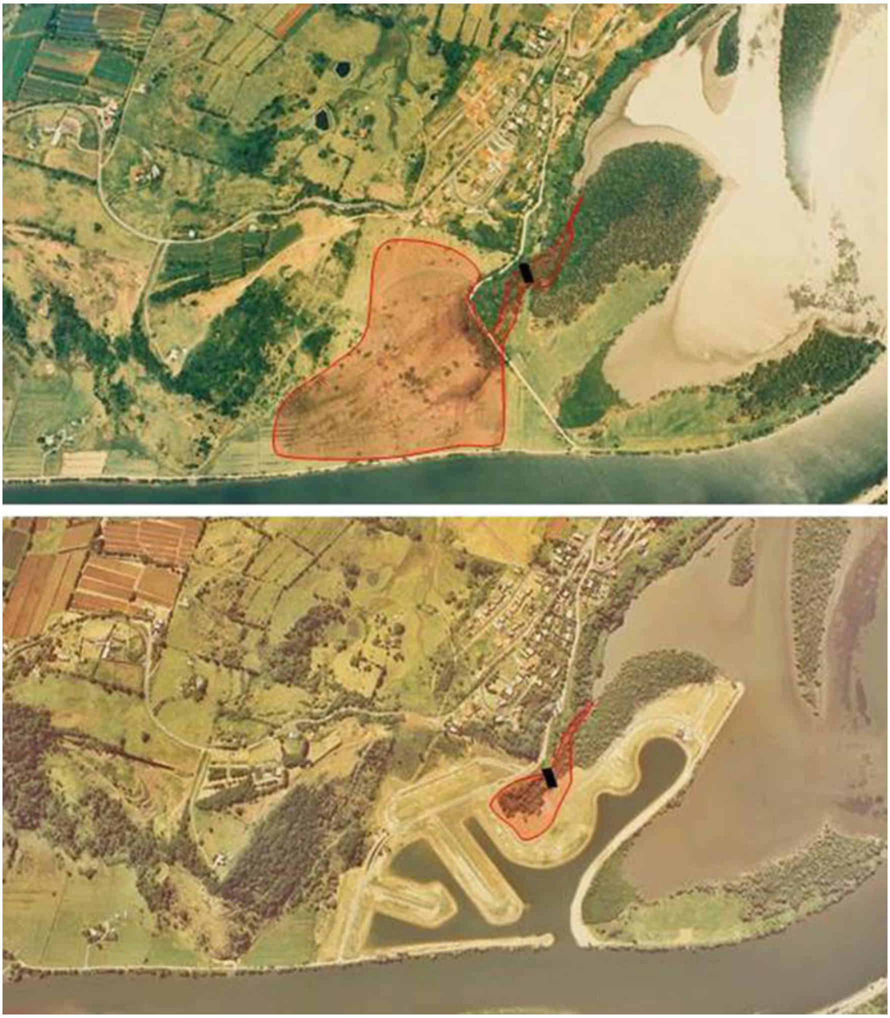

Fig. 33.4 Aerial photos from 1970s (top) and 1980s (bottom) showing the levee and catchment change that have contributed to the odour, poor water quality, weed incursion and mosquito hazard experienced by today's residents

incursions. The site has been regularly treated for the mosquito hazard via pelletised application of S-methoprene. However, persistent complaints from residents prompted Tweed Shire Council to consider a more holistic solution.

Preliminary investigations found part of the mangrove wetland to be poorly flushed due to a constructed levee across the tidal creek, limiting tidal exchange and creating an artificial back basin. The 0.4 m high levee is thought to be a legacy from the installation of overhead powerlines at the site in 1962. Subsequently, construction of an adjacent canal estate reduced the size of the catchment area of the waterway substantially, limiting catchment inflows and tidal amplitude (Fig. 33.4). Collectively, these works created a basin that is inundated by only the highest tides and by runoff from rainfall creating an ideal saltwater mosquito habitat.

33.4.5 Constraints and Approvals

To restore tidal flushing and rehabilitate ecosystem function at the site, with the purpose of improving ecosystem services and minimising disservices, Knight et al. (2013b) recommended that the Tweed Shire Council:

- reconnect the basin by modifying the level of the levee, and
- enhance tidal connectivity to:

  (a) manage mosquito production; and
  (b) restore system health.

These physical works triggered environmental assessment via a Review of Environmental Factors (REF) required by the *Environmental Planning and Assessment Act* 1979. The REF mandated management of potential acid sulfate soils, sediment and erosion control and other measures to avoid or minimise impacts of the proposed works. The REF process also identified that a conditional approval under the *Fisheries Management Act* 1994 was required. During the approval process the presence of major underground telecommunications cables in the vicinity of the levee was also identified. This delayed action and forced an assessment of how the physical works would be undertaken.

33.4.6 Lessons

Retrofit sites often require site specific tailored solutions. They require the specific mobilisation of plant and equipment in established areas where there are additional constraints on operations. Retrofit projects are rarely undertaken within a strategic framework and are often ad hoc in response to persistent public complaints. They often have limited funding available. Consequently, retrofit works often involve compromise. In this case study what was initially perceived as an obvious and easy solution became more complicated because of the legacy of historic and existing infrastructure. With each compromise the potential to actually improve on the degraded state favouring services rather than disservices should be re-evaluated. With this case study, while the constraint presented by the telecommunication cables was not identified until late in the planning process, its identification does demonstrate a strength of the existing regulatory and assessment framework.

33.5 Discussion

33.5.1 Constraints on Integrated Development and Mosquito Management

A framework of legislation and policy that constrains development within and adjacent to coastal wetlands is necessary for maintaining the valuable ecosystem services they provide. However, the existing framework can be perceived as a disincentive to restore degraded wetland function and improve ecosystem services. Similarly mosquito control agencies have found obtaining approvals to modify wetlands and use alternative environment-based approaches to reduce the mosquito hazard can be difficult (Webb et al. 2009; Dale and Knight 2012; Webb 2013). A trigger is needed within the existing framework of legislation and policy to assess the form, function and management of wetlands when adjacent lands are being developed. Further, it needs to promote (or require) action that reduces the mosquito hazard while also sustaining or rehabilitating coastal wetlands to favour the delivery of ecosystem services.

33.5.2 Local Government Planning Programs

Appropriate land use planning programs can make savings for local governments and their communities (Burby et al. 2000), but must address relevant problems. For peri-urban development in coastal areas planning programs need to consider population growth, mosquito hazard and wetland services. Assessment of development proposals adjacent to wetlands, including mosquito risk and management options, can be a catalyst for addressing orphan infrastructure and other legacies of former land uses. This should include correcting fractured ecological function and minimising the mosquito hazard. Investigations and assessments should consider the whole wetland as a single hydrologic unit rather than the extent of a planning zone or property boundary (Dale et al. 2010). Adopting a wetland hydrologic unit approach maximises both the environmental outcomes and benefits for new residents of developing peri-urban areas.

33.5.3 Codes to Ensure Sustainable Outcomes

Codes of practice can be used to outline activities that can and cannot be undertaken in coastal wetlands. They should identify wetland forms and rate their vulnerability to certain classes of activity. Where low risk activities are proposed, specific operating procedures tailored to specific wetland forms can outline the circumstances under which an activity can occur.

Codes should reflect the need for understanding of the vulnerability of wetland form and function to subtle changes in or beyond the wetland. Codes should facilitate wider application of well managed rehabilitation actions based on appropriate science. Codes should ensure that the development actions of proponents do not make things worse. They should set out the need for ongoing monitoring by landowners to facilitate adaptive management and preparedness to respond to unforeseen changes in wetland response. We also recommend that a code be developed which outlines how local authorities can, and should, maintain a register of wetland rehabilitation sites and a library of management strategies that have been employed.

33.5.4 Practical Considerations for Peri-Urban Areas

The majority of coastal greenfield development sites retain infrastructure or landscapes from their historic land uses. Ignoring or poorly managing these legacy features, particularly during land use change, can further degrade coastal wetlands, exacerbate mosquito hazards and potentially cause other disservices (odour, poor water quality, weeds, etc.). When ecosystem function is not considered during the development process, future residents may experience considerable cost in either tolerating the disservice or restoring the services (Niemelä et al. 2010). The cost of replacing lost or degraded ecosystem services should be taken into account in development decisions (Gomez-Baggethun and Barton 2013). Otherwise the desire amongst developers to avoid assessment and the risk of onerous conditions will continue to outweigh undertaking even low cost and small scale changes in wetland form that might improve wetland function.

Environmental assessment of new or developed sites in peri-urban coastal areas needs to focus on the relationship between wetland function and mosquito habitats. Understanding ecosystem function at the site is critical when considering the degree of intervention or rehabilitation of landscape needed to favour delivery of ecosystem services and reduce disservices.

33.6 Future Directions and Conclusion

In order to restore ecological processes, legislation, policy and guidelines are required to clarify what can be done in coastal wetlands, how it can be done and a robust and relatively simple procedure for permitting those activities. There are three areas that need to be considered. First, the misconception that some zoned and protected coastal wetlands do not require intervention to sustain or reinstate functional drivers needs to be addressed. This is particularly relevant during regulation and assessment of rehabilitation works and mosquito control activities. Second, codes need to take account of ecosystem functions with emphasis on hydrology and sedimentation in the wetland. Third, planning needs to trigger appropriate environmental assessment to include both ecosystem services and disservices both relating to longer-term impacts and the broader landscape context.

The two case studies demonstrated that restoration of ecological process can be a shared objective of both coastal wetland rehabilitation and saltwater mosquito hazard reduction. In coastal peri-urban areas, particularly, when greenfield sites with an adjacent mosquito hazard are proposed for development, planning frameworks should trigger assessment of ecosystem function with the desired outcome of strategies that address saltwater mosquito hazard and the rehabilitation of adjacent coastal wetlands.

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References

ABS (2014) Australian Bureau of Statistics. www.abs.gov.au/ausstats/abs@nsf/Products/3218.0~201213~Main+Features~Main+Features?OpenDocument#PARALINK6. Accessed 9 May 2014

Ballina Shire Council (2003) Chapter 11 – Mosquito management. Ballina Shire Council, Development Control Plan. Ballina

Ballina Shire Council (2004) Minutes of the Ballina Shire Council Planning Committee meeting 11 Mar 2004

Barbier EB, Hacker SD, Kennedy C, Koch EW, Stier AC, Silliman BR (2010) The value of estuarine and coastal ecosystem services. Ecol Monogr 81:169–193

Bolund P, Hunhammar S (1999) Ecosystem services in urban areas. Ecol Econ 29:293–301

Burby R, Deyle R, Godschalk D, Olshansky R (2000) Creating hazard resilient communities through land use planning. Nat Hazards Rev 1:99–106

Costanza R, Wilson M, Troy A, Voinov A, Liu S, D'Agostino J (2006) The value of New Jersey's ecosystem services and natural capital. New Jersey Department of Environmental Protection. Institute for Sustainable Solutions Publications. PDXScholar, Portland State University, 179p

Dale PER, Knight JM (2012) Managing mosquitoes without destroying wetlands: an eastern Australian approach. Wetl Ecol Manag 20:233–242

Dale PER, Dale MB, Dowe DL, Knight JM, Lemckert CJ, Low Choy DC, Sheaves MJ, Sporne I (2010) A conceptual model for integrating physical geography research and coastal wetland management, with an Australian example. Prog Phys Geogr 34:605–624

Dale PER, Knight JM, Dwyer PG (2014) Mangrove rehabilitation: a review focusing on ecological and institutional issues. Wetl Ecol Manag 22:587–604

Elliott M, Burdon D, Hemingway KL, Apitz SE (2007) Estuarine, coastal and marine ecosystem restoration: confusing management and science – a revision of concepts. Estuar Coast Shelf Sci 74:349–366

Gilbert S, Forsyth A, Gear I, Sullivan D, Yard D (2013) Listening to the experts – the advice that drove the national programme. In: Kay BH, Russell RC (eds) Mosquito eradication: the story of killing "Campto". CSIRO Publishing, Collingwood, pp 65–80

Gislason GM, Russell RC (1997) Oviposition sites of the saltmarsh mosquito, *Aedes vigilax* (Skuse) (Diptera: Culicidae), at Homebush Bay, Sydney, NSW – a preliminary investigation. Aust J Entomol 36:97–100

Gomez-Baggethun E, Barton DN (2013) Classifying and valuing ecosystem services for urban planning. Ecol Econ 86:235–245

Goodrick GN (1970) A survey of wetlands of coastal New South Wales, vol 5, Technical Memorandum. CSIRO Division of Wildlife Research, Canberra, 36p

Granek EF, Polasky S, Kappel CV, Reed DJ, Stoms DM, Koch EW, Kennedy CJ, Cramer LA, Hacker SD, Barbier EB, Aswani S, Ruckelshaus M, Perillo GME, Silliman BR, Muthiga N, Bael D, Wolanski E (2010) Ecosystem services as a common language for coastal ecosystem-based management. Conserv Biol 24:207–216

Griffin LF, Knight JM, Dale PER (2010) Identifying mosquito habitat microtopography in an Australian mangrove forest using LiDAR derived elevation data. Wetlands 30:929–937

Gurran N, Squires C, Blakely E (2006) Meeting the sea change challenge: best practice models of local and regional planning for sea change communities. Report No. 1 for the National Sea Change Taskforce. Planning Research Centre, Faculty of Architecture, University of Sydney

Harley D, Sleigh A, Ritchie S (2001) Ross river virus transmission, infection, and disease: a cross-disciplinary review. Clin Microbiol Rev 14:909–932

Hulsman K, Dale PER, Kay BH (1989) The runnelling method of habitat modification – an environment-focused tool for salt-marsh mosquito management. J Am Mosq Control Assoc 5:226–234

Irving AD, Connell SD, Russell BD (2011) Restoring coastal plants to improve global carbon storage: reaping what we sow. PLoS One 6(3):e18311

Jacups SP, Kurucz N, Whelan PI, Carter JM (2009) A comparison of *Aedes vigilax* larval population densities and associated vegetation categories in a coastal wetland, Northern Territory. Aust J Vector Ecol 34:311–316

King & Campbell Pty Ltd (2003) Sovereign gardens Ballina, development application No. 2004/328. King & Campbell Pty Ltd, Port Macquarie

Knight JM (2011) A model of mosquito-mangrove basin ecosystems with implementations for management. Ecosystems 14:1382–1395

Knight JM, Dale PER, Spencer J, Griffin L (2009) Exploring LiDAR data for mapping the micro-topography and tidal hydrodynamics of mangrove systems: an example from southeast Queensland, Australia. Estuar Coast Shelf Sci 85:593–600

Knight J, Griffin L, Dale P, Phinn S (2012) Oviposition and larval habitat preferences of the saltwater mosquito, *Aedes vigilax*, in a subtropical mangrove forest in Queensland, Australia. J Insect Sci 12:6

Knight JM, Griffin L, Dale PER, Sheaves M (2013a) Short-term dissolved oxygen patterns in subtropical mangroves. Estuar Coast Shelf Sci 131:290–296

Knight JM, Dale PER, Dwyer PG (2013b) Proposed management of the mangrove wetland at Bosun Blvd. Unpublished report prepared for Tweed Shire Council. Griffith University, Brisbane, 12p

Lee SY, Dunn RJK, Young RA, Connolly RM, Dale PER, Dehayr R, Lemckert CJ, McKinnon S, Powell B, Teasdale PR, Welsh DT (2006) Impact of urbanisation on coastal wetland structure and function. Austral Ecol 31:149–163

Lewis RR (2005) Ecological engineering for successful management and restoration of mangrove forests. Ecol Eng 24:403–418
Lyth A, Holbrook NJ, Beggs PJ (2005) Climate, urbanisation and vulnerability to vector-borne disease in subtropical coastal Australia: sustainable policy for a changing environment. Glob Environ Chang Pt B Environ Hazards 6:189–200
Lyytimaki J, Sipila M (2009) Hopping on one leg – the challenge of ecosystem disservices for urban green management. Urban Urban Green 8:309–315
McGinn D (2012) Aspen Ballina creek management plan mosquito risk issues update. Unpublished report prepared for Aspen Communities Pty Ltd
McGinn D, Sullivan D (2013) Who knows how to do broad-scale aerial control of mosquitoes? In: Kay BH, Russell RC (eds) Mosquito eradication: the story of killing "Campto". CSIRO Publishing, Collingwood, pp 81–96
Mcleod E, Chmura GL, Bouillon S, Salm R, Björk M, Duarte CM, Lovelock CE, Schlesinger WH, Silliman BR (2011) A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2. Front Ecol Environ 9:552–560
Naish S, Hu W, Nicholls N, Mackenzie J, McMichael A, Dale P, Tong S (2006) Weather variability, tides, and Barmah forest virus disease in the Gladstone region, Australia. Environ Health Perspect 114:678–683
Naish S, Mengersen K, Wenbiao H, Tong S (2012) Wetlands, climate zones and Barmah forest virus disease in Queensland, Australia. Trans R Soc Trop Med Hyg 106:749–755
Niemelä J, Saarela S, Söderman T, Kopperoinen L, Yli-Pelkonen V, Väre S, Kotze D (2010) Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study. Biodivers Conserv 19:3225–3243
NNDSS (2014) National notifiable diseases surveillance summary, notes for selected diseases 5 April to 18 April 2014. www.health.gov.au/internet/main/publishing.nsf/Content/nndss-fortnightly-summary-notes-2014. Accessed 9 May 2014
NSW Govt (2013) Policy and guidelines for fish habitat conservation and management (update 2013). Fisheries NSW. New South Wales Government
NSW Govt (2014) NSW biodiversity offsets policy for major projects. Office of Environment and Heritage. New South Wales Government
Perillo GME, Wolanski E, Cahoon DR, Brinson MM (eds) (2009) Coastal wetlands – an integrated ecosystem approach. Elsevier, Amsterdam, 974p
Pressey RL, Middleton ML (1982) Impacts of flood mitigation works on coastal wetlands in New South Wales. Wetlands (Australia) 2:27–44
Ratnayake J (2006) The valuation of social and economic costs of mosquito – transmitted Ross River virus. PhD thesis, Griffith University, Brisbane, 285p
Rogers K, Wilton KM, Saintilan N (2006) Vegetation change and surface elevation dynamics in estuarine wetlands of southeast Australia. Estuar Coast Shelf Sci 66:559–569
Russell RC (2002) Ross river virus: ecology and distribution. Annu Rev Entomol 47:1–31
Saintilan N, Rogers K, Mazumder D, Woodroffe C (2013) Allochthonous and autochthonous contributions to carbon accumulations and carbon store in southeastern Australian coastal wetlands. Estuar Coast Shelf Sci 128:84–92
Saintilan N, Wilson NC, Rogers K, Rajkaran A, Krauss KW (2014) Mangrove expansion and salt marsh decline at mangrove poleward limits. Glob Chang Biol 20:147–157
Schmidt JP, Moore R, Alber M (2014) Integrating ecosystem services and local government finances into land use planning: a case study from coastal Georgia. Landsc Urban Plan 122:56–67
Sheaves M, Brookes J, Coles R, Freckelton M, Groves P, Johnston R, Winberg P (2014) Repair and revitalisation of Australia's tropical estuaries and coastal wetlands: opportunities and constraints for the reinstatement of lost function and productivity. Mar Policy 47:23–38
Simenstad C, Reed D, Ford M (2006) When is restoration not? Incorporating landscape-scale processes to restore self–sustaining ecosystems in coastal wetland restoration. Ecol Eng 26:27–39

Tomerini DM (2007) The impact of local government mosquito control programs on Ross River virus disease in Queensland. PhD thesis, Griffith University, Brisbane, 205p
Tong SL, Dale P, Nicholls N, Mackenzie JS, Wolff R, McMichael AJ (2008) Climate variability, social and environmental factors, and ross river virus transmission: research development and future research needs. Environ Health Perspect 116:1591–1597
Turner RE, Lewis R (1996) Hydrologic restoration of coastal wetlands. Wetl Ecol Manag 4:65–72
Turner PA, Streever WJ (1999) Changes in productivity of the saltmarsh mosquito *Aedes vigilax* (Diptera: Culicidae) and vegetation coverage following culvert removal. Austral Ecol 24:240–248
Visser JM, Baltz DM (2009) Chapter 15 – Ecosystem structure of saline tidal marshes. In: Perillo GME, Wolanski E, Cahoon DR, Brinson MM (eds) Coastal wetlands – an integrated ecosystem approach. Elsevier, Amsterdam, pp 425–443
Webb CE (2013) Managing mosquitos in coastal wetlands. In: S Paul (ed) WET eBook workbook for managing urban wetlands in Australia. Sydney Olympic Park
Webb CE (2014) Explainer: what is Ross River virus? The conversation. www.theconversation.com/explainer-what-is-ross-river-virus-24630. Accessed 9 May 2014
Webb CE (2015) Does wetland rehabilitation need mosquito control? Mosq Bites Mag 9:2
Webb CE, Russell RC (2009) Living with mosquitoes in the Lower Hunter and Mid North Coast regions in NSW, 2nd edn. Department of Medical Entomology, Westmead, 59p
Webb CE, Prichard G, Plumb G, Russell RC (2009) How does legislation influence mosquito-borne disease management in New South Wales? Arbovirus Res Aust 10:178–182
Williams R, Watford F (1997) Identification of structures restricting tidal flow in New South Wales, Australia. Wetl Ecol Manag 5:87–97

Chapter 34
An Integrated Simulation and Visualisation Platform for the Design of Sustainable Urban Developments in a Peri-Urban Context

Meenakshi Arora, Tuan Ngo, Lu Aye, Hector Malano, and Oliver Lade

Abstract Designing sustainable urban development is a multi-dimensional and multi-disciplinary challenge that can benefit from next-generation modelling tools to achieve high performance outcomes and integrated assessments. This chapter presents and demonstrates the use of 'MUtopia', an information modelling platform for assessing alternative urban development scenarios. The use of the platform is illustrated through the application to a peri-urban development in the city of Melbourne, Australia. The modelling platform allows simulation of various transition and future scenarios at the precinct level. The platform is capable of extracting data to assist in developing and assessing the performance of different components (land use, individual buildings and infrastructure related to energy and water supply and use, waste management and transport systems) by taking advantage of the platform's unique scalability. The selected case study is a 31.5 ha Parcel of land, a typical peri-urban development in Melbourne's fringe located in West Cranbourne. A key aspect of the development is the design of a sustainable precinct that is affordable, provides a greater level of amenity and incorporates biolink corridors and natural open spaces critical to the preservation of native biodiversity. As a low rise suburban development this project presents a unique opportunity for the application of the MUtopia platform and to demonstrate how the tool can lead to optimum design parameters for achieving sustainable development. This chapter also describes how MUtopia can be used to optimise the selection and design of sustainable and resilient energy, water and waste infrastructure and its integration with existing infrastructure.

Keywords Urban development • Performance outcomes • Infrastructure • Biodiversity • Sustainable development • Modelling platform

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34.1 Background

Fast growth is being witnessed in the world's urban and peri-urban regions due to unprecedented rural migration coupled with natural population growth. In 2008, the number of people in cities surpassed 50 % of the total population for the first time in our history and will likely reach up to 70 % by 2050. In the same time-frame global population is expected to reach 9.3 billion with most of the growth taking place in the world's developing regions and mainly in peri-urban areas. This influx and development will dramatically change the makeup of peri-urban landscapes. Converting agricultural land for urban use will require holistic planning and systematic consideration to food, energy and water services, and ensuring sustainability will be of utmost importance.

These changes make peri-urban areas highly dynamic in their makeup and understanding these dynamic changes presents significant challenges. Research has been conducted on specific aspects of peri-urban growth such as water, energy and infrastructure, however, there is a paucity of research efforts placed on using an integrated systems approach such as UrbanSim (Waddell 2002).

It is therefore important for policy makers, urban and peri-urban planners and municipal council managers to understand the current issues and future challenges posed by peri-urban development. Significant modelling capability is required to evaluate the multiple sustainability dimensions associated with these dynamic changes. At the core of this challenge is the ability to integrate various subsystems that form a peri-urban system. This entails the ability to take into account the multiple interactions that exist between the multiple processes involved in the peri-urban system. For instance, among others, the provision of water involves significant use of energy and associated carbon emissions, thus modelling of the water supply systems must be closely linked to the energy use system.

This chapter presents an integrated modelling and visualisation platform called MUtopia (Mendis et al. 2012) that is capable of simulating the most important processes involved in sustainable peri-urban growth – water, energy, transport and waste – and the interrelationships between them. The platform is a tool capable of assessing the key sustainability metrics of new or existing peri-urban developments at multiple scales. In this case study, the platform was used to assess several peri-urban development scenarios in the Melbourne outer suburb of West Cranburne comprising a 31.5 ha parcel of land. The design and development places a major focus on sustainability and high amenity levels. These include a bio-link corridor connecting and preserving biodiversity and providing natural open spaces for recreation which must be provided in conjunction with affordable and low to medium rise housing. It serves as a typical application for MUtopia platform enabling demonstrations of how it can be used as a tool to assess design outcomes and assist in the process of achieving integrated sustainable development.

34.2 An Integrated Platform

The MUtopia platform allows for integrated simulation and visualisation of data on a geospatial level. Key sustainability metrics can be quantified and rated while being displayed in a 3-D model of the precinct itself. This 3-D visualisation allows design professionals to quickly assess the outcomes of introducing alternative strategies to increase the likes of energy or water efficiency, waste management, or even construction and maintenance. By integrating a whole range of aspects within the one platform, MUtopia can serve to evaluate urban planning, as well as provide economic modelling associated with operational costs and benefits of a proposed development (Fig. 34.1).

The MUtopia platform was created by a team of planners, engineers, environmentalists and economists. The key features offered by MUtopia include:

- A virtual 3D environment that mimics the real world based on GIS data.
- Visualisation of inputs (such as energy, transport, water demands) and outputs (such as greenhouse gas emissions) both temporally and spatially.
- Analysis of sustainability outcomes through quantitative modelling.
- Capacity to accommodate a range of different demands across a variety of built environment disciplines.
- While Mutopia is primarily designed for modelling precinct level developments, it can handle modelling across small to larger scale geospatial districts.

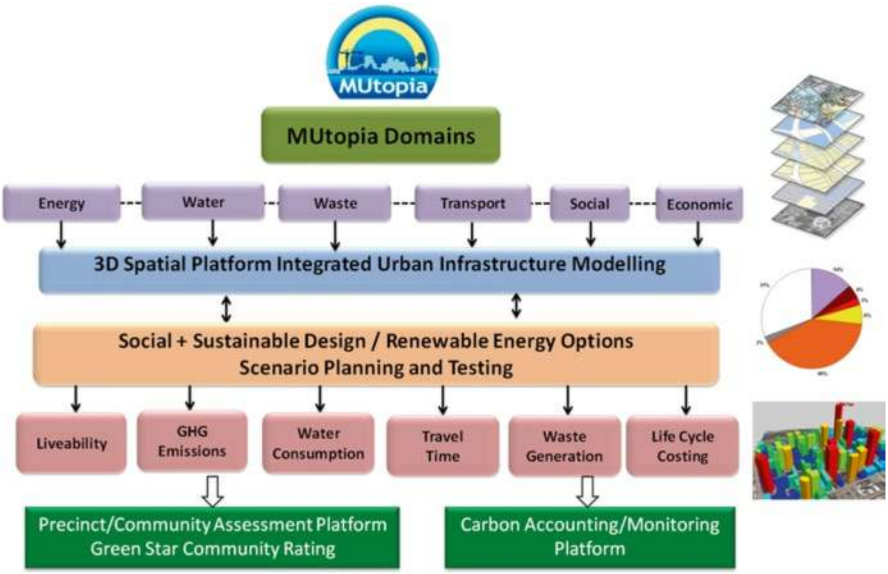

Fig. 34.1 MUtopia domains

MUtopia offers a number of benefits to developers and planners. These include:

- The ability to simulate a range of design scenarios, thus allowing for maximum efficiency in the development and planning process.
- The appearance of being a leader in sustainable development approaches.
- Assistance with meeting legislated greenhouse gas offset targets.
- Improving market position and international profile of users.
- Monitoring of the sustainability performance of a project.
- Proving a commitment to and more easily meeting sustainability benchmarks.
- Allowing for collaborative Community 'consultation' workshops based designs to be modelled for best outcomes.

A number of municipalities in Melbourne have recently added an amendment to their planning schemes to include a clause on Environmentally Sustainable Design. The policy applies to residential, mixed use and non-residential development and requires the developer to submit either a Sustainable Design Statement or Sustainability Management Plan. This submission must respond to design objectives in the following areas:

- Energy efficiency,
- Water resources,
- Indoor environment quality,
- Storm water management,
- Transport,
- Waste management,
- Innovation, and
- Urban ecology (City of Moreland 2014).

The MUtopia platform has the potential to be a very useful tool for quantifying responses to the objectives stated in a Sustainable Design Statement or Management Plan. As more local governments look to include such items in their planning schemes, it will become more important for planners and developers to carry out sustainability assessments.

34.3 Methodology

The process undertaken for this project involved an integrated model that is used to calculate energy and water usage across a range of scenarios. The individual model engines have been developed collaboratively by a number of University of Melbourne researchers. By integrating them within MUtopia, inputs could easily be changed and outputs interconnected within a web application resulting in instant visual and data feedback for the user.

34.3.1 Energy

In calculating future energy usage and resulting greenhouse gas emissions from the West Cranbourne development site, the model in MUtopia was simplified resulting in only modelling residential energy and water usage while assuming that electricity was the only source of energy provided to the site.

Total energy demand for lighting in kW-h/year is estimated by:

$$El = (A \times R) / \eta_l \tag{34.1}$$

where, A = residential floor area, R = basic lighting rate (kLumen.h/m^2.year), η_l = lamp efficiency (lumens/W).

Total energy demand for cooking in kWh/year is given by:

$$Ek = c_k \times p \tag{34.2}$$

where, c_k = energy demand for cooking per person (kWh/person/year), p = the number of residents.

Total energy used for space heating in kW-h/year is calculated by:

$$Eh = a \times b \times c \times d \times f \times m \tag{34.3}$$

And total energy used for space cooling in kW-h/year is calculated by:

$$Ec = a \times (1 - b) \times c \times e \times f \times m \tag{34.4}$$

where heating energy, *Eh*, and cooling energy, *Ec*, are taken as multiples of a range of factors outlined below and gross floor area, m (m^2).

a = ratio of met load to modelled load
b = heating as a fraction of total heating and cooling energy
c = AccuRate thermal performance based on climate zone
d = space heating technology factor
e = space cooling technology factor
f = conditioned floor area as a fraction of gross floor area (GFA).

Appliances and equipment energy consumption in kWh/year are given by:

$$Ea = \sum (Estar \cdot n) \tag{34.5}$$

where, *Estar* = appliance consumption from each household (kWh/household/person), and n = number of dwellings.

Appliance consumption per household (kWh/household/person) is given by:

$$Estar = Estar1 \times (1 - Er)^{(star-1)} \tag{34.6}$$

where, *Estar1* = energy usage assuming 1 star appliances and the given the number of bedrooms (kW-h), *Er* = the energy reduction factor and *star* = star rating of the appliance.

Appliances considered: fridge, dishwasher, washing machine and clothes dryer.

Greenhouse gas emissions in kg (CO_2)/year are given by:

$$GHG = E \times VIC\_GHGI \tag{34.7}$$

where *VIC_GHGI* = Greenhouse intensity of electricity in Victoria and is assumed as 1.35 kg (CO_2)/kWh, *E* = energy usage in kWh/year.

34.3.2 Water

Urban water supply and waste water systems are highly complex. Accordingly the model needs to account for various interactions between subsystems and be applicable to a precinct development. It also needs to be able to link the associated energy use and GHG emissions to the various stages of the urban water life cycle for analysis.

The water balance model developed by Arora et al. (2013) was utilised in this study which takes into account six stages of the urban water cycle: extraction and transport to treatment plants, treatment, distribution, wastewater collection and transport to treatment plants and treatment of waste water and disposal.

34.4 Case Study

The 31.5-ha Natural Resources Conservation League (NRCL) site is located at 950 Western Port Highway, Cranbourne West. It is the intention of the NRCL to create a commercially viable yet sustainable concept master plan to be delivered alongside a range of development models. The development is to have a range of different housing types, plenty of open space, and '*clean light smart industry*'. Particular attention is applied to the makeup of residential dwellings. A mixture of detached houses, townhouses and apartments is designed to ensure the best possible sustainability outcomes. Dwelling arrangement and design aim to maximise accessibility to walkable active spaces, allow best practice surface water management and pay particular attention to biodiversity outcomes. Energy usage on site is to be minimised including having no connections to gas infrastructure. This concept forms part of the plan for Zero Carbon emissions (RMIT Centre for Design 2012).

The following is a list of guidelines outlining the most prominent building types within the development:

1. **Residential**
   (a) Detached Houses – 200 m^2 blocks, one to two story
   (b) Townhouses – 150 m^2 blocks, three storeys
   (c) Apartments – around four storeys
2. **Retail** – small in size, to include the likes of a local grocery, butcher, bakery, small café and possible mini Independent Grocers of Australia (IGA) supermarket.
3. **Commercial** – mainly small offices with an incubator hub for innovative start-ups proposed.
4. **Community and educational** – community facilities and light industry similar to the Centre for Education and Research in Environmental Strategies (CERES), Melbourne.
5. **Potential NRCL headquarters** – As the anchor tenant and precinct manager, the NRCL's headquarters to be prominent and central.

34.4.1 Inputs to the Model

The algorithms used in MUtopia require the following inputs:

- Number of dwellings.
- GFA/dwelling.
- Dwelling heights.
- Percentage of open space.
- Commercial GFA remained the same for all scenarios.
- Percentage of rainwater and grey water harvested.
- Commercial GFA remained the same in all scenarios (just under 20 % of land area) and thus its only effect on the model was a reduction in overall site area.
- No natural gas infrastructure – only electricity assumed (linked to Zero Carbon).
- 5 star water fittings were assumed in all scenarios.

34.4.2 Scenarios Investigated

In this particular case study, MUtopia is used to assess residential energy and water uses for three different scenarios proposed in the NRCL Pilot Study (RMIT Centre for Design 2012) conducted by the Royal Melbourne Institute of Technology (RMIT): One of low density and few dwellings, one of medium density but a large number of scattered dwellings, and one aggregated high-density scenario with 50 % occupied by open space.

Table 34.1 Summary of design parameters

Feature	Design 1	Design 2	Design 3
Approach	Medium density	Low density	High density
Number of dwellings	800	500	600
% open space	40 %	35 %	50 %
% low density housing	10 %	25 %	10 %
Arrangement of dwellings	Scattered	Scattered	Aggregated

In 2012, the Centre for Design at RMIT was contracted to investigate and inform the development on the Greenfield Cranbourne West site. As part of this process they conducted a design charrette that brought together an array of experts to collaboratively design the development closely in line with the design principals and site vision. The charrette itself consisted of a site visit, and a number of sessions that looked at setting the boundaries, instilling the design principles and designing the actual site under varying scenarios.

Ultimately, the charrette exercise created five different designs, all with different specifications of dwelling density, open space, service integration and a number of other factors. An initial simplified process of comparative appraisal was then conducted rating each design against design principals. The MUtopia platform was used to evaluate the proposed designs from the charrette in greater detail focusing specifically on energy and water usage and rain and greywater harvesting. Out of the NCRL Pilot study, scenarios 1, 2 and 3 were combined to become one option, *Design 1*, consisting of 800 dwellings. This option was subsequently compared to *Design 2* and *Design 3* (scenarios 4 and 5 respectively from the charrette). Table 34.1 summarises the key characteristic values for each design option used for the comparison.

In assessing the water harvesting potential and overall water efficiency of each of the three *Designs*, they were modelled against rain and greywater harvesting rates of 0, 50 and 100 %.

34.5 Results

MUtopia produced a range of different outputs from each scenario, which enabled their assessment against key criteria, namely: water, energy efficiency and greenhouse gas emissions. Water consumption was calculated and compared with on-site potential to determine how much water would need to be imported from water efficiency off-site. In addition, a proportional water usage graph was produced to demonstrate efficiency on a per resident basis.

Of the three designs evaluated with the model, *Design 2* had the least aggregate water consumption while Design 1 has the largest water capture potential which can be ascribed to the largest number of dwelling and associated impervious area (Fig. 34.2).

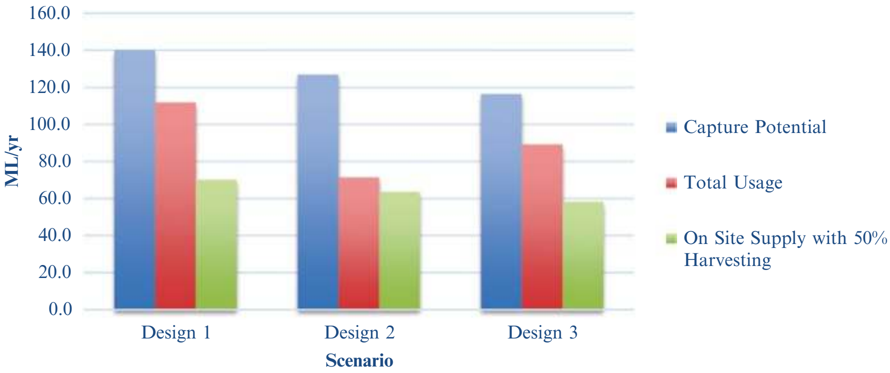

Fig. 34.2 Water capture potential and usage

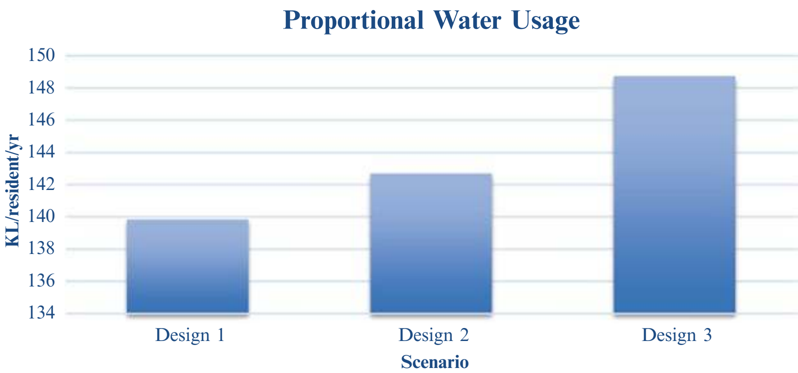

Fig. 34.3 Per capita water usage

When the designs are considered on a per resident basis, *Design 1* with 800 residents is also the most efficient (Fig. 34.3). Conversely, *Design 3* proportionally uses the most water, which is due to the large amount of open green space with high watering requirement.

Design 3 turned out to have the least water harvesting potential as a result of much of the rainfall penetrating into the ground because of large open spaces.

MUtopia proved very useful in providing a numerical as well as a visual tool for explanation to stakeholders. Figure 34.4 provides a visual depiction of the differing land uses on the site showing their capacity for capturing rainwater. By altering the model the user could very quickly understand, visually and quantitatively, the implications of increasing the proportion of impermeable surfaces.

Design 3 proved to be not only the scenario with the most efficient use of energy but also has the least CO_2 emissions per resident (Fig. 34.5). *Design 2*, a low density

Fig. 34.4 Permeable qualities of surfaces

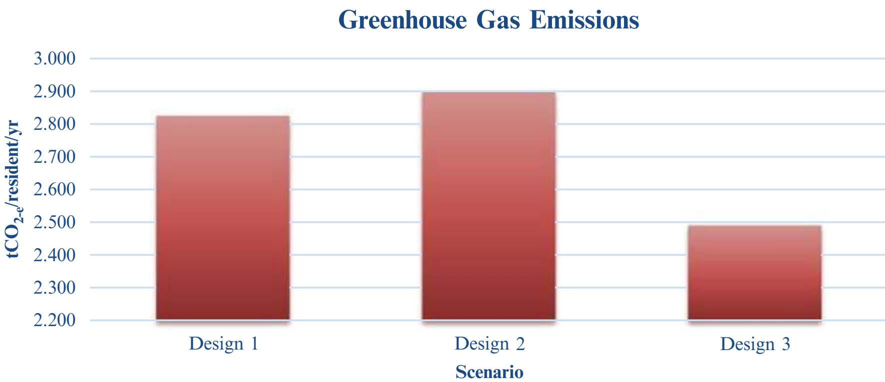

Fig. 34.5 Greenhouse gas emissions per resident

scenario, was the worst performing Design with 2.9 $tCO_{2\text{-}e}$ per resident per year from residential buildings.

The analysis of carbon dioxide emissions by the MUtopia 3-D model demonstrates the relative consumption of various buildings. Figure 34.6 shows a visual representation of total emissions for each building depicted by the relative height of each building. This provides the user with a easy-to-understand visual indicator as to what buildings are responsible for the highest proportion of emissions.

Fig. 34.6 CO_2 emissions by building

Finally, it was found that *Design 3* proved to be the least expensive to operate with utilities totalling just over $100 per year per resident – assuming wholesale energy prices (Table 34.2).

34.6 Discussion

The MUtopia platform provided a practical way of testing three alternative scenarios proposed for the West Cranbourne site development. The main benefits of using MUtopia are the simple format to change the model inputs compared to other tools such as spreadsheets and the immediately viewable data visualisation. The user is able to quickly see what elements of the design that account for most of the varying outputs, and can be readily adjusted to achieve a desired outcome.

The model also provided clear quantitative outputs upon which decisions around choosing a desired design can be made. *Design 3*, based on high-density housing and 50 % open space proved to be the most efficient in all sustainability parameters evaluated except for water consumption. The higher water consumption per resident is due to the large amount of green space which requires significant watering to maintain the green cover.

Table 34.2 MUtopia simulation results summary

Name	Unit	Scenarios		
		Design 1	Design 2	Design 3
Total water consumption	**ML/year**	**111.9**	**71.3**	**89.2**
	kL/resident	**140**	**143**	**149**
Energy electricity	kWh/year	1,289,988	832,730	813,763
Energy water	kWh/year	384,567	241,681	293,364
Energy demand total	**kWh/year**	**1,674,554**	**1,074,411**	**1,107,127**
	kWh/resident	**2093.2**	**2148.8**	**1845.2**
GHG water	tCO_2e/year	519	326	396
GHG energy	tCO_2e/year	1741	1124	1099
GHG emissions total	**tCO_2e/year**	**2261**	**1450**	**1495**
	tCO_2e/resident	**2.826**	**2.901**	**2.491**
Cost energy	$/year	$ 70,756	$ 45,675	$ 44,635
Cost water	$/year	$ 21,093	$ 13,256	$ 16,091
Total cost	**$/year**	**$ 91,849**	**$ 58,931**	**$ 60,726**
	$/resident	**$ 114.81**	**$ 117.86**	**$ 101.21**

In this particular case study, MUtopia allowed visual modelling of building's energy usage by applying colour-coding to buildings based on the energy usage range. The ability to vary density, dwelling numbers and the proportion of water harvesting resulted in performance changes that can assist the user to find a superior design solution depending on their specific objectives.

In particular, the MUtopia platform proved a valuable tool to visualise rainwater capturing potential. This feature can also assist with stormwater management, a growing problem in cities with a high proportion of impermeable surfaces. The platform also has the capability to explore stormwater management, predict flood risk and mitigation options.

While MUtopia was not available at the RMIT's design charrette stage, there is no doubt it would have served to provide useful feedback about each of the scenarios created by the participants at this stage. Scenario testing to assist community consultation, is a task that MUtopia has great potential to assist.

34.7 Conclusions

This chapter describes the MUtopia modelling and visualisation platform and its application to a peri-urban precinct development in outer Melbourne, located in West Cranbourne. The platform fundamental modelling algorithms and visualisation architecture are described together with the physical characteristics of the case study area.

The platform was used to evaluate three Design scenarios distilled from an earlier design charrette for their key sustainability performance variables, with specific reference to water and energy use. The key findings of this analysis showed that:

- The platform proved to be particularly effective in communicating sustainability performance through its quantification and visualisation capability.
- *Design 2* was shown to have the least aggregate water consumption but was the worst performing due to its low housing density.
- *Design 1* proved to be the most efficient per resident water use.
- *Design 3* proportionally used the most water due to the large amount of open green space with a high watering requirement but proved to be the scenario with the most efficient use of energy and least CO_2 emissions per resident.

References

Arora M, Aye L, Malano H, Ngo T (2013) Water-energy-GHG emissions accounting for urban water supply: a case study on the urban re-development in Melbourne. Water Util J 6:9–18

City of Moreland (2014) Amendment C71: environmentally efficient design local planning policy. Viewed 15 Sept 2014. http://www.moreland.vic.gov.au/building-and-planning/planning-scheme-amendments/amendment-c71.html

Mendis P, Ngo T, Aye L, Malano H, Rajabifard A (2012) Innovative modelling and visualisation platform for sustainable cities – Mutopia. In: Proceedings of the International Conference on Sustainable Built Environments (ICSBE 2012), Kandy, Sri Lanka, 14–16 December 2012, pp 1–8

RMIT Centre for Design (2012) Pilot study: NRCL community development site – final report. RMIT University, Melbourne

Waddell P (2002) UrbanSim: modeling urban development for land use, transportation, and environmental planning. J Am Plan Assoc 68(3):297–314

Chapter 35
Options and Strategies for Balanced Development for Liveable Cities: An Epilogue

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Abstract This chapter provides a snapshot of what is covered in the preceding chapters on options and strategies for balanced development leading to liveable cities. The chapters are organized under nine sections, including peri-urbanization; culture and social economy; land use planning; water security; wastewater and irrigation; urban agriculture and food security; impact of climate change and adaptation; legal, policy and institutional framework; and integrated urban development. The chapters under these sections cover a broad range of issues for the planning of future cities and peri-urban regions with respect to (1) balanced urban development policies and institutions for future cities; (2) understanding the effects of land use change, population increase, and water demand for the liveability of cities; (3) long-term planning needs and transboundary approaches to ensure secured future for generations ahead; and (4) strategies for optimal land, water, and energy uses for viable and liveable cities. The book emphasizes integrated planning for future development of liveable, resilient, and sustainable cities and peri-urban areas.

Keywords Peri-urbanization • Social economy • Land use planning • Water security • Wastewater irrigation • Urban agriculture • Food security • Climate change • Integrated urban development

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35.1 Introduction

Thorbeck (2012) defined an urban area as an area that has the characteristics of a city, meaning it has buildings and towns that define the urban landscape. He defined a rural area as an area that combines natural and human characteristics, meaning buildings and towns are components of open landscapes and ecosystems. Both urban and rural areas aim to embrace quality of life. Haughton and McGranahan (2006) explain that "urban ecology has become multi-scalar, extending from individual urban systems to systems of cities and towns, and from ecosystems within urban settlements to urban settlements as ecosystems, to the way in which cities and towns shape ecosystems beyond as well as within urban boundaries."

Migration of people from rural areas to urban areas is a global phenomenon and is occurring at an accelerating pace, particularly in developing countries, such as Brazil, China, Egypt, India, and Mexico. People are moving for economic advancement, in search of jobs, better educational opportunities, easy access to needed health services, availability of transport services, particularly airports, cultural, entertainment and recreational amenities, and potential for start-up businesses. Currently, the world population is over seven billion and there is almost an even split of the population living in rural and urban areas. It is estimated that by 2050, the global population will increase to about ten billion. Much of the increase will occur in urban population largely because of migration. The migration is leading to urbanization, with the result that urban development is moving into the countryside, eliminating much of the best farmland surrounding cities. It is therefore of utmost importance that urban design and planning undergo a new thinking such that areas of transition from rural to urban and land use at the urban/rural edge in the peri-urban landscape are managed from both urban and rural perspectives in order to shape, manage, and preserve the ecosystems that people depend upon. In many countries, some of the highly valued natural resource assets, such as biodiversity, native vegetation, wetlands, and waterways, occur in peri-urban landscapes. Peri-urban agricultural production is important globally and its value will rise in view of the impacts of climate change, energy costs, rising world population, and changing patterns of food consumption.

Urban centers are the highest centres of anthropogenic activities causing the build-up of Green House Gases (GHG), such as CO_2 and methane, leading to increased global temperature. Cities are major consumers of fossil fuels with over 80 % of the global consumption. Urban areas represent sites of high consumption of energy and production of waste. Global sustainable development is therefore tied to the management of growing urban influence.

Rivers situated in peri-urban landscapes constitute the prime natural resource base for the urban construction industry. Studies show that while the river is the source for water supply for many cities, it is the sectors doing sand and clay mining for the construction industry and dumping waste that are causing social and environmental degradation. Plausible remedial measures are the integration of fair and effective intervention by government authorities, and stakeholder education with technical measures and economic instruments.

35.2 Peri-Urbanization

Thomas Sieverts (2003), the Berlin-based planner, calls the peri-urban lands the 'in-between lands.' The implication here is that urban-rural landscapes can be a new form of city that intermingles built-up areas and rural landscapes. He has been advocating the development of a new cultural landscape in which food production, recreation, and ecological balance create new relationships with built-up areas. This leads to the development of new urban agriculture associated with hybrid urban forms which innovatively combines architecture, landscape, infrastructure and high technology farming. Rural urbanism may retrieve lands for urban agriculture. Hence, urban agriculture may contribute to sustainable, climate-optimised, urban development.

Rural areas around the world are undergoing profound demographic, economic, cultural, and environmental change, creating considerable challenges and stress for their residents and on the ecosystems upon which they depend for their livelihood and quality of life. Critical global issues, such as climate change, renewable energy, water resource protection, food security, and healthy human development, have begun to receive much attention these days nationally and internationally. The peri-urban landscape is of particular concern, because urban expansion has historically required large amounts of land for developing infrastructure and public services.

Peri-urban areas are attractive for living in a semi-rural setting. However, sometimes people and nature come into conflict, as birds, animals and plants often do not respect property boundaries or intrude into the lives of residents in the interface areas. Thus, it becomes a challenge for public land managers and local governments to manage such conflicts. Further, in order to help resolve land-use issues in the peri-urban landscape and improve the quality of life and the economies of people living and working in both rural and urban areas, it is important to incorporate the connection of urban and rural futures in rural design.

Archaeological evidence points to the pivotal role that peri-urban zones once played in the survivability of ancient urban centres. Over the last three to four decades, accelerating urban growth and associated transitional changes have posed major challenges to the development of resilient cities that are capable of absorbing climatic, economic and environmental shocks. Industrialisation and market interdependence have altered urban fringes, increasing environmental impacts, such as the loss of natural resources and environmental buffers which are now regarded as essential for urban resilience. Further, environmental change and increasing socio-economic inequality are generating new priorities, as peri-urban zones consolidate, erode and shift outwards. An argument can therefore be advanced for a hybrid approach to the planning and design of peri-urban interfaces, that draws on integrated, agropolitan-type perspectives embedded in a resilient, locally appropriate regional-urban focus within broader socio-spatial and geo-economic framework.

One of the consequences of urbanization is the increase in pollution, containing trash and litter, sediment, suspended solids and emulsified hydrocarbons. These pollutants pollute urban runoff. The removal of contaminants from urban runoff waters is vital to preserving the health of urban communities that live in contact with and around the receiving waters.

35.3 Peri-Urban Culture and Social Economy

By bridging science and society, transdisciplinarity permits the translation of knowledge into useful and relevant information for planners and decision-makers. There are a multitude of socioeconomic realities that demand different and specific political approaches to sustainable peri-urban territories. The social economy of peri-urban areas considers identities and lifestyle issues, such as age, family patterns, living and working conditions, and economic characteristics, such as main economic activities, economic organization and structuring, and attractiveness. The influence of a metropolitan area is expressed by continuing investments in peripheral areas that offer sources of labor and natural resources, such as land. The presence of industries, services, logistics and distribution platforms, enterprises, housing, and chain-stores constitutes a manifestation of this influence. Further, the peri-urban landscape can be a hybrid territory promoting the coexistence of a rural-agriculture matrix where distinct activities coexist defining distinct degrees of specialization/diversity of the economic fabric.

The increasing tendency to urbanisation is now a reality. The high growth rate of the urban population increases the demand for agricultural commodities on one hand and widens the demand for land for the construction of houses, roads and other civil amenities on the other hand. With expanding urban areas, the adjoining rural areas are transforming to peri-urban areas in terms of facilities, amenities, and lifestyle. This transformation is tremendously increasing the value of land in peri-urban areas for cities. This culminates in the changing scenario of land utilisation, change in farming system, and composition of household income in peri-urban areas.

35.4 Peri-Urban Land Use Planning

Peri-urban areas are undergoing radical change in much of the world, displacing traditional agriculture and reducing the capacity of cities to adapt to non-linear change. It is important to relate rural and urban land supply and demand; develop land use planning techniques for limiting rural land development and transferring demand for rural land to regional settlements; establish stronger statutory planning measures in order to stem the loss of peri-urban agricultural land; and develop a range of strategies to strengthen the resilience of city food systems. Urban resilience is best maintained through a regional approach which connects urban and peri-urban systems. Maintaining the natural resource base for food production around cities would become an increasingly important part of city planning.

Engaging landholders in natural resource management is a challenge in any landscape, and is inherently more difficult in peri-urban landscapes. Current paradigms employed for engaging peri-urban landholders in natural resource management are in many cases based on conventional methods. However, the design and delivery of engagement must be modified in order to be effective in peri-urban landscapes.

Maintaining the rural character of peri-urban landscape is a significant challenge, especially when permitting sustainable agriculture, horticulture and forestry. The Western Sydney Parklands is an example of urban park system located in Western Sydney with a view to develop a master plan for future land uses, called the Western Sydney Parklands Plan of Management 2020. The Parklands is a 27 km long public open space corridor of approximately 5200 ha. This plan includes a commitment to provide 10 % (or about 500 ha) of the Parklands for urban farming. The objective is to develop an approach for converting fallow public land to productive space by providing commercial growers a secure tenure in the Sydney basin. The implementation of the master plan will have a number of vexing challenges, including legislative and regulatory processes; environmental; and social issues.

35.5 Urban Water Security

Urban wetlands and water bodies play a pivotal role in influencing the urban environment, for they reduce overheating of the environment and function as natural water purification systems. Their significance notwithstanding, urban wetlands are either diminishing or shrinking from their original shape and size due to the pressures mounting from the housing sector and unplanned urbanisation.

Natural wetlands act as nature's own purification plant. In the presence of different plant species they purify the wastewater in a natural way by reducing the COD content of water, oxygenation, elimination of pathogens, ammonium degradation, degradation of nitrate, and removal of phosphates and heavy metal. It is observed that the filling up and shape modification of water bodies from their original shapes significantly affect the urban micro-climatic cooling capacity and natural water purification potential. Several studies indicate that pollution of an urban water body due to human induced land use is correlated with its shape and complexity. Water bodies with simple geometric shapes are related to human induced land use, whereas natural water bodies are mostly of complex geometric shape. Water bodies with complex geometric shapes can reduce the magnitude of water pollution. Relationships have been found between water quality of urban and peri-urban water bodies and shape complexity, micro-climatic temperature and land use around water bodies.

Urban wetlands enhance habitats for birds and fish, and help establish a thriving ecosystem which would also enhance recreational activities like bird watching. Wetlands also help recharge groundwater which in turn reduces the vulnerability to earthquakes. Urban land use has a direct impact on urban microclimate that results in Urban Heat Island Effect. Urban water bodies play an effective role in microclimatic cooling of the urban area. Urban wetland areas serve as 'landscaped water parks' that can be used for water purification and micro-climatic cooling, leisure and park amenities. Urban cooling can help reduce the growing energy crisis in cities. Further, the wetlands can help deal with the recycled urban waste water by natural means.

Growth and density of population and urbanisation influencing groundwater indicate that large cities may soon face a groundwater crisis, if the population influx is not retarded. The reduction in the influx can be accomplished by improving economy and infrastructure in the adjoining regions, thus making large city centers less attractive for the migrating population. Further, the construction activity, especially in recharge zones, should be prohibited in order to ensure future groundwater sustainability.

In most peri-urban communities of developing countries, shortages of domestic water supply relative to demand are a common feature. This is because most of these peri-urban communities usually fall outside the physical boundaries of urban water supply. Thus, the people who live there are forced to consume water from doubtful sources that may contain pathogens found in human faeces. Apart from consuming water from doubtful sources, most of these inhabitants travel long distances to collect water or pay dearly to purchase it from water vendors.

Three factors that impede a safe water supply in peri-urban communities are open defecation near the water source, dominant type of land use near water sources, and contaminated refuse dumps found in most of these peri-urban communities. There should be water policy documents by governmental bodies to prohibit these unsafe practices.

In the developed world recent years have witnessed a dramatic increase in exploration and production of coal seam and shale gas in peri-urban areas using both the hydraulic fracturing (fracking) technique of gas production and the method of extraction of naturally occurring groundwater by pumping it from coal formations to release coal seam gas. This has given rise to growing concerns about water security. In order to maintain and increase the natural resource base as well as the need to protect and sustain the supply of potable and agricultural groundwater in peri-urban areas, one important issue is whether the increasing popularity of fracking in peri-urban and semi-rural areas poses a risk to the quality of groundwater supply as well as its contamination. The other issue of concern is whether the extraction of groundwater from coal seams where fracking is not needed has a major impact on groundwater depletion and what the risk is and how the risk should be managed.

Fracking involves pumping of ground water, sand and chemicals under high pressure into layers of coal or shale to create fissures or cracks that force gas to the surface, where it is collected and processed. The technique impacts water supplies in two main ways. First, it requires large quantities of water at the pumping stage and it is alleged to produce vast amounts of contaminated groundwater containing chemicals known collectively as BTEX, methane gas and excessive amounts of salt. The evidence based on the development of drilling sites using fracking in many areas suggests that environmental concerns may not be given as much consideration as they should be, particularly because compliance with environmental risk assessment is not rigorously specific.

35.6 Wastewater and Irrigation

Because of its reduced treatment cost relative to seawater desalination and imported surface water, the supply and sustainable use of recycled water may play an important role in enhancing urban water supplies in many water-scarce parts of the world. Despite significant benefits of recycled water, there are several concerns related to environmental and health risks. If not properly managed, recycled water may deteriorate soil health in terms of increased salinity and sodicity, heavy metal accumulation and decreased hydraulic conductivity of soil. However, there are ways to reduce risks of recycled water due to urban irrigation, including national and state-wide standards of recycled water quality for urban irrigation, sustainable urban water management strategy, and pollutant control framework.

The need for irrigated agriculture is increasing day by day and the largest water withdrawals from renewable water resources are for irrigation. On the other hand, the available water resources are decreasing and non-conventional water resources for irrigation are therefore needed. However, the volume of wastewater being treated and used is limited due to the lack of adequate data and knowledge and/or negative effects of improper wastewater management (i.e. use of untreated wastewater). Although a study of wastewater irrigation from crops, soil, groundwater, health, irrigation equipments, modern technologies, and other environmental aspects is useful, management studies in comparison with other aspects can lead to more reliable and more extensive findings and finally a better decision on using wastewater for irrigation. There are challenges and prospects that may help decision making for the use of wastewater in irrigation.

There is, however, the question of the effect of reuse of wastewater in the peri-urban area on the quality of soil, vegetable crops and groundwater in reference to heavy metal contamination. Heavy metal accumulation in groundwater irrigated vegetables has been found to increase with increasing contamination of these metals in the groundwater at different locations. However, the metallic accumulation in vegetable crops, such as cauliflower, cabbage, brinjal, spinach, tomato and radish, irrigated by groundwater at many locations have been found to be within the maximum permissible limits as prescribed by World Health Organization (WHO). For wastewater irrigated spinach, tomato and radish the accumulation of Fe, Zn and Cd has been found to cross the maximum permissible limits. In particular, urban wastewater irrigated spinach has been found to have accumulated Fe, Zn and Cd to a great extent (more than the maximum permissible limit) and is most unsafe for human consumption.

35.7 Urban Agriculture and Food Security

Industrial agriculture is becoming part of the food system that is the dominant mode of feeding many cities. However, this food system has caused crises in public health in the form of rising incidence of non-communicable disease linked to diet; and crises in environmental health stemming from industrial agriculture and the food processing and distribution network. It is therefore argued that changes in the law and policy for the urban food system should be brought about by framing and communicating health and ecological problems, and alternatives, such as urban agriculture, should be promoted as a response to this food system crisis.

By working together with state and local planners and agricultural practitioners, it may be possible to develop a new paradigm to identify high quality agricultural lands. This may combine land capability or suitability for horticulture and dry land cropping and grazing with irrigation supplies, rainfall and yield information. It can then rank large tracts of "similar" lands according to their versatility for a range of agricultural land uses. This information can also be used in land use planning.

Peri-urban areas are emerging as strategically important built environments that should integrate appropriate food efficient design and planning. In order to understand food responsive design and form specific characteristics of new residential neighbourhoods in peri-urban areas, three key food urbanism approaches can be considered: (1) Developing a strong evidence base; (2) understanding community aspirations; and (3) formulating appropriate planning policy and recognising trandiscplinary connections of food efficient design and planning. These considerations would be vital for building resilient communities of the future.

Peri-urban agriculture, especially livestock and vegetable farming, has deep roots in the food system. However, agricultural land in these areas is increasingly at risk from urban encroachment, which is likely to adversely affect the city's food security. Population growth, artifical distortions to the value of land, the booming construction industry as well as the creation of recreation and leisure facilities have escalated the competition for land in peri-urban areas between agricultural use and urban-type developments.

35.8 Impacts of Climate Change and Adaptations

Climate change presents many challenges for local governments. In many areas, the future climate is likely to include more hot days, less rainfall and runoff, and increased frequency and intensity of extreme events, such as drought, flash flooding and wildfire. It is, therefore, important to identify, analyse and evaluate climate change risks and develop an adaptation plan that would assist planning for likely impacts of climate change.

Climate change impacts are exacerbating the number and extent of disasters. Rapid population growth, poor urban management, and non-implementation of various policies are creating a peculiar situation for many countries. Scarcity of water resources is already at an alarming situation and climate change impacts will exacerbate it. It is found that in many developing countries local officials have low level of education and are poorly trained. Local officials are ill-equipped for preparing any climate change adaptation plan to reduce future flooding. Local officials are unaware of the use of geographical information systems and their importance in planning. When prompted, the GIS-prepared climate change maps can be helpful in raising the climate change awareness among public and these maps should, therefore, be prepared.

Climate change affects food production, with particular reference to urban agriculture and the associated impacts on food security. The value of urban agriculture to the health and nutrition of developing and developed countries needs to be assessed.

There are international, including urban, aspects, such as agricultural disruption, economic disruption and logistical disruption to food availability, food access and food quality as a result of natural disasters remains an under-investigated topic. Climate change is affecting (and will affect) global food production and hence global food security. Urban agriculture plays a significant role in maintaining and improving the health of city dwellers, particularly those disadvantaged. Climate change is likely to impact more severely urban environments with associated negative effects on food security. Existing research programmes are not addressing these aspects of climate change and deserve attention.

Social, economic and environmental impacts on urban and peri-urban Indigenous communities inhabiting coastal areas need to be highlighted. These impacts include loss of community and environmental assets, such as cultural heritage sites, with significant impacts on their quality of life and the establishment of potential favourable conditions for the spread of plant diseases, weeds and pests. Opportunities do not readily exist for engagement with climate change adaptation policy and initiatives and this is further exacerbated by acute shortages of qualified/experienced indigenous members that could represent their communities' interests in climate change adaptation forums. The evidence emerging from research shows that consideration of the future by many communities, even with the overlay of climate change and the requirements for serious considerations of adaptation, are significantly influenced by economic aspirations which are seen as fundamental survival strategies for their communities.

There are a number of local-specific issues that emerge from climate change, such as potential for indigenous involvement in the industry utilising wild plant species that may suffer from changes in species availability; concern about changes associated with peri-urban and urban development which appears to be escalating micro-environmental changes; peri-urbanisation as a major environmental change which threatens cultural assets; and indigenous communities that need to be represented in climate change adaptation forums and be more directly involved in land and sea care projects.

Climate change awareness is an imperative to achieve sustainability in developing countries. Lack of awareness is a significant barrier to climate change adaptation. Raising climate change awareness at the local level is critical, as climate change impacts are exacerbating the number and extent of disasters in different parts of the world.

The development of an adaptation plan must be founded on a risk management approach to climate change at the local peri-urban government level. The approach can help build capacity in climate change, adaptation and the process of undertaking a risk assessment and define the area of operation, influence and responsibility in regard to adaptation actions, and the role of other external stakeholders. Further, it can help integrate the risks and associated adaptation options directly into the existing risk register system and understand the relativity of climate risks to non-climate risks that the local government may have to face, such as land use change, increasing proportions of absentee landholders and an ageing demographic.

35.9 Legal, Policy and Institutional Challenges

Voluntary collective action is essential for natural resource governance. In a peri-urban setting, a complex behavioural and institutional matrix, the net balance of incentives and disincentives, and the support and impediments determine the likelihood of effective governance. Coupled with governance, each problem has biophysical and social characteristics that intersect with the character of the community. Taken together, there is the need for a realistic understanding of what will make collective action feasible, and design of institutional arrangements to manage the totality of the behavioural setting and the reality of the problem being addressed.

Real estate is a major driver of the economy in many countries of the world, developing as well as developed. It is one of the main barriers to the development or implementation of zoning and planning regulations that would make urban agriculture more than a fortuitous and temporary use of space. Moreover, many urban societies are undergoing a paradigm shift in social thought and action towards valuing heritage, public space, social cohesion, and accessibility to leisure and cultural activities, recognising that these factors can enhance urban liveability. The landscape approach has potential in addressing multiple features of urban/peri-urban areas. The gentrification is one of the drivers of the city development, causing de-territorialisation and incongruous land use coexistence.

There are major challenges posed by the spatial expansion of urban areas. Urban spatial expansion can be defined as having two general features. The first is the territorial expansion of urban activities outside the cores of urban areas. The second is the urban expansion that includes all the changes that occur in the urban system defined on the basis of population both within urban areas and in the national urban system. An example of changes in the urban system is the ongoing increase in population and spatial expansion of the secondary cities in the urban hierarchy.

In the contemporary era the interpretation of urban expansion is influenced by the following arguments. First, the globalisation is leading to the increasing integration of mega urban regions into the global economy. This encourages policies that are designed to create more efficient and productive urban areas that capture income from investment in industrial production, improvements in the built environment and higher-order services. Many of the policies focus on investment in improving transportation systems, digital networks, providing services, such as sanitation, energy and the amenity spaces.

Second, populations located in urban spaces are adapting, accommodating and resisting the environmental, economic and social consequences of globalization.

The reshaping of urban spaces driven by globalisation should be positioned in a more interactive and local paradigm that emphasizes the contextual setting.

Third, the telescoping transitions are being driven by accelerated transactional flows of people, commodities, capital and information between and within countries. The international components of this transactional revolution are generally referred to as part of a new era of globalisation in which foreign investment, encouraged by national states, is an important component.

Fourth, the transition is best seen as a process of transformation of national and urban space in which interaction, networks and linkages reflect a new urban reality and permeates both rural and urban areas. This is leading to a rapid change in the conventional polarising between rural and urban spaces. A network of international, national, regional and local linkages provides a dynamic spatial framework in which flows of people, commodities, information and capital drive both the rural-urban transformation and changes within the urban system.

The reality of transcending networks means that the restructuring of rural and urban spaces is occurring simultaneously, particularly in the transaction networks that are focused on mega-urban regions and corridors that link the urban system. Globalism is embraced at the national level but it acts at the local level. In this way, urbanisation is made up of the interaction among individuals and households at the national scale, provincial scale, urban scale and individual scale. This idea is captured well by Forbes (1997), "Macro-representations of globalisation subsume the internal dynamics of urban development, the subtleties of local politics, the resilience of urban patterns of life, the tensions embedded in fractured social structures, the multiple strands of modernity and the resistance to the imposition to change." It is important to emphasize that the urbanisation is driven by a complex array of social, economic and political processes. There are processes of both "articulation" with global flows in certain urban spaces (and social groups)" and "disarticulation" in others where "global spaces" are intertwined with "local spaces." In many mega-urban regions of Southeast Asia urban space has been reconfigured into articulated networks of interaction between middle and upper class dwellers, while excluding "much of the intervening or peripheral spaces from accessing networks, because the networks pass through the spaces without allowing local access."

35.10 Integrated Urban Development

It is now being increasingly realised that peri-urban areas surrounding metropolitan cities and regional towns are highly dynamic regions characterised by unique social, environmental and economic changes. A peri-urban region is a diffused territory existing between the urban and rural townships, and river systems in such regions are often used as a source of urban water supply. The urban regions extract significant supplies of water for domestic, industrial and agricultural purposes, while the river system is also used to discharge treated and sometimes untreated municipal effluent originating from urban townships.

The peri-urban landscapes are continuously expanding to accommodate the communities who are migrating into diffused territories in search of a better lifestyle and mostly work in nearby townships, creating a range of competing and conflicting land use issues. As a result, the health of many peri-urban river systems in Australia and other parts of the world has gradually deteriorated over the last decade. Being key river users, the life cycles of aquatic species and social activities of humans are severely impacted by the deteriorating state of peri-urban river systems.

In the face of competing water users and urbanisation, managing and sustaining peri-urban river systems are huge challenges. It is desirable to understand how the management of a river system evolves and the role played by government agencies, communities and other stakeholders in the sustainability of the river system. Hence, a framework to assess future management proposals for protection and remediation of the river system can be developed. There should be a multidisciplinary approach to planning for development of peri-urban areas, which can consider ecosystem services and disservices and if development is occurring at the expense of coastal wetlands.

Wetlands can serve as bastion for mosquito production that affects residents and impose costs on individuals and government from both health and management perspectives. Most coastal peri-urban areas, including adjacent wetland sites, retain legacy infrastructures and landforms that degrade wetland functions and often exacerbate the mosquito hazard. Rehabilitating coastal wetlands can improve wetland function, while also reducing the mosquito hazard. Coastal wetlands are almost always overlaid with a number of different zones and ownership boundaries that increase the complexity of both mosquito management and wetland rehabilitation actions. It is recommended that land use planning frameworks incorporate a trigger for both assessment of adjacent coastal wetland ecosystem function and restoration of wetland ecological processes that includes provision for habitat based source control of mosquito hazard and coastal wetland rehabilitation.

Designing sustainable urban development is a multi-dimensional and multidisciplinary challenge that can benefit from next-generation modelling tools to achieve high performance outcomes and integrated assessments. An information modelling platform can be developed for assessing alternative urban development scenarios. The modelling platform can allow simulation of various transition and future scenarios at the precinct level. The platform can extract data to assist in developing and assessing the performance of different components (land use, individual buildings and infrastructure related to energy and water supply and use, waste management and transport systems). A key aspect of the development is the design of a sustainable precinct that is affordable, provides a greater level of amenity and incorporates biolink corridors and natural open spaces critical to the preservation of native biodiversity. The platform can also be used to optimise the selection and design of sustainable and resilient energy, water and waste infrastructure and its integration with existing infrastructure.

References

Forbes D (1997) Metropolis and mega urban region in Pacific Asia. Tijdschr Econ Soc Geogr 5:457–468

Haughton G, McGranahan (2006) Editorial urban ecologies. Environ Urban 18:3–8

Sieverts T (2003) Cities without cities: an interpretation of the zwischenstadt. Spon Press, London

Thorbeck D (2012) Rural design: a new design discipline. Routledge, London