

Chapter

Droughts and Floodings Implications in Agriculture Sector in Rwanda: Consequences of Global Warming

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Abstract

Global warming driven either by human activities that emit greenhouse gases in the atmosphere or by natural shifts in weather patterns results in climate change. Short as well as long climate changes have impacts on the people's livelihoods worldwide through the intensification of natural desert, increased temperatures and precipitations, lack of access to (clean) water among others. This description is true in Rwanda as climate change affects agricultural sector which is proven to be a cornerstone of sustainable development of the country. However, it is possible to minimize the negative effects of climatic changes by reducing the vulnerabilities to it. This requires sound adaptation measures and mitigation strategies. Using literature review, this chapter shed light on ambitious mechanisms developed by the government of Rwanda to combat and to adapt to the effects of climate change, especially in its agricultural sector.

Keywords: Droughts, flooding, global warming and agricultural sector

1. Introduction

The degradation of the environment is undoubtedly one of the most serious threats to the people's livelihood across the world today, and Climate change happens to be one of principal causes and consequences of environmental degradation. Originally, climate change was considered as an environmental challenge, but now is being recognized as a political, social and sustainable development issue. In this views, Antwi [1] explains that adaptation related policies have been viewed in different contexts over the years. Antwi points out that climate change is now regarded as a major threat to human security with focus on different aspects. Martin [2] argues that climate change severely affects people's livelihoods worldwide through the intensification of natural disasters; global warming which leads to increased temperature and changes in precipitations resulting in droughts and flooding. These hazards affect agricultural production and access to clean water. The Stern Review [3] points out that with a greater amount of warming, global food production is likely to be seriously affected; especially in Africa, declining crop yields could leave hundreds of millions without the ability to produce or purchase sufficient food.

In addition, Misra [4] mentions that the impacts of climate change such as the depletion of water resource and the rise in global average temperature have created conditions for a decline in agricultural production which, in turn, leads to food price inflation globally as well as food shortages in developing countries.

However, it is crucial to shed light on the complex link between climate change and land use in order to capture, the impact of global warming on agricultural sector in general, and in Rwanda particularly. Land use practices (anthropogenic activities) affect the global concentration of greenhouse gases. While Land use practices constitute an important driver of climate change, a changing climate change on the other hand can lead to changes in land use. Thus, for example, farmers might change their customary crops to crops that are climate smart.

In Rwanda, agriculture is an important sector, because it largely contributes to crops production, national and household income, and food security to mention few [5]. Despite its important contribution to the Rwanda's economy, agriculture in Rwanda is highly sensitive to climate change. High temperatures eventually reduce yields of desirable crops and tend to encourage weed and pest proliferation, long periods of sun provoke desertification in some areas, while erratic rainfall leads to floods, erosion, landslides and loss of suitable arable soil. That is why the government of Rwanda aligns its self in the implementation of mitigation and adaptation strategies recommended by international protocols such as Sustainable Development Strategies (SDGs).

2. Description of Rwanda in terms of population and climate

2.1 Relief of Rwanda

The topography of Rwanda constitutes itself, an element of vulnerability. The relief profile of Rwanda is hilly and mountainous with an altitude varying between 900 m and 4507 m above sea level. The components of that relief are: Congo Nile Ridge Overlaying Lake Kivu with an altitude between 2500 m and 3000 m, it is dominated in the Northwest by the volcanic ranges consisting of five volcanic massifs of which the highest is Karisimbi with 4507 m. The central plateau presents a relief of hills with an altitude ranging between 1500 m and 2000 m. The lowlands of the East are dominated by a depression characterized by hills with a more or less round top and 1000 to 1500 m in altitude. And the lowlands of the South-West in the Bugarama plain with an altitude of 900 m are part of the tectonic depression of the African Rift Valley [6].

2.2 Climate of Rwanda

Rwanda is located in tropical temperature climate due to its high altitude. The average annual temperature ranges between 16°C and 20°C, without significant variations. Rainfall is abundant although it has some irregularities. Winds are generally around 1–3 m/s in the high regions of the Congo Nile ridge, average temperatures ranges between 15°C and 17°C and the rainfall is abundant. The volcanic region has much lower temperatures that can go below 0°C in some places. In areas with intermediary altitude, average temperatures vary between 19°C and 21°C and the average rainfall is around 1000 mm/year. Rainfall is less irregular, and sometimes causes periods of drought. In the lowlands (East and Southeast), temperatures are higher and the extreme can go beyond 30°C in February and July–August. The absolute temperature of 32.8°C was recorded in the Southeast by Karama-plateau station on September 1980. Thermal constraints are more considerable in

lowlands than in the remaining parts of the country. Rainfall is also less abundant in that region with around 700-970 mm/year. Rwanda has two rainy periods that are from mid-September to mid-December and from March to May, other periods are characterized by dry seasons [7].

2.3 Population of Rwanda

Rwanda's population density is the highest in Africa and it is estimated to be 13.11 million in 2021, 17.5% lives in urban centres, while 82.5% lives in rural areas [8]. About 72% of the population that is economically is engaged in agricultural sector [9]. FAO further argues that the majority of people who lives in rural areas relies on agriculture as the main source of income.

3. Impact of climate hazards on agricultural sector in Rwanda

Climate change has the potential to threaten agriculture through its effects on soil properties and processes [10]. Thus, the soil degradation implies decline in the quality and capacity of soil to perform its function. Qafoku [11] reveals that climate change, i.e., high atmospheric carbon dioxide concentration (≥ 400 ppm), along with increasing air temperature (2–4°C or greater) that persist for an extend period of time, significantly affect soil proprieties and fertility, thus agriculture sector fails in providing food quantity and quality. Furthermore, Islam and Wong [12] points out that, changes in the carbon dioxide concentration in soil affects the organic matter content of soil and soil quality, resulting in soil degradation. In return, Soil degradation reduces the output of agriculture and the efficiency of inputs.

It is crucial to consider the the impact of changing climate on soil in Rwanda, in order to cope with it. According to Famine Early Warning Systems Network [13] Rwanda is ecologically diverse with highland mountain forests, savannah grasslands, and lowlands. The western part of the country is characterized by highland mountain landscapes and gentle slopes leading toward the lowland areas in the east.

Rwanda is divided into twelve zones excluding Kigali city which is considered as an urban area and they offer a form of economic geography adapted to food security analysis. These livelihood zones are defined on the basis of local economies and livelihood opportunities, National Institute of Statistics of Rwanda [14], and are regularly used to analyze food security in Rwanda [13].

According to the 2018 analysis of food security and vulnerability in Rwanda conducted by NISR, the three eastern livelihood zones, namely, Bugesera Cassava Zone; Eastern Agro-Pastoral zone and Eastern Semi-Arid Agro-Pastoral zone are areas prone to drought conditions which prevent farmers from performing well in their farming activities. Besides, there is East Congo-Nile highlands subsistence farming zone that is at risk of prolonged dry spells as well as severe flooding. This zone is located in a high altitude mountainous area of Rwanda Southern Province. As the Eastern Semi-Arid zone, East Congo-Nile Highlands zone suffer from poor roads conditions and steep terrain which impede access to markets during the rainy seasons, the period when landslides occur more frequently. These conditions prevent farmers from selling their products.

Moreover, Ministry of Foreign affairs [15] notes that the mountainous west of the country constitutes a subject to erosion, part of central north and south experience severe floods, and the east and south suffer from droughts and desertification.

The consequences are not only seen on production but also on the demand of labour. Especially, poor households are at risk of food insecurity since they rely on their own production which is done in small plots of land, in-kind payment and market purchase mainly through agricultural activities/labour to meet most of their annual food needs.

3.1 Vulnerability of agricultural sector in Rwanda

The vulnerability of the agriculture sector in Rwanda is found in the characteristics of the country's topography. The western part of the country is dominated by highland mountain landscapes and gentle slopes while the eastern is consisted of lowland areas. These conditions make the whole country's arable land susceptible to severe landslides, erosion and floods. Another challenge is the demography of the country, which constitutes one of the most densely populated in the region. In addition, there is limitation in ability to cultivate with climate smart related options coupled with small size plot hold by farmers.

According to REMA [5], agriculture is highly sensitive to climate change and extreme weather conditions such as droughts, floods and severe storms. This is so in Rwanda, since all farming activities are dominantly rain-fed. In line with the observation of REMA [5] several factors account for the direct connection between climate change and agriculture productivity. These include average temperature increase, changes in rainfall amount and patterns; rising atmospheric concentrations of CO₂; pollution levels such as tropospheric ozone; climatic variability and increase in frequency and intensity of extreme events such as droughts, floods, intense and destructive rains, as well as other related events such as landslides.

As observed by Mutabazi [16] rainfall behavior shows that the rainy seasons in Rwanda are becoming shorter with higher intensities. As a result, there are events such as floods and landslides in areas experiencing heavy rains; and drought in dry areas. This tendency leads to decrease in agricultural production. For instance, heavy rains that have been observed in the northern and the western provinces coupled with a loss of ecosystems services due to the deforestation have resulted in soil erosion, rock falls, landslides and floods which destroy crops. On the other hand, the eastern province has been experiencing rainfall deficits over the decade of 2000–2010, leading to droughts.

The impact of climate change on agriculture and allied sectors in Rwanda is presented in **Figure 1**.

As REMA [5] observes, there are some climatic conditions which have increased crop growth vulnerability. First of all, the shifts in rainy seasons (September–December) and (March–May) and short or prolonged dry seasons in some regions distort growing seasons. This usually confuses farmers on critical decisions such as planting dates, which affects the timing of field preparation and planting in turn. These also affect crop growth, cause intensification of crop diseases and pests and result in lower crop yields. For instance, the shift in rainfall patterns leads to reduction in the amounts of rain water harvested therefore affecting both hillside and valley irrigation projects, through either decreased water levels in ponds/dams or high amount of water destroying dam/pond embankments and causing erosion and silting. Sometimes, the high amount of rainfall destroys the quality of the soil and affects the growth of crops.

For instance, REMA [5] highlights the floods observed in the Northwest and in the marshes of the River Valleys of Nyabugogo and Akanyaru in Rwanda resulted in loss of food production, property destruction which usually leave the farmers homeless and without food. Besides, they lead to serious soil erosion and destruction of irrigation infrastructure both on the hill slopes and down the valleys.

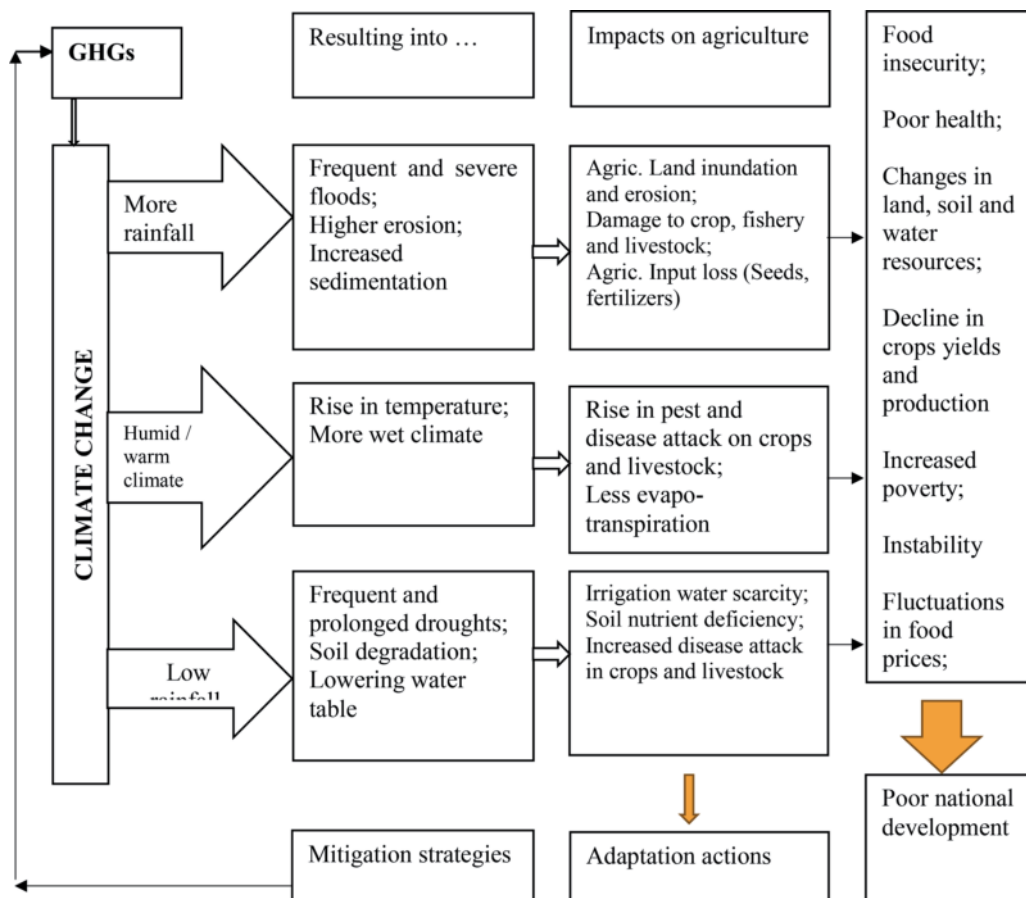


Figure 1. Climate change effects and related impacts in the agricultural and allied sectors. Source: Adapted from [5].

Another major factor of vulnerability that REMA [17] showed is the prolonged and cyclical droughts. This drought is encountered in the Southeast of the country resulting from decreasing annual rainfall amounts (from 1000 mm to 700 mm) which leads to food insecurity and displacement of communities. Moreover, this calls for relief supplies and resettlement which would have budgetary implications. On the other hand, REMA reported that since 2011, the intense rains in the Northwest and the droughts and erratic rainfall in the districts of Bugesera, Nyanza, Gisagara, Huye, Rusizi-Nyamashoke have affected over 60–90% households. These climate hazards do not only affect food production, but also results in food and nutrition insecurity.

3.2 Droughts

As a result of global warming, Rwanda's drought vulnerability is observed to be high. Mutabazi [16] notes that drought; irregular rains and dry spells were the most commonly reported shocks for households. For instance, drought made the Southeast region vulnerable where decrease in annual rainfall as well as prolonged and cyclical droughts led to food insecurity.

Drought mostly affects the agro-bioclimatic regions of the East and Southeast of the country and sometimes some zones of the Central plateau. For example, Bugesera used to receive rainfall amounts between 700 and 800 mm/year before the 1990s but in the 2000s; it only receives 300 mm/year which is more than 70% of water deficit. As a result, the production of cereals and leguminous plants such as

maize and beans has become almost impossible in this region. Another consequence of drought is the proliferation of parasites like caterpillars on sweet potatoes and predators of beans [18]. These parasites prevent crops from growing normally leading to low production which increases the risk of food insecurity in the country.

For example, NISR [14] shows that severe drought in the main growing seasons (A and B see **Figure 1**) impact between 28,500 and 157,700 people in all seven districts of the Eastern Province (Kayonza, Gatsibo, Kirehe, Nyagatare, Rwamagana, Ngoma and Bugesera). Moreover, the analysis highlights that about 62,000 MT and 157,700 MT of major crops are vulnerable to severe drought in season A and season B, respectively. Among these major crops such as banana, cassava, and Irish potato are the most vulnerable.

3.3 Flooding

The Global Facility for Disaster Reduction and Recovery (GFDRR) associated with the World Bank [19] state that floods are most frequent disasters in Africa. This may be a result of number of transboundary river systems located in Africa in addition to 160 major fresh water lakes and several small rivers, consequently this situation leads to frequent seasonal floods. Moreover, the report further notes that the impacts of natural disasters such as floods and landslides among others are further exacerbated by the weak flood protection, insufficient urban drainage systems, and increased run off caused by land degradation and poorly planned development.

Concerning landslides, Kervyn *et al.*, [20] highlights that landslides constitute a major hazard in many mountainous and hilly regions. Obura [21] weigh in by advancing the view that in countries with hilly terrain and high levels of rainfall, landslides risk is high due to widely prevalent soil erosion, deforestation and unsustainable land management which constitute the main causes of landslides in Africa. Rwanda is a good example in these case. Rwanda is in the African Great lakes region and is highly elevated; its geography is dominated by mountains in the west and savanna to the east, with numerous lakes throughout the country, where does the nickname “country of a thousand hills’ come from.

Ministry of Environment [6] describes the relief of profile of Rwanda as follow: Rwanda is hilly and mountainous with an altitude varying between 900 m and 4507 m above sea level. The components of that relief are: Congo Nile Ridge Overlaying Lake Kivu with an altitude between 2500 m and 3000 m, it is dominated in the Northwest by the volcanic ranges consisting of five volcanic massifs of which the highest is Karisimbi itch 4507 m. The central plateau presents a relief of hills with an altitude ranging between 1500 m and 2000 m. The lowlands of the East are dominated by a depression characterized by hills with a more or less round top and 1000 to 1500 m in altitude. And the lowlands of the South-West in the Bugarama plain with an altitude of 900 m are part of the tectonic depression of the African Rift Valley [6].

According to MINITERE [18], in Rwanda, the most frequent direct risks to which agriculture is exposed are related to flooding and landslides. Erosion affects at least 50% of all farmers with a 30% decline in farm productivity while deterioration of soil is detrimental to Rwanda’s food security for over 90% of the people who depend solely on agriculture in the country [16]. Soil erosion contributes to the decrease of agricultural productivity, causing therefore food insecurity problems. Floods, landslides and collapses are acute in regions with high altitude. These are dominantly in the west, southwest and north and central regions of the country.

4. Rwanda's specific climate change related actions in agricultural sector

Rwanda seeks to transform the agricultural sector from subsistence farming to a sustainable, value-creating, market-oriented food sector with high contributions to national output and household food security [22]. This makes the government of Rwanda to be ambitious concerning the mitigation of and adaptation to climate change. The basis for actions, by the government of Rwanda, on climate change is enshrined in international and national legal provisions. Among them we can mention United Nations Framework Convention on Climate Change (UNFCCC), the Millennium Development Goals (MDGs) targets that guided actions of countries. MDGs largely succeeded in capturing the popular imagination and reflecting shared priorities [23]. In 2015 UN, member states adopted an ambitious new agenda "transforming our world": the 2030 Agenda for Sustainable Development (Agenda 2030), establishing 17 Sustainable Development Goals (SDGs) to be achieved by all countries and stakeholders by 2030 to finish the unfinished mission of MDGs and transform the economies and societies of all countries. It has been proven that achieving all the SDGs will be much more challenging without urgent climate action (SDG 13).

At the regional level, Rwanda subscribes to EAC Climate Change Policy (EACCCP) that has been developed for the EAC region to engage a more strategic and cooperative approach to responding to the impacts of climate change and maximizing any potential benefits of the changing climate. Moreover, Rwanda's commitment to combating climate change impacts on the agricultural sector is set out in its Nationally Determined Contributions (NDCs) reports under the 2015 Paris Climate Change Declaration that embody its efforts to reduce national emissions and adapt to the impacts of climate change.

Specifically, in Rwanda climate change is recognized at the highest level of government as a potential threat to productivity and sustainability of the agricultural sector and livelihoods. This is more so because the agricultural sector constitutes the backbone of the economy of the country and contributes up to the third of GDP of the country. As a result, the government of Rwanda developed and is implementing a number of policy initiatives including: mechanisms to implement provisions of international climate change provisions, for instance the implementation of National Adaptation Programmes of Actions (NAPA); reforming public institutions by including climate change management functions; and mainstreaming climate change within policy processes.

4.1 Land use consolidation

The agricultural land in Rwanda is fragmented and mainly located at hilly slopes [22]. In order to optimize the use of available farmland, the government focused on the agriculture land utilization systems. In this regard, the Ministry of Agricultural and Animal Resources (MINAGRI) initiated the Crop Intensification Program in 2007 in which the main pillar was the Land Use Consolidation policy of 2008. According to NISR [14], land consolidation is a reallocation of parcels of land to overcome the effects of fragmentation. Farmers in the same area, adjacent to each other choose a single crop and use of a single cultivation regime (inputs, schedule of planning...). through this approach, the boundaries and rights of parcels remain intact and the government provides subsidized inputs for farmers in a given area with closed parcels to grow the same priority crops on a minimum size area of 5 hectares in a synchronized manner and hence improves the productivity.

4.2 Soil protection and land husbandry

Analysis of rainfall trends shows that the rainy seasons are becoming shorter with high intensity rains which lead to decrease in agricultural production. Moreover, MINAGRI [22] notes that 90% of agriculture land is on slopes. In this regard, the putting in place of effective land management structures is of a great importance to improving productivity. Thus the government of Rwanda has introduced a number of measures which comprise radical terraces accompanied with soil fertility management and soil erosion control. For farmlands on gentle slopes, progressive terracing and agroforestry have proven success in reducing soil erosion.

NISR [14] highlights that an average of 67% of agricultural households in Rwanda is engaged in land conservation practices. These practices include terracing and agroforestry that minimize soil erosion and promote water conservation. According to Gasheja and Gatabazi [24], PSTA I and PSTA II programmes were largely successful in terms of progressive and radical terraces, accompanied by soil fertility management and soil erosion control.

4.3 Irrigation and water management

Around 22% of agricultural households have land under the land consolidation programme and 9% of them have a part of their land irrigated [14]. Irrigation was identified as a key strategic activity in PSTA II in concordance with the commitment of Rwanda under CAADP compact which establishes Land and Water management in its pillar I. Researches show that irrigation is important in increasing agricultural productivity by allowing multiple cropping, and reducing vulnerability to weather shocks. By signing the CAADP, the government of Rwanda promised to allocate 2% of public funds for irrigation development.

In fact, irrigation allows farmers to move from rain-fed agriculture to diversified high value crops, thus increased cropping intensity and land productivity as well as resilience to climate change [22].

4.4 Input in farming

The provision of farming inputs has also contributed to increased crop productivity in a number of areas in Rwanda. Since 2007, there has been an increase in fertilizer use. Gasheja and Gatemberezi [24], reveal that the application of fertilizers in crop intensification programme areas has reached an annual average of 29 kg/ha/year in 2011–2012 compared to a national average of 4.2 kg/ha/year from 1998 to 2005 which increased crops yields. For example, maize yields increased from 0.65 MT/ha in 2000 to 2.5 MT/ha in 2010 while wheat yields increased by 2.5 times during the same period.

4.5 Improved seeds

As noted by Huggins [25], the efforts exist to make the agriculture in Rwanda more climate-smart. MINAGRI [26] observes that availability, accessibility and optimal quality seeds enhance crop yields and their subsequent contribution to food security, balanced nutrition, value of the product in the market, and economic growth. In the line with CIP policy, farmers, where it is applicable for now, must use improved seeds for selected crop to increase the production to ensure food security and to increase incomes [27].

4.6 Agricultural mechanization

Agricultural mechanization is for efficiency and expanding production scope. In Rwanda, mechanization of the agriculture sector consists of different forms of machinery which performs different farm operation: land development and land preparation, planting, crop treatment, harvesting, post-harvesting and agro-processing.

Mechanization of agriculture has many benefits. Gasheja and Gatemberezi [24], argue that mechanization contributes to improving productivity of cultivated land and facilitates expansion of cropping areas, thus improving overall food security. MINAGRI [22] emphasized that agricultural mechanization is among the key technological pillar to boost the yield and production by minimizing the harvest and post-harvest losses while saving human and capital investment farm operation.

MINAGRI has facilitated the ownership of farm machinery to interested farmers, through a lease agreement with them. Actually, MINAGRI, in partnership with private service providers, provides the necessary equipment, tools and training with the aim of accelerating the mechanization of agriculture.

4.7 National post-harvest staple crop strategy

The National Adaptation Programme of Action and the National Strategy of Rwanda on Climate Change and Low Carbon Development highlight improved post-harvest management as a key climate change adaptation priority.

In Rwanda, climate change is causing floods and droughts, increasing the incidence of thunderstorms and associated high winds. It is also changing traditionally dry seasons, increasing the incidence of rainfall in the midst of higher temperature. These changes affect existing rural infrastructure and pose a threat to traditional practices in harvest storage [28]. Besides, the success of the Crop Intensification Program, launched in 2007 with the objective of increasing productivity in selected food crops while improving food security and self-sufficiency, increases in crop yields resulted in unanticipated surpluses in key staple grains and cereals [29]. In handling the problem of crop yield loss, under MINAGRI, the government initiated the National Post-Harvest Staple Crop Strategy in 2011 with the goal of assisting and strengthening farmers with the harvesting, post-harvest handling, storage, trade and marketing within staple crop value chains in Rwanda in the effort to reduce post-harvest losses. The fundamental vision of this strategy is to reduce food insecurity through an efficient post-harvest private sector system delivering staple food to the people of Rwanda [29]. This framework has been guided by Vision 2020 of the Government of Rwanda, EDPRS and PSTA.

5. Conclusion

Climate change is a reality. It has much more impacts in regions where vulnerability is high. That is why countries, regions and even at international level, concerned stakeholders must look on how to reduce vulnerabilities. Based on literature this study noted that achievement is seen in land management using soil erosion mitigation strategies such as terracing and irrigation schemes. The land consolidation model has been key to raising production.

The government of Rwanda developed and is implementing numerous strategies and programmes across the country. Since 1992, the country started to ratify and sign international and regional treaties and protocols which it domesticated

according to its needs. In this sense, Rwanda started its journey with Vision 2020 which the objective was transforming the country from the status of a low income economy into a middle-income economy and a mission of overcoming poverty. Because of successful adaptive strategies in farming activities, a significant growth in agricultural productivity has been one of the main rivers of growth and poverty reduction. The performance of agricultural sector has been impressive after the introduction of the Rwanda national agricultural policy and strategies such as the Land use consolidation programme, improved seed, inputs like fertilizes and use of pesticides, water management, terracing, agricultural mechanization and improved post-harvest storage.


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