Effects and Consequences of Global Climate Change in the Carpathian Basin

János Rakonczai
University of Szeged, Department of Physical Geography and Geoinformatics Hungary

1. Introduction

The consequences of global climate change are quite versatile on Earth. The rise of surface temperature is more or less general, however its degree can be different in space. Its effect can mostly be proved by the well-measurable changes observed in ice-covered areas. Significant alterations are observed also in the distribution of precipitation which means excess rainfall at certain places and water-shortage elsewhere. In the last century a 0.8°C rise in surface temperature and a 60–80 mm decrease in precipitation were detected in the Carpathian Basin. Since both temperature values and precipitation show considerably high standard deviation, it is very difficult to prove the trend character of these changes. Nevertheless, based on our research, there are some environmental indicators (groundwater, soil, vegetation, and biomass) which are suitable for revealing the true consequences and tendency of climate change.

2. Climate changes of the geologic recent past

Several researches in the field of climatology, geology, archaeology and environmental history inform us about the climatic changes of the last centuries and millennia. The volumes of the IPCC published in the last two decades have revealed in detail that in the tertiary period, surface temperature on Earth was even 10°C higher than today, and during the glacials (e.g. several ten thousand years ago during the last ice age) relatively rapid fluctuations (even 10°C) occurred in mean annual temperature (Broecker 1997). For the last thousand years, evaluable records and observations are available. Based on these data, main temperature tendencies can be drawn for the globe but at the same time more significant spatial differences occur. This statement can be confirmed by the temperature changes of the last millennium in the world and in the Carpathian Basin (Fig. 1). It can be observed that the little ice age in the middle ages caused a more significant fall in temperature in the basin and lasted longer than globally.

Precipitation also showed significant alterations in the last thousand years. Paleobotanical researches showed that in the boreal phase (8–9 ka ago) dry steppe was characteristic in the Carpathian Basin with around 300 mm mean annual precipitation. Archaeological data indicate a significantly drier period around the end of the Sarmatian age (1–5th century A. D.), and for example along with these, even 3–5 metres groundwater-table fall was also revealed near the River Danube (Knipl & Sümegi 2011). The changes in precipitation can also be designated by the alterations in the water level of Lake Balaton in the last millennium (Fig. 2), however it was also artificially modified occasionally because of military purposes.

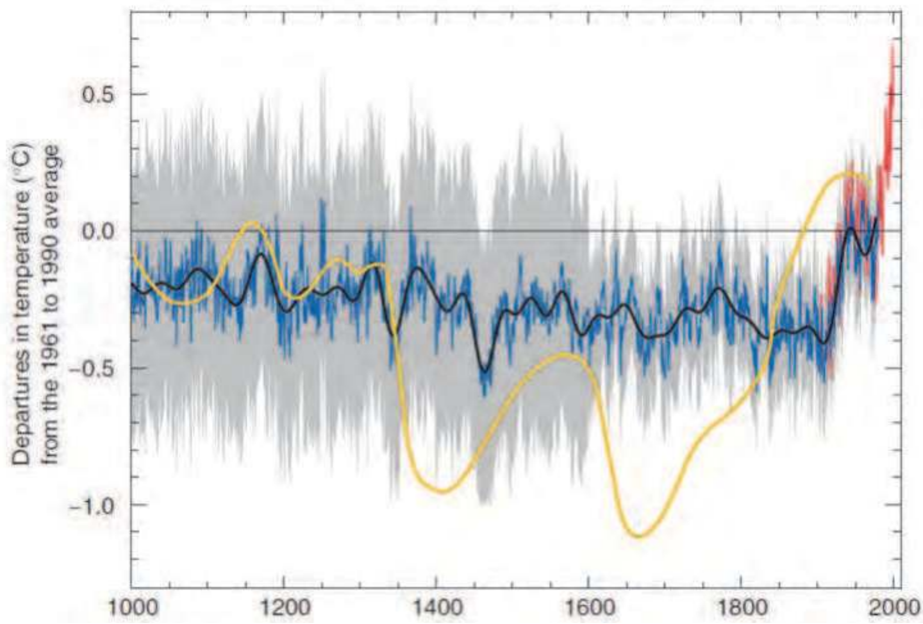


Fig. 1. Mean annual temperature in the Northern Hemisphere (black) and in Eastern-Europe (yellow) (based on IPCC 2001 and Varga-Haszonits 2003).

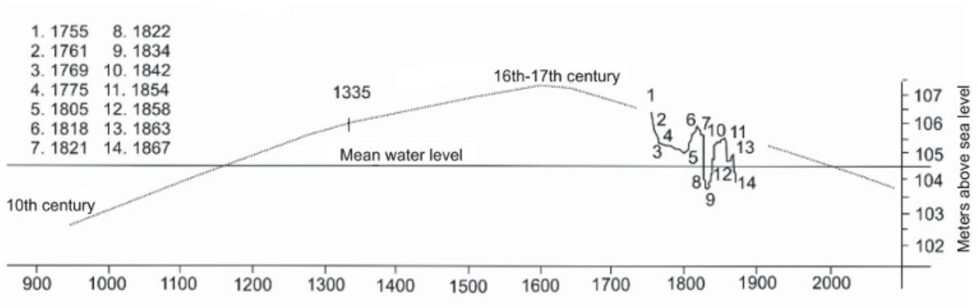


Fig. 2. The water level of Lake Balaton in the last thousand years (Rácz 2011).

More and more detailed environmental historical researches have also revealed that the Carpathian basin, which has a small territory on an Earth scale (around 100.000 km^2), provided quite variable conditions (many times just because of its basin characteristics) for the ecosystem (Sümegi 2011). Thus, the effects of climate change can occur diversely in the landscape. Therefore, in the research of the consequences of recent climatic changes, climate historical analogues are advisable to be taken into consideration.

3. Groundwater as an indicator of climate change

The primary water source of near-surface aquifers is precipitation, changes of which can be reflected by these reservoirs. Where the groundwater* can be refilled from surface waters or by subsurface flow from distant areas, this connection is not strong. In those areas where there is no opportunity for external water supply, significant alterations in the water-table can be formed due to climatic changes showing the trends of precipitation relations.

The territory located between the two large rivers of the Carpathian Basin (the River Danube and the River Tisza) is an ancient alluvial fan and appears as an elevated ridge (about 60–80 metres high) (Fig. 3). It has no surface or underground water-influx from the surroundings, so precipitation is the only source of groundwater, except of the areas with lower elevation along the rivers. In this maximum 10–20 km wide zone, the characteristic annual fluctuation of groundwater-table remains invariable (maximum in spring, minimum in autumn) but longer periods with lower precipitation causes decrease in its amplitude (Fig. 4)

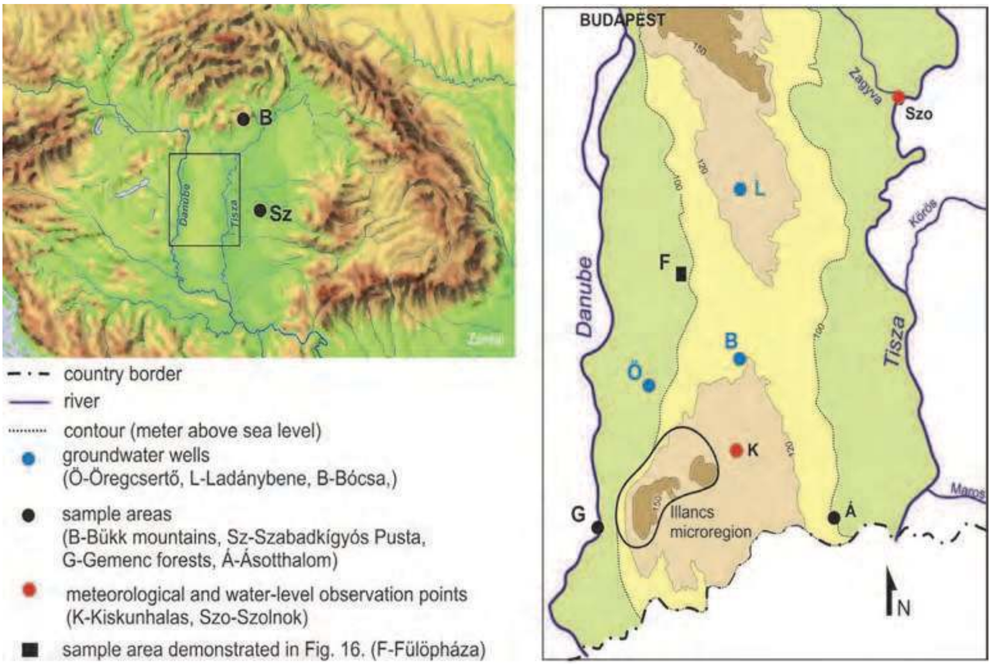


Fig. 3. Terrain model of the Carpathian Basin and the Danube–Tisza Interfluve, displaying the areas under investigation and demonstration in this study.

*shallow groundwater which means the water of the porous aquifer above the uppermost water-retaining layer. As these aquifers have priority for agricultural purposes, well network has already been built in the 1930s for collecting data of the groundwater table by continuous monitoring. However, the number of these observing wells changes, 1500–1700 wells working permanent (Szalai 2011) provide reliable base for spatial evaluation.

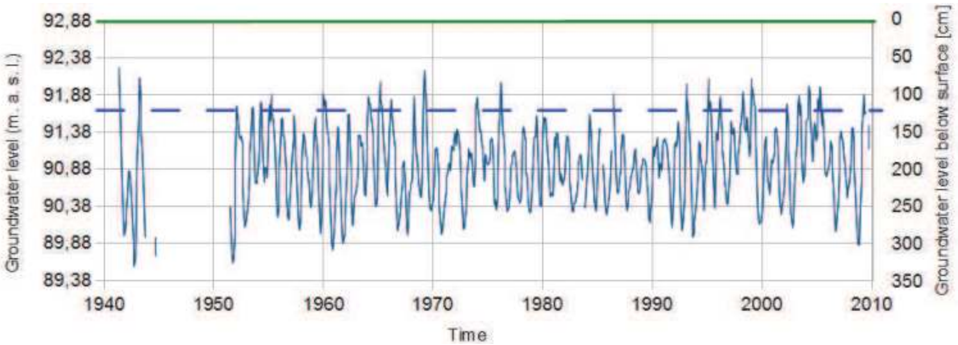


Fig. 4. The multiyear-changes in the level of groundwater-table (at Öregcsertő) on the alluvial flood plain of River Danube (20 km from the river) do not refer to decreasing precipitation (Data source: VITUKI, Hungary).

The green line represents the surface, the blue dashed line shows the average of yearly highest water-levels between 1996–2005 on River Danube.

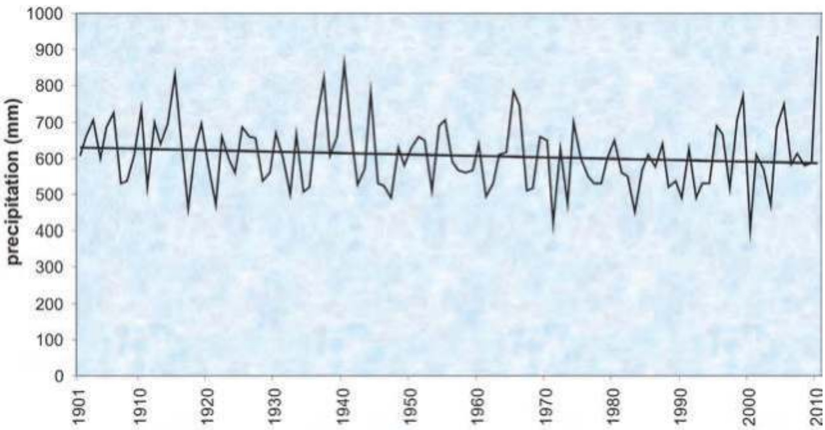


Fig. 5. Spatial averages of mean annual precipitation in Hungary between 1900 and 2010 (Data source: Hungarian Meteorological Service).

In higher areas, the decreasing annual precipitation – in spite of extremities (Fig. 5) – resulted in a continuously decreasing groundwater-table (Fig. 6). In the upper aquifers, the annual average water-levels have sunk as much as 6–8 m in the last 40 years. The decline of the groundwater-level is in close connection with the relief (height above sea level), which confirms that the main cause of sinking here is precipitation-shortage. In areas, where the decrease of the groundwater-table is less significant (related to the height above sea level too), a period with higher amount of precipitation can contribute to the rise of the water level, or even can normalise its state (Fig. 7). Where the groundwater-table fell significantly and the infiltration is limited due to the relief, humid years cause only temporary rise in water-levels, the decreasing tendency continues almost irresistibly (see Fig. 6). Moreover, certain anthropogenic causes also contribute to the process, for example the irrigation from subsurface aquifers in dryer periods.

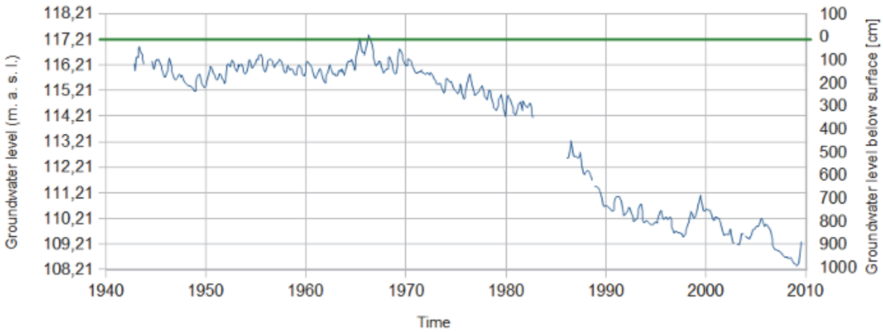


Fig. 6. The declining groundwater table in at a test site (Ladánybene) with higher elevation, where precipitation is the only source of groundwater, showing the consequences of the decreasing amount of precipitation. (Data source: VITUKI, Hungary) It can be seen that humid periods (like 1999 or 2010) can only temporarily modify the negative trend.

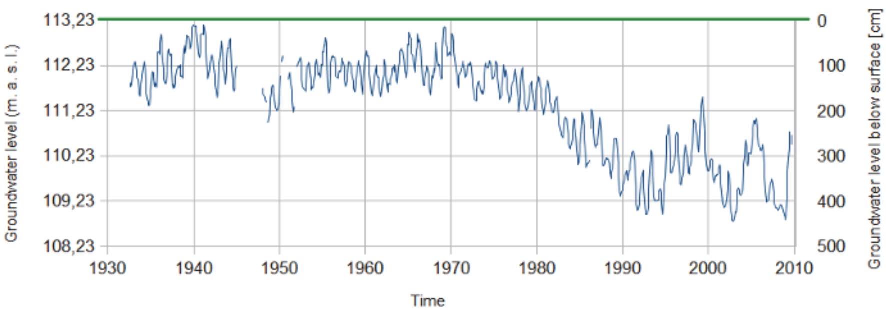


Fig. 7. Groundwater-well (Bócsa) showing the permanent effect of the decreasing precipitation but reacting more sensitively to precipitation surplus (Data source: VITUKI).

Year	Water shortage (km^3)
1980	1,15
1985	2,32
1990	4,08
1995	4.80
2000	2,84
2003	4,81
2010	~ 0,5–0,8

Table 1. The approximate quantity of water deficit in the Danube-Tisza Interfluve related to the first part of the 1970s.

By geoinformatical methods, we determined the degree of water shortage in the Danube–Tisza Interfluve, being the most affected territory in the Carpathian Basin (Fig. 8). We calculated that following arid periods, the water shortage of the region (about ten thousand km^2) is around 5 billion km^3 (Table 1), which approximately equals the total annual water

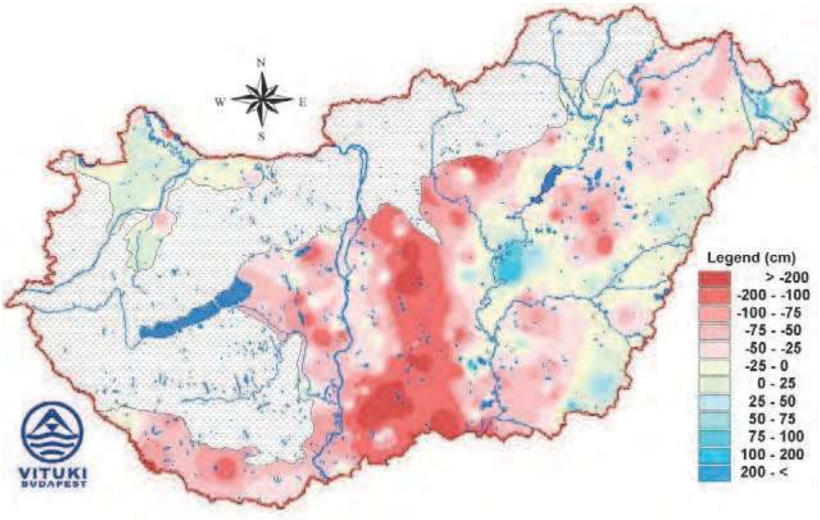


Fig. 8. Spatial distribution of differences between the average groundwater-level in the 1971–2000 period and the mean groundwater in 2009 in Hungary (Data source: VITUKI Environmental Protection and Water Management Research Institute).

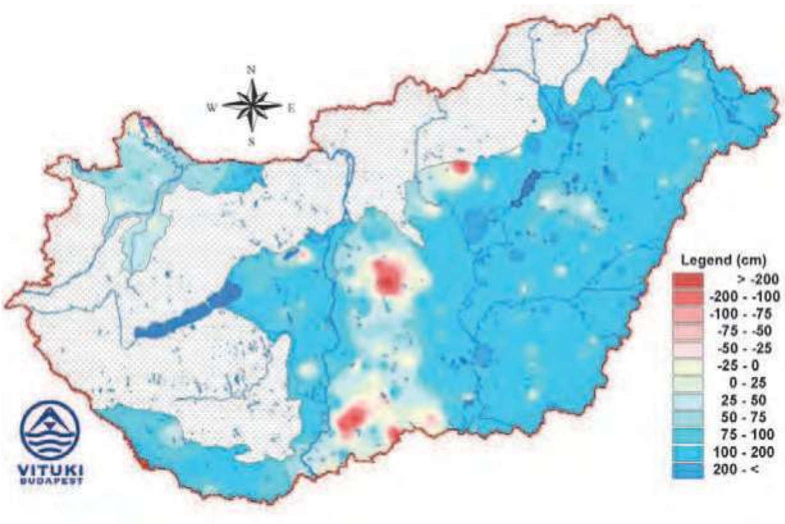


Fig. 9. Spatial distribution of differences between the average groundwater level in the 1971–2000 period and the mean groundwater level in December 2010 in Hungary* (Data source: VITUKI Environmental Protection and Water Management Research Institute).

* In the case of areas without data, there is no groundwater due to geological attributes or there are no observations allowing map representation because of small spatial extension.

consumption of Hungary. From August 2009 until the end of 2010, the most humid period has been experienced on record in the Carpathian Basin but in the case of areas with the highest fall in groundwater level, water-shortage can be still observed – however, its degree has significantly declined. These confirm our previous hypothesis (Rakonczai 2007) that on one tenth of the territory the aridification processes seems to be irreversible, since the groundwater-resources can not regenerate after an extreme humid period (Fig. 9).
The descending groundwater-table causes significant economic damage in areas mostly affected by the aridification process: fruit plantations and traditionally dug groundwater-wells dried out, farming became unpredictable, thus the aridification process has become a socio-political question as well (Ladányi et al. 2011).

4. Altering soils

The continuous sinking of the groundwater-table due to precipitation-shortage causes the alteration of certain soil types. The most spectacular changes can be observed in the case of saline soils. Since the waters of the Carpathian Basin are characterised by high salt content, the decrease of groundwater modifies vertical salt transfer processes (and its direction) in the soil profile, resulting usually the descending of the salt-accumulation zone.
Nature conservation specialists have already been registering the decreasing extent of wetlands from the 1970s and in some areas the diminishing salt content of soils related to the declining groundwater-table level as well (Kákonyi 2006). A well-observable consequence of the alterations is the decreasing extent and number of salt efflorescences being previously frequent in saline areas. In the 19th century, the salt swept and collected from the dry surface had an important economic role in the Great Hungarian Plain. E.g. according to the official registering Akasztó, a small settlement in the Danube–Tisza Interfluve, was the first on the list of "salt-producers" with 400-500 tons of salt in Hungary in 1893 (Aradi & Iványosi-Szabó 1996). According to a comprehensive soil evaluation in 2002, salt efflorescences can be observed only in the case of 32 places from the previous 164 saline areas in Hungary (Tóth 2002) and salt-collection has already been discontinued for long decades. The desalinisation process was revealed by Hungarian investigations related to the MEDALUS program* in the case of more sample areas (Kertész et al. 2001). However, the most exact alterations were detected by the author of this paper (due to some luck).
In the middle of the 1970s, detailed geomorphological and pedological investigations were performed on the Szabadkígyós Pusta (being a division of the Körös-Maros National Park at present – see Fig. 3 point Sz) as a part of the preparations for declaring the area protected. Beside the precise morphological mapping of sodified bench microforms typical in the saline landscape, sample plots were identified for joint evaluations made together with botanists (Rakonczai 1986). In the framework of the later study detailed botanic surveys were made along with the analysis of the chemical parameters of soils lying under different vegetation types. At that time nobody thought that after 25–30 years this area can be appropriate to detect the consequences of climate change. The research activity has been renewed at Szabadkígyós from 2003, when it was noticed on a field trip that during the elapsed quarter of a century the previously saline territory significantly changed, though most of the original sampling sites remained identifiable (Photo 1). We have already suspected at this point that the observed transformations were driven by the changes in the

* Mediterranean Desertification And Land Use

water cycle. Later it turned out that there were some further factors in the background as well, though the aridity experienced between the late 1980s and mid 1990s seemed to be the most important factor behind changes. During the long lasting drought period the groundwater table sank, and thus the effect of waters, having sometimes a 5000 mg/l salt content, became less and less apparent on the surface. As a result saline precipitations (salt efflorescence) started to disappear from the soil surface and the decreasing salt content enabled the gradual advance of grassy vegetation (Photo 2 and Photo 3).

Photo 1. Sample area assigned in 1979 in May 2006 (in Szabadkígyós Pusta).

Photo 2 and 3. Saline soil with salt efflorescences in 1976 become covered with steppe vegetation by 2006.

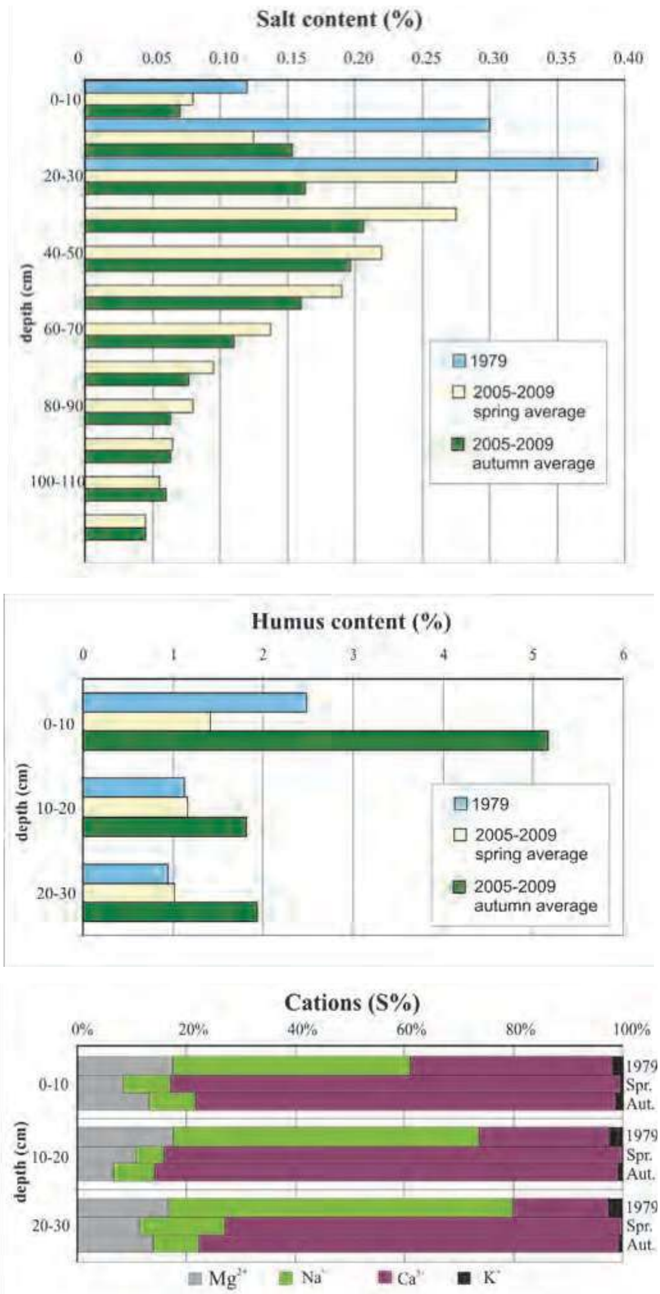


Fig. 10. Alteration of some characteristic attributes of a saline soil profile based on the measurements between 1979 and the average of 2005–2009 period in Szabadkígyós Pusta (Note: Soil sampling in 1979 was performed for the upper 30 cm).

Soil samples collected regularly since 2005 (Barna 2010) made the quantitative assessment of soil transformation possible. Results justify the physical and chemical background of modification. During the past 30 years, due to the mentioned environmental changes, the total salt content of soils has decreased significantly, especially the amount of Na dropped, thus providing more favourable conditions for plants. The gradual advance of vegetation has been followed by the considerable increase of humus content (Fig. 10).
Research prove that as a result of the aridification process, a decreasing salt content and an increasing humus content can be observed in the upper soil of saline areas in the Carpathian Basin, and at the same time steppification process can be registered. According to our experiences, this alteration can take place within 2-3 decades.

5. Vegetation as an indicator of climate change

One of the best indicators of climate change is vegetation, since it can indicate short-term alterations and it can be an important marker of extremities as well. By buffering the effects of climate extremities it can also be suitable for detecting long-term tendencies. Vegetation can sign the changes of life conditions by the degree or the lack of adaptation. Previous research revealed that in the past flora reacted to the alterations of climatic conditions by the shift of the vegetation zones. But at what extent is vegetation able to respond to the changes faster than before in landscapes fragmented by anthropogenic activities (Csorba 2008) and detached by artificial barriers?

5.1 Biomass

In terms of agriculture, a good or a bad harvest of a year is mainly determined by the consequences of climatic variability. Nevertheless, on the same territory different plants are grown year by year and water can be supplemented by irrigation if it is needed. Therefore, it is not possible to examine properly the relationship between crop yield and climatic data at the same place.
Based on our investigations, forests can be suitable for analysing the connection between biomass production and climatic conditions, since their location is permanent for many years and the effects of natural precipitation is not modified by irrigation. Increasing spatial resolution (and quality) as well as the easier availability of satellite imagery improved our investigations.
Using (NDVI and EVI) vegetation index series data of the MODIS sensor, carried by the Terra satellite, the relationship between forests and precipitation was investigated in case of several forest areas. It was shown that vegetation index data proved to be suitable for revealing the spatial differences of water up-take by plants (from precipitation and groundwater) (Ladányi et al 2009).
As a first step of our investigation, forests of a microregion (Illancs see Fig. 3) mostly affected by the groundwater depletion were analysed. In this case, landuse was influenced by the forestation in the 1900s. Even though forest management plays an important role in the area, large homogenous forest patches are rare, rather many small ones with different composition of species are characteristic. Nowadays, native stands are uncommon, mainly planted acacia and pine are the dominant tree species.
On the basis of a 10-year-period (2000–2009), vegetation dynamics of the main forest types were analysed and the relationship between precipitation and biomass production was investigated (Ladányi et al 2011). Vegetation dynamics were taken into consideration only

during the vegetation period (from April to September) because this is the most active period of trees, and in winter snow and cloud cover can highly modify the evaluation. Forests were chosen as control sites, where the groundwater-sinking is not significant and where the groundwater is easily available for trees.

Our evaluation, not reviewed in detail at this time, showed the differences of the main forest types (acacia as deciduous and pine as coniferous forest) in vegetation dynamics (Fig. 11) and demonstrated the relationship between vegetation index values and precipitation distribution (Fig. 12). The tendency of annual curves for both the NDVI and EVI vegetation indices shows unambiguously the natural features of both forest types. As a consequence of the different character of the foliage, deciduous forests are characterised by lower values than coniferous forests in the first part of the year and reach higher values later. The reduced importance of precipitation at the end of the vegetation period can also be observed (September 2001).

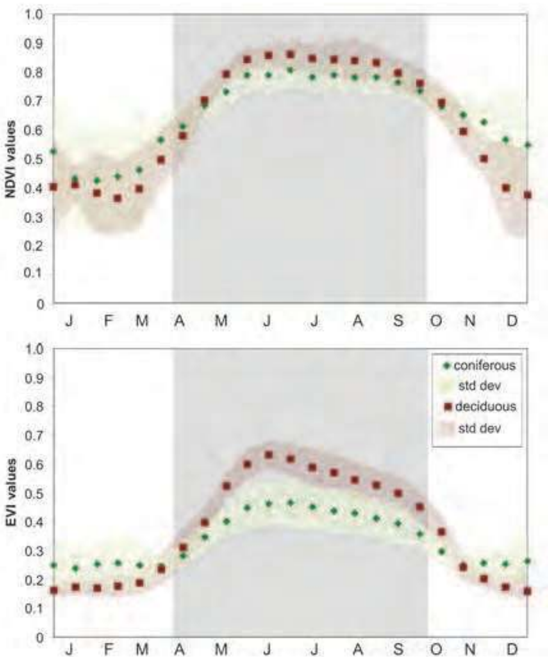


Fig. 11. Vegetation index values of coniferous and deciduous forests (2000–2009) (Ladányi 2011).

In the sample area, the relationship between biomass production (its calculation is not demonstrated in detail, it can be found in Ladányi et al. 2011), and precipitation was investigated (Table 2). In the demonstrated results the intervals are given where the correlation between the vegetation indices and the determining periods of precipitation was the strongest.

Based on the investigations, a strong relationship can be established between precipitation and biomass for both vegetation indices in the Illancs microregion. The strength of the connection slightly differs in case of the different tree species but it is significant in both cases. It can be strange for the first sight that winter precipitation has no significance in biomass production in this landscape, since (as we know) soil is impregnated by water in the winter period which supply later moisture for vegetation.

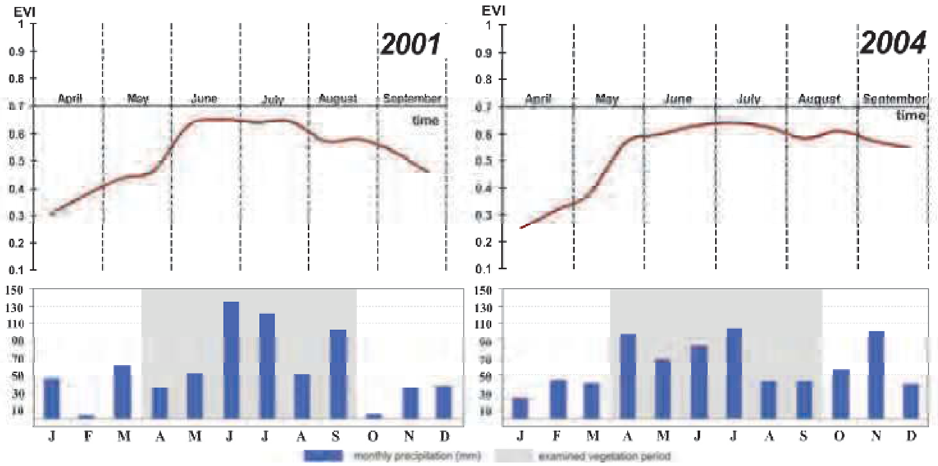


Fig. 12. Vegetation indices for deciduous forests in years with different precipitation distributions (Ladányi 2011).

Examined forests	Correlation coefficient (EVI)	Determining period (EVI)	Correlation coefficient (NDVI)	Determining period (NDVI)
Illancs microregion, coniferous forest	0.76 – 0.84	III–VI	0.85 – 0.93	III–VI
Illancs microregion, deciduous forest	0.84 – 0.95	III–VI	0.83 – 0.92	III–VI
Alluvial flood plain, Gemenc forest (control)	<0.2	-	<0.2	-
Edge of the Sandland, Ásotthalom, coniferous forest (control)	0.8	XII-IV	0.76	I-VIII

Table 2. Correlation between precipitation and biomass production based on vegetation indices. Roman number labels indicate the month range over which precipitation was accumulated. (Precipitation data source from Kiskunhalas) (Ladányi 2010).

In order to determine the appropriateness of vegetation indices in analysing "climate sensitivity" of various landscapes, control sites were selected in the neighbourhood of the sample area where vegetation is not solely dependent on rainfall variability but can use other sources of water as well. Gemenc forest (being a part of Duna–Dráva National Park – see Fig. 3 – G), is such an area on the floodplain of the Danube. Here, the regular river floodings and the continuous connection of groundwater with the river through the sandy, pebbly silt ensure stable water supply for local tree species. (The comparison can be slightly influenced by the fact that this forest stand consists of a mixture of tree species typically with larger water demand). In this area, vegetation index curves showed less differences in each year compared to the Illancs sample area. Furthermore, biomass production did not show a strong correlation with any periods of precipitation so – according to our prehypothesis – this control site does not appear to be sensitive to environmental changes from the point of view of precipitation.

As a further control site, a larger pine forest was selected on the eastern edge of the Danube-Tisza Interfluve (Ásotthalom) on soils with heavier structure, where the effect of regional groundwater-sinking process is less severe (1–2 m) and where rivers do not affect the groundwater-level substantially. The analysis of vegetation indices also showed strong relations with the precipitation (Table 2) but winter period proved to be important as well. In this case groundwater affects the water balance of vegetation so it is less exposed to the variability of precipitation.

Biomass investigations in certain parts of the Danube–Tisza Interfluve demonstrated that in areas highly affected by the groundwater table decreasing process, forests hardly depend on deep situated groundwater (since water demand is supplied from other source) so they are more sensitive to the extremities in the distribution of precipitation. Furthermore the results show that biological activity of woody vegetation can be sensitive to the declining groundwater table, so in an indirect way, it can be in connection with the long-term alterations of climate change.

5.2 Precipitation as the limiting factor of woody vegetation

Living organisms are influenced by several environmental factors (according to their own attributes). The most typical of them are water, air (oxygen, nitrogen, carbon-dioxide), nutrients and a certain range of temperature. Water supply and temperature can be directly affected by climate change.

As an effect of global climate change, the shift of forests towards the poles (and towards the peaks of mountains) can be observed in several parts of the Earth. The advancing edges of forests are investigated by researchers worldwide, but less attention is paid to the retreating low-latitude and low elevation limits of forest, however, this would be more important from both ecological and social viewpoint, as well. Beside the obvious ecological reasons of the shift of forests towards the poles (for example decreasing biodiversity of forest ecosystems), the yield-loss of forests can also result economical damages. Furthermore, the changes of landscape (the disappearance of forests) can have esthetical consequences or can affect even the quality of life (Mátyás 2010).

In the 1970–1980s, Central Europe was hit by massive forest dieback. In this period, the damage affected many commercial species, wiping out about 15 percent of oaks in a decade. The reasons were not known exactly at that time, acid rain, pests or illnesses were assigned as the main cause of the problem (Jakucs 1990). The reason could also be climate change at that time, exactly the shifting of the xeric limit, there were not enough precipitation for forests.

In the last decade the death of forests can also be observed due to the shifting xeric limit in Hungary. The spatial retreat of oak as the most sensitive species of the current climatic changes, its weakening vitality and mortality has already been obvious. It was shown that oak forests have been significantly withdrawing between the first and the last decades of the 20th century (Mátyás et al. 2010, Fig. 13). Research in the last years revealed that not the decreasing mean precipitation but the water shortage of arid years are the limiting factors of

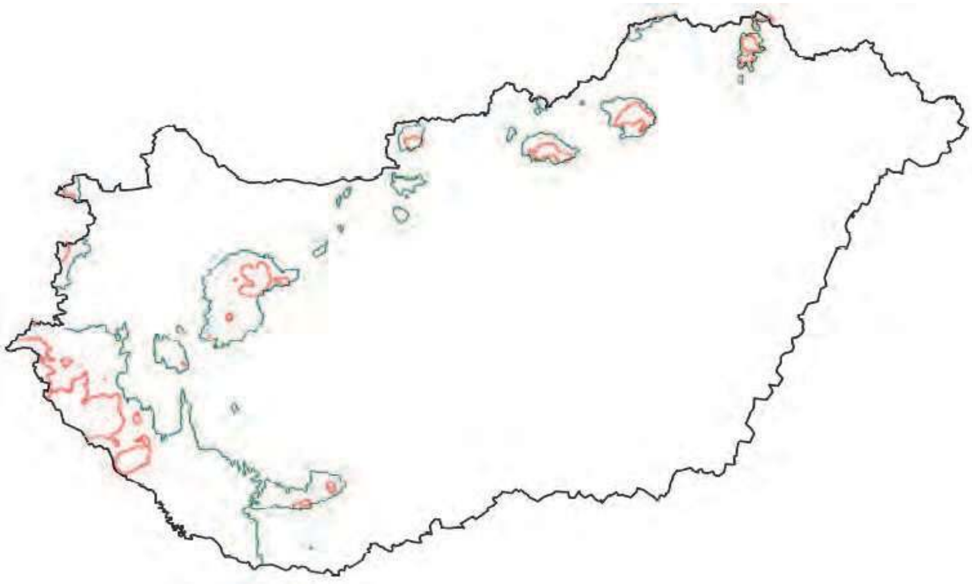


Fig. 13. Change of climate favourable for beech in course of a century: shift of contour line 24 of Ellenberg's climate quotient (=long-term minimum for beech) for Hungary, in the average of the years 1901–1930 (green) and 1975–2004 (red) (Mátyás et al 2010)

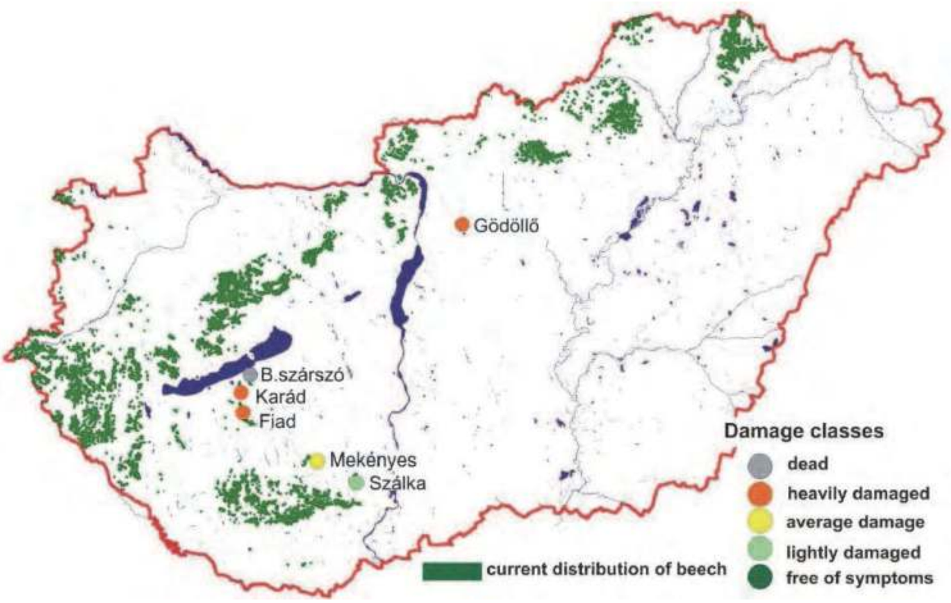
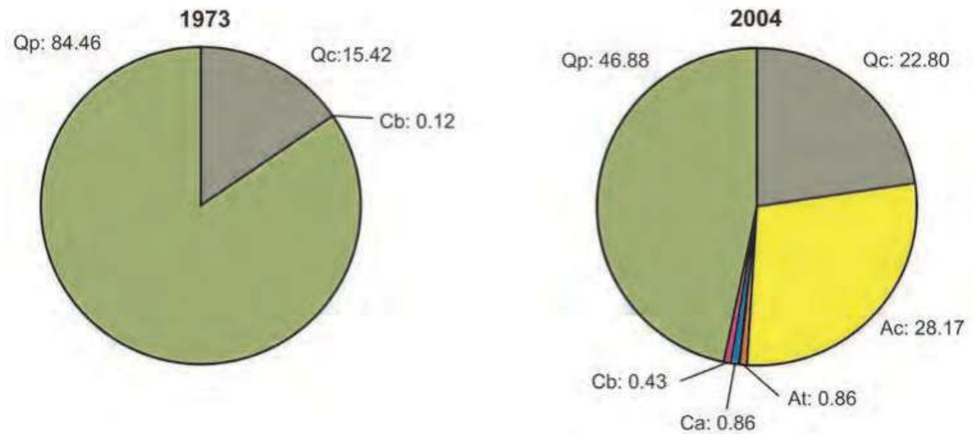


Fig. 14. Beech decline observation points with the observed damage classes in 2005 (Berki et al. 2007)

beech forest stands to subsist (Berki et al 2007). Due to the small amount of precipitation in the first decade of the 21st century, especially between 2000 and 2004 (for example the mean areal precipitation was 400 mm in Hungary but in significant territories only 200–300 mm were measured) significant damages were detected in the south-western part of the country and in case of some small forests on the xeric limit (Fig. 14). In the most endangered areas regarding climatic changes in West-Hungary, there was a need for salvage cutting in case of 30–50 percent of forests; trees had to be removed long before the economic optimum. Forest management can adapt hard to the rapid environmental changes, since the long lifespan of forest trees needs planning for 80–120 years (Mátyás 2010). As a result of the species drying out due to climate change, the composition of forests changes in an unfavourable direction. For example in the Bükk Mountains (see Fig. 3 – B), the retreating of *Quercus petraea* was followed by the expansion of shrubs and later the spread of maple (Fig. 15), and soil attributes were worsened by the composition of the changing leaf-litter (Tóth et al. 2008).



Qp=*Quercus petraea*, Qc=*Quercus cerris*, Ac=*Acer campestre*, At=*Acer tataricum*, Ca=*Cerasus avium*, Cb=*Carpinus betulus*

Fig. 15. The alteration of species composition of the forest stand in a sample area located in the Bükk Mountains (Kotroczó et al. 2007).

Similar forest- and tree damages were detected worldwide after 2000 mainly in mountain regions but these events have been treated as isolated problems. In certain areas, for example in North Africa, they are not even considered problematic, as dying trees simply make room for more goat pastures. But it has been realised that the advancing xeric limit negatively affects Ukraine, Center Asia and even North China, moreover the western part of North America. In these areas there have been sparse observations about forest mortality, however, they were considered local, transient problems and the global coherence of the process was not revealed. Forests are rarer in plain areas due to the more intensive agriculture and the dense settlement structure, thus the effects of climate change on forests can be recognised more difficult. By nowadays it has become clear that the alteration, registered in the Carpathian Basin, is not a transient and isolated phenomenon, but a part of a global process. Thus, strategic preparations are needed because of the predicted climate change in the next decades. For example, the spread of drought tolerant species has to be promoted professionally and an important task is to protect the genome of the endangered valuable populations. There is a need for changing in nature conservation practices as well: instead of the previous passive protection, active steps are necessary (Mátyás 2010).

5.3 The effect of climate change on the alteration of plain's vegetation

Landuse has changed significantly in the plain areas of the Carpathian Basin during the last 1,5–2 centuries due to human activity: e.g. as a result of the high demand for cereals at the beginning of 19th century, almost all the potential cultivatable area was converted into arable land. In the mid-19th century one of Europe's largest regulations of rivers was completed in the Great Hungarian Plain. It resulted that nature conservation research developing in the second half of 20th century in Hungary could take into account just those areas which are unsuitable, less worthy for more intensive farming on the base of „principle of remains". The extension of these remained natural areas are relatively small, they are often wetlands at lower elevation, which could have been utilized only as pastures. Thus the effects of climate change on natural vegetation can be found in a highly mosaic landscape, where the response of vegetation is strongly restricted and the climatic affects are often combined with the consequences of anthropogenic interventions. In the followings we present some typical examples for the reaction of vegetation to changing environmental conditions.

The reaction of vegetation to changing water supply and altering soil conditions can be perceived first in the decrease of the number of individuals. One of its well-conceivable consequences was e.g. the stock-decrease of the halophyte herb of *Matricaria chamomilla* during the last two decades. The reduction of its collected amount was explained first by socio-economical reasons (buying up became stricter), and nobody thought that soil-alterations resulted by the drier climate are standing in the background, which was revealed by later research.

We mentioned at point 4 (altering soils) that 5 sample plots (see Photo 1) were pointed out for a soil-vegetation connection research at the end of 1970s in a saline area in Southeast Hungary (see Fig. 3 – Sz point). Their first detailed botanical surveys were performed in the vegetation period (between April and September) of the years of 1980–1982 (Kovács & Molnár 1986). Repeated surveys occurred in these plots in 2006 and 2009 (Margóczi et al 2008, Barna 2011).

The alteration of the area is significant considering the vegetation, and the decrease of salinity can be confirmed unambiguously. The number of species has decreased: in 1980 40, but in 2009 only 33 species occurred in this area. Because of the higher productivity of soils resulted by the alterations the coverage of vegetation became higher in 2006 and in 2009 too comparing with the one in 1980. The total coverage of the plant species of strongly saline soils almost halved; while the number of plant species of slightly and moderately saline soils increased to a less degree, as they took the places of the regressive euhalopyte plant species. The number of non-salt-tolerant pseudohalopyhte species decreased, but their total coverage increased significantly. On the other hand the number and coverage of species with higher soil moisture requirement became higher to 2006 reflecting more precipitation of those periods (2005, 2006), however it decreased again because of the dry first half of the year 2009. The changes are illustrated on a sample plot covered by the strongly halophyte saline meadow community of Agrostio-Beckmannietum (Fig. 16). It can be seen well that the alteration of soils results the change of plant communities too: this strongly saline plot covered by Agrostio-Beckmannietum saline meadows in 1980 was turned to a less saline meadow type of Agrostio-Alopecuretum until 2006.

As a consequence of climatic drying and water regulations during the last decades the wetlands of the sand-ridge of the Danube–Tisza Interfluve have also begun to dry out in many places. This has also been accompanied by the degradation of vegetation. These aridification processes promote the desiccation and leaching of the saline habitats in the sand-ridge becoming uncharacteristic which results that the annual salt pioneer vegetation and *Puccinellia* swards (salty meadow-type) of solonchak soils are turned into less saline *Agrostio-Caricetum* saline meadows, then into degraded *Achilleo-Festucetum*-like sand steppe-grasslands. The less salt-tolerant species (e.g. *Festuca pseudovina* and *Agropyron repens*) have become dominant in these leaching grasslands.

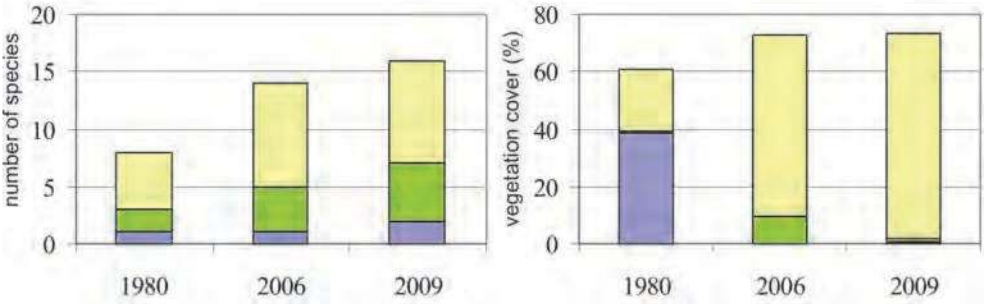


Fig. 16. Number and coverage of non-salt-tolerant pseudohalophyte species (yellow), astenohalopyte species of moderately saline soils (green) and euhalophyte species of strongly saline soils (blue) in a sample plot covered by *Agrostio-Beckmannietum* in 1980 (Barna 2011).

The former wetter *fen-woodlands* were suppressed partly because of climatic reasons, on the other hand they were cut out. Nowadays on their places mainly tussock meadows and wet fens (e.g. with *Schoenus nigricans* or *Eriophorum sp.*) can be found, but they became rare too. The above mentioned wettest fen vegetation-types were replaced by Molinia fens, sedgefields and meadows (these grassland-types were also formerly widely distributed in moderately wet depression formed by deflation), which are turned into stepping Molinia fens then sand steppe-grasslands as an effect of further dry-out. The above mentioned transformation resulted a *shift in habitat-zonation* on the edge of the deflation hollows (Deák 2011). In Hungary all the fens and bogs are maintained by local groundwater-flows and microclimatic conditions (e.g. special geomorphological position, protective buffer-zone forest maintained microclimate), so these are highly climate-sensitive communities. The groundwater-level decrease due to climate change (see point 3) caused the force back and extinction of fen habitats in large areas, and this process will probably intensify in the future if the climatic trends of the last decades continue. In the Danube–Tisza Interfluve affected by aridification the most in the Carpathian-basin, the above mentioned two typical direction of degradation processes can be pointed out (Fig. 17), but there are also such areas where the degradation of natural habitats hasn't appeared during the last 1.5 decades (Margóczi et al. 2011). These are mainly relatively deeper places in the edge-zone of the sand-ridge, where the lateral groundwater-flows maintain some moisture even in the drier seasons. There is also an example for a special rescue effect, when the former more extended fen vegetation found its (probably last) refuge in an artificial channel reach.

One of the important consequences of vegetation changes in the Great Hungarian Plain is that the present stocks of a certain vegetation-type occur not necessary in the place where they were 100–200 years ago. While the typical annual salt pioneer vegetation, loess steppe-grasslands and sandy oak forests live just there, where they existed even 200 years ago, the present stocks of sand steppe-grasslands and the willow-poplar alluvial forests were wet meadows for the most part 200 years ago, however their stocks of that time have mainly disappeared for today (Molnár & Biró 2011). The extension and place of the alluvial forests were highly influenced by the regulation of the rivers, the abandonment of pastures and the plantation of the forests. The transformation and the regression of the natural vegetation make favorable conditions for the aggressive expansion of adventive species. Though these species occupy the natural grasslands less frequently (e.g. non-treated wet meadows can be exceptions), but their expansion can be seen well on the increasing number of fallows, which cover more and more areas mainly in areas with insufficient soil conditions for arable lands.

Altogether it can be stated that the effect of climate change in the case of non-woody vegetation of the plains can be very various because of the differences in water supply, soils and micro-relief. Certain vegetation-assemblages have disappeared, degradation controlled vegetation transformation rows can be registered depending on soils and water supply and the species composition of the different plant associations and their surface-coverage ratios transformed significantly too even in case of slighter external changes in the most drying areas. But it can also happen that a habitat-type is forced back to a tolerable refugium with compulsory migration. In some cases it can be observed that landscape features can buffer more or less even the unfavorable effects of climate change, so the vegetation hardly changes or doesn't change at all.

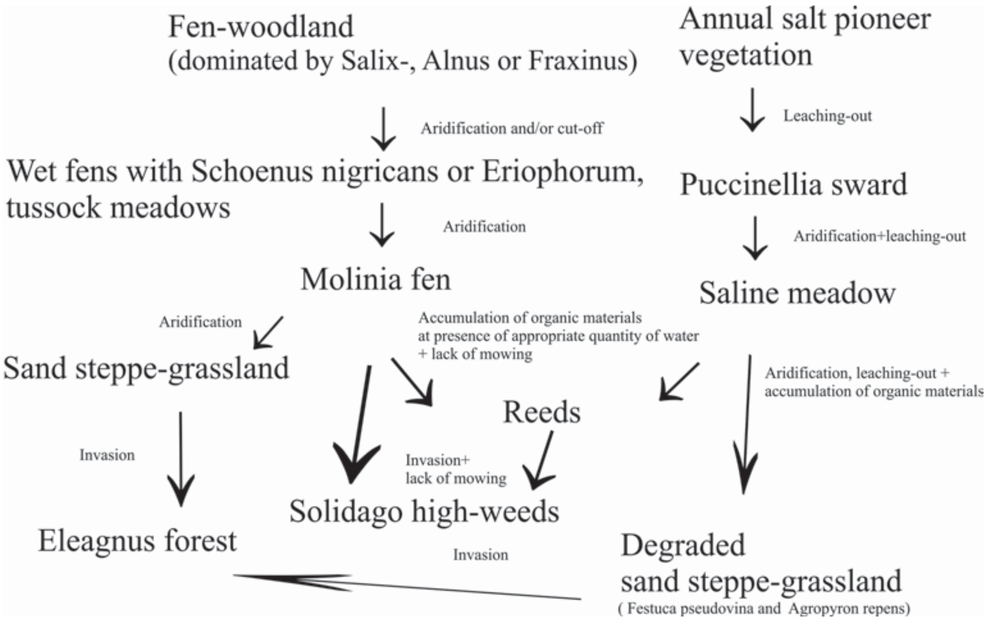


Fig. 17. Registered degradation processes of the vegetation in the Danube-Tisza Interfluve (Deák 2011).

Photo 4. Retreating fen vegetation to the channel crossing a deflation hollow in Illancs region (forced shift of the vegetation zones). (Photo: Ladányi 2010)

6. Landscape changes

Due to the decrease of near-surface water resources, the alteration of landscapes can be observed in many places. This process has been going on for a long time, however background reasons have changed in the last few decades. While in the previous 1.5-2 centuries mainly anthropogenic influence had dominated landscape change (causing alterations), in the last 30–40 years the consequences of natural alterations have taken over. The most spectacular changes are the decrease and the alteration of wetland habitats (Fig. 18). For example, only a few number of saline lakes remained from the previously numerous ones, their extent also decreased and their bed is occupied by offshore weed vegetation (*Bolboschocnus maritimus* is spreading the most agressively). In certain humid years the previous wetlands seems to regenerate but this is impossible just due to the weed vegetation (Kovács 2008). Landscape alterations related to climate change are much more complex than the decreasing extent of wetlands – however it is doubtless that most of the changes are due to the alteration in the natural water-cycle of landscapes. The simplified connection system of the changes are demonstrated in Fig. 19.

The long-term precipitation shortage (which indicates higher water-exploitation from subsurface aquifers for irrigation in lack of surface water) causes permanent decrease of the groundwater-table. This significant and permanent decline of groundwater level modifies the salt transfer in soils which might result the transformation of genetic soil type. This modification is followed by the change of natural vegetation which results in the significant alteration of natural landscapes (see Photo 2 and 3). As the ratio of agricultural fields and built-up areas in the Carpathian Basin is high, the effects of climate change on landscapes

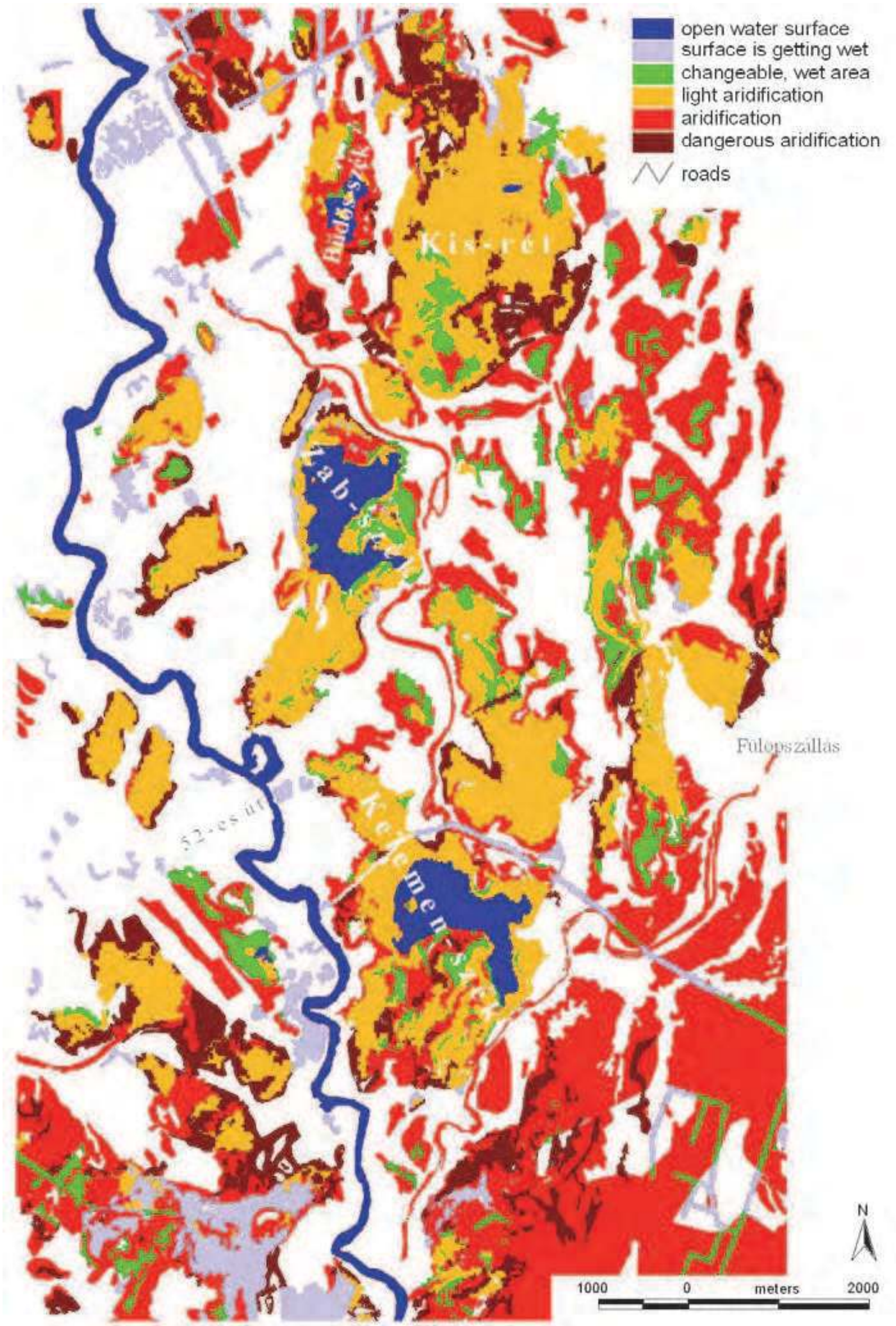


Fig. 18. Evaluation of a sample area located in the Danube–Tisza Interfluve in the viewpoint of the aridification process (Kovács 2008).

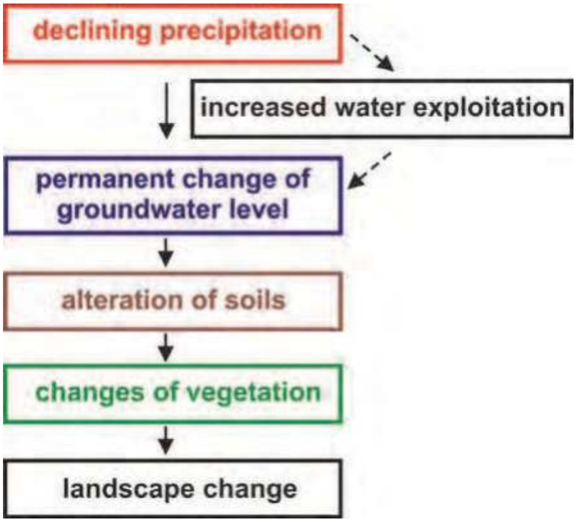


Fig. 19. The process of landscape change due to aridification.

can be observed more difficult. However, at least two of the most important consequences can be presumed:

- Due to the decreasing extent of saline areas, typical landscapes alter, for example the famous Hungarian "pusta" is under transformation at numerous locations
- The decrease in salt content and the increase in organic matter content of soils enable agricultural utilisation in several protected areas (e.g. Natura 2000) discontinuing the causes of their protection.

7. Floods and climate change

One consequence of the global climate change (due to the assessment of the IPCC) is the increase of extremities (for example in terms of precipitation). This statement – as it was shown before – is also confirmed by Carpathian Basin data. Increasing flood levels of the large rivers detected in the last decades are considered as a consequence of the climate change. However, it is not supported by the detailed evaluation of floods, since extreme precipitation events do not occur at the same time in the whole catchment, but they affect only some tributaries. In the Tisza River Basin the last flood forming in the whole catchment area occurred in 1970. Nevertheless, in the last decade (since 1999) the highest water-levels were exceeded several times. These maximum water stages were not in accordance with the maximum water discharge (Fig. 20) (and they formed only in certain parts of the river) showing that *climate change is not in the background of the increasing flood levels in case of large rivers* (Rakonczai & Kozák 2011). This is also confirmed by the fact that in the case of Hungarian rivers, the highest flood levels occurred in 20 different years (Fig. 21).
To sum up, it can be established that the increasing number of "flash floods" in smaller catchments can be connected to the extremities of precipitation due to climate change, however, in the case of large rivers, the changes in river channel capacity (for example floodplain aggradation) is the main cause of record floods.

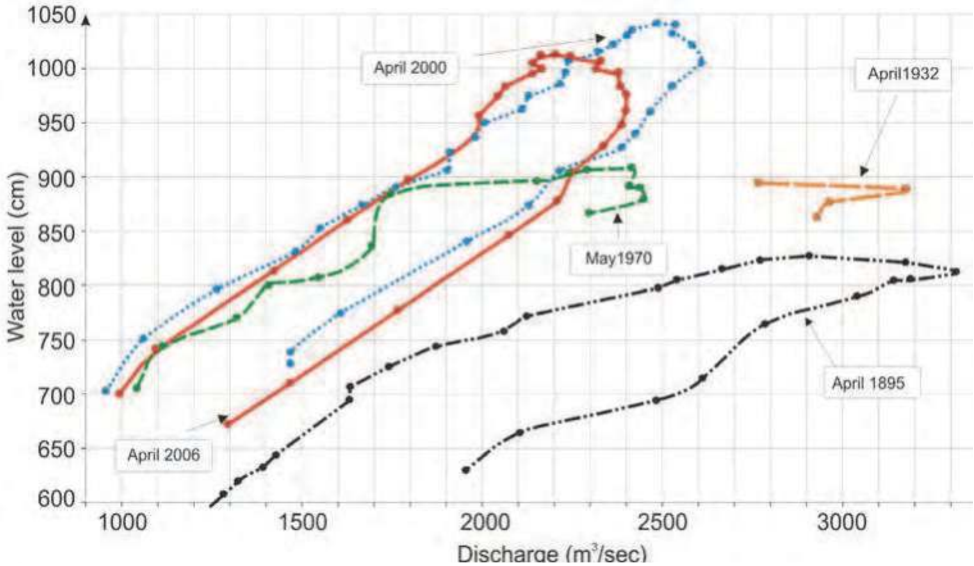


Fig. 20. Characteristic stage-discharge curves on the Szolnok reach of the Tisza (based on the data of the Middle Tisza District Water Directorate).

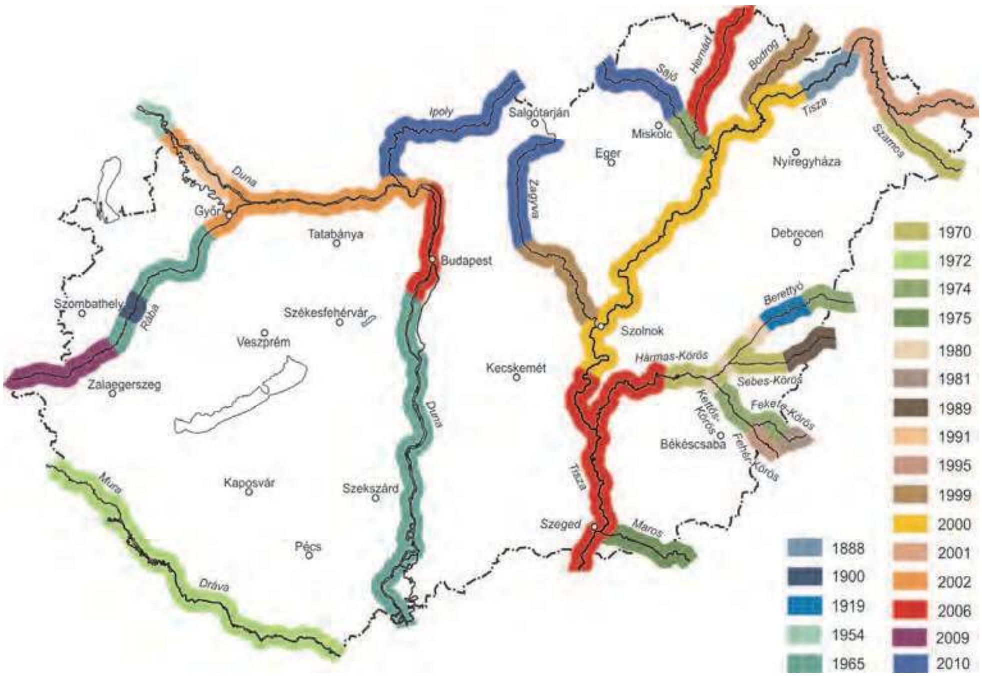


Fig. 21. Periods of record floods in Hungary.

8. Summary

Global climate change observed nowadays has preliminaries: geological and environmental historical data prove its former occurrence (having more significant consequences) in the past. The consequences of the changes – due to the differences in physical geography – cause changes with quite different scales in the landscape.

Significant territories of the Carpathian Basin are so much influenced by human activities that the effect of climate change can not be detected directly. Detailed research proved that the changes of the two main climate elements (precipitation and temperature) in the last decades have contributed to significant, trend-like alterations in the landscape. Furthermore, natural alterations are completed by the consequences of anthropogenic activities and the changes have significant social relations as well (Fig. 22). The decreasing precipitation caused groundwater-table sinking, as a result of which soil and vegetation altered, contributing to landscape changes. The detected landscape changes can serve as a base for a climate-sensitivity map in the future. However, it is important to note that every alteration in the landscape can not be explained exclusively by climate change.

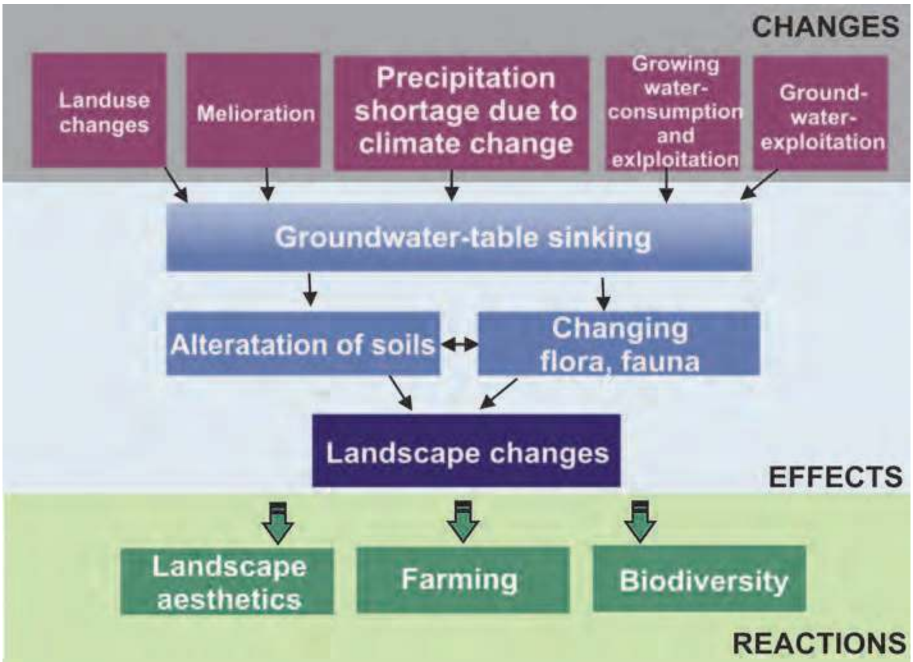


Fig. 22. The revealed relationship-system of aridification in the Danube-Tisza Interfluve (Great Hungarian Plain) (Ladányi 2010).

9. Acknowledgements

The research was funded by the Project named „TÁMOP-4.2.1/B-09/1/KONV-2010-0005 – Creating the Center of Excellence at the University of Szeged", supported by the European Union and co-financed by the European Regional Development Fund.

10. References

Aradi, Cs. & Iványosi-Szabó, A. (1996). Az Alföld természeti szépségei (Natural values of the Great Hungarian Plain). In: *A mi Alföldünk* (Our Great Hungarian Plain), Rakonczai, J. & Szabó, F. (eds.). pp. 17–36. Nagyalföld Alapítvány. ISBN 963 85437 3 6, Békéscsaba, Hungary

Barna, Gy. (2011). Tájváltozás vizsgálata a Szabadkígyósi pusztán (Analysis of landscape changes in Szabadkígyós Pusta). In: *Környezeti változások és az Alföld* (Environmental changes and the Great Hungarian Plain), Rakonczai, J. (ed.), pp. 345–354. Nagyalföld Alapítvány. ISBN 978-963 85437 8 3, Békéscsaba, Hungary

Berki, I.; Móricz, N.; Rasztovits, E. & Víg, P. (2007). A bükk szárazságtolerancia határának meghatározása (Determination of the drought tolerancelimit of beech). In: *Erdő és klíma (Forest and climate)* Vol.V., Mátyás, Cs. & Vig, P. (eds.). pp. 213–228. Sopron, Hungary

Broecker, W. S. (1997). *Will Our Ride into the Greenhouse Future be a Smooth One? GSA Today* 5. pp. 1-7.

Csorba, P. (2008). Landscape ecological fragmentation of the small landscape units (Microregions) of Hungary based on the settlement network and traffic infrastructure. *Ekológia* Vol. 27. No.1. pp. 99-116, ISSN 1335-342X, Bratislava, Slovakia

Deák, J. Á. (2011). A növényzet tájléptékű változásai a Kiskunság délkeleti részén (Changes of vegetation on choric level on the southeastern part of Kiskunság). In: *Környezeti változások és az Alföld* (Environmental changes and the Great Hungarian Plain), Rakonczai, J. (ed.), pp. 327–338. Nagyalföld Alapítvány. ISBN 978-963 85437 8 3, Békéscsaba, Hungary

IPCC (2001). Climate Change. Third Assessment Report. Intergovermental Panel on Climate Change. ISBN 0521 80767 0

Jakucs, P. (1990). A magyarországi erdőpusztulás ökológiai megközelítése (Forest dieback in Hungary from ecological aspects). *Fizikai szemle* Vol.40. No.8. pp. 225-234.

Kákonyi, Á. (2009). Szikes tavak a Duna–Tisza közén (Saline lakes on the Danube–Tisza Interfluve). In: *Magyar Hidrológiai Társaság Vándorgyűlése. ISBN 978-963-8172-23-5.* 01-03.07.2009. Available at:
http://www.hidrologia.hu/vandorgyules/27/dolgozatok/12kakonyi_arpad.htm

Kertész, Á.; Papp, S. & Sántha, A. (2001). Az aridifikáció folyamatai a Duna-Tisza közén (The processes of aridification on the Danube-Tisza Interfluve). *Földrajzi Értesítő.* Vol.50. No.1–4. pp. 115-126.

Knipl, I. & Sümegi, P. (2011). Két rendszer határán. Az ember és a környezet kapcsolata a sárközi dunai allúvium és a Duna–Tisza köze peremén (On the border of two systems. Connection of humanity and the environment on the edge of the Danube alluvium and the Danube–Tisza Interfluve). In: *Környezeti változások és az Alföld* (Environmental changes and the Great Hungarian Plain), Rakonczai, J. (ed.), pp. 45–54. Nagyalföld Alapítvány. ISBN 978-963 85437 8 3, Békéscsaba, Hungary

Kotroczó, Zs.; Krakomperger, Zs.; Koncz, G.; Papp, M.; Bowden, R.D. & Tóth J.A. (2007). A Síkfőkúti cseres-tölgyes fafaj összetételének és struktúrájának hosszú-távú változása (Long-term alterations in species composition and structure of sessile oak - turkey oak forests at Síkfőkút). In: *Természetvédelmi Közlemények* Vol.13. pp. 93-100.

Kovács, F. (2008). Evaluation of landscape changes using GIS methods with special regard to aridification. In: *Proceedings Volume of 15th Congress of ISCO*, Kertész Á. (ed.). Available at: http://tucson.ars.ag.gov/isco/isco15/pdf/Kovacs%20F_Evaluation%20of%20landscape%20changes%20using.pdf

Kovács, A. & Molnár, Z. (1986). A Szabadkígyósi Tájvédelmi Körzet fontosabb növénytársulásai (Main plant communities of Szabadkígyós Landscape protection area). In: *Békés megyei Környezet- és Természetvédelmi Évkönyv* (Yearbook of nature conservation and environmental protection in Békés county), Réthy Zs. (ed.) Vol.6. pp. 165–200. Békéscsaba, Hungary

Ladányi (2010): Evaluation of landscape changes in the case of an environmentally and climate sensitive landscape located in the Danube–Tisza Interfluve, the Illancs microregion. PhD thesis. University of Szeged, Hungary.

Ladányi (2011): A természeti és társadalmi környezet hatása egy Duna–Tisza közi kistájra. Illancs környezetállapota és tájváltozásai az elmúlt évszázadban (The effect of natural and socio-environment on a microregion located in the Danube–Tisza Interfluve. The environmental state and the landscape changes of Illancs in the last century). In: *Környezeti változások és az* Alföld (Environmental changes and the Great Hungarian Plain), Rakonczai, J. (ed.), pp. 295–306. Nagyalföld Alapítvány. ISBN 978-963 85437 8 3, Békéscsaba, Hungary

Ladányi, Zs.; Rakonczai, J.; Kovács F.; Geiger, J. & Deák J. Á. (2009). The effect of recent climatic change on the Great Hungarian Plain. *Cereal Research Communication*. Vol.37. (suppl.) pp. 477-480.

Ladányi, Zs.; Rakonczai,J. & van Leeuwen, B. (2011). Precipitation vegetation interaction on the Danube–Tisza Interfluve. *Journal of Applied Remote Sensing*. Vol.5. (in press)

Margóczi, K.; Rakonczai, J.; Barna, Gy. & Majláth, I. (2008). Szikes növénytársulások összetételének és talajának hosszú távú változása a Szabadkígyósi pusztán (Long-term alterations in species composition of saline plant communities and the soils in Szabadkígyós Pusta). *Crisicum*. Vol.5. pp. 71–83, Szarvas, Hungary

Mátyás, Cs. (2010). Forecasts needed for retreating forests. *Nature*. Vol. 464. (Issue 7293.) p. 1271.

Mátyás, Cs.; Berki, I.; Czúcz, B.; Gálos, B.; Móricz, N. & Rasztovits, E. (2010). Future Beech in Southeast Europe from the Perspective of Evalutionary Ecology, *Acta Sylvatica&Lignaria Hungarica*. Vol 6. pp. 91–110. Sopron, Hungary

Molnár, Zs. & Biró, M. (2011). A Duna–Tisza köze és a Tiszántúl természetközeli növényzetének változása az elmúlt 230 évben: összegzés tájökológiai modellezések alapozásához (Changes of natural vegetation on the Danube–Tisza Interfluve and the Transtisza Region in the last 230 years: summary to establish landscape modelling). In: *Környezeti változások és az* Alföld (Environmental changes and the Great Hungarian Plain), Rakonczai, J. (ed.), pp. 75–85. Nagyalföld Alapítvány. ISBN 978-963 85437 8 3, Békéscsaba, Hungary

Rácz, L. (2011). Éghajlati változások az Alföldön a honfoglalástól a 19. század végéig (Climate changes in the Great Hungarian Plain from the Hungarian conquest until the end of the 19th century). In: *Környezeti változások és az Alföld* (Environmental changes and the Great Hungarian Plain), Rakonczai, J. (ed.), pp. 55–62. Nagyalföld Alapítvány. ISBN 978-963 85437 8 3, Békéscsaba, Hungary

Rakonczai, J. (1986). A Szabadkígyósi Tájvédelmi Körzet talajviszonyai (Pedology of the Szabadkígyós Landscape Protection Area). In: *Békés megyei Környezet- és Természetvédelmi Évkönyv* (Yearbook of nature conservation and environmental protection in Békés county), Réthy Zs. (ed.) Vol.6. pp. 19–41. Békéscsaba, Hungary

Rakonczai, J. (2007). Global change and landscape change in Hungary. Geografia fisica e dinamica quaternaria. Vol.30. No.2, 229-232.

Rakonczai, J. & Kozák, P. (2011). The consequences of human impacts on Hungarian river basins. Zeitschrift für Geomorphologie. Vol.55. (suppl.) pp. 95-107, Stuttgart, Germany

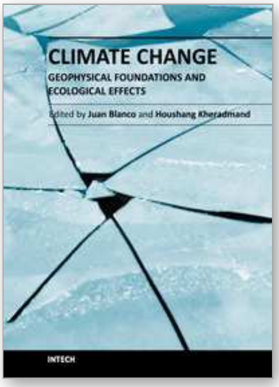
Sümegi, P. (2011). Az Alföld élővilágának fejlődése a jégkor végétől napjainkig (The development of ecosystem in the Great Hungarian Plain from the end of iceage untill nowadays). In: *Környezeti változások és az Alföld* (Environmental changes and the Great Hungarian Plain) , Rakonczai, J. (ed.), pp. 35–44. Nagyalföld Alapítvány. ISBN 978-963 85437 8 3, Békéscsaba, Hungary

Szalai, J. (2011). Talajvízszint-változások az Alföldön (Changes in groundwater-table on the Great Hungarian Plain). In: *Környezeti változások és az Alföld (*Environmental changes and the Great Hungarian Plain), Rakonczai, J. (ed.), pp. 97–110. Nagyalföld Alapítvány. ISBN 978-963 85437 8 3, Békéscsaba, Hungary

Tóth, J. A.; Krakomperger Zs.; Kotroczó Zs.; Koncz G.; Veres Zs. & Papp M., (2008). A klímaváltozás hatása a Síkfőkúti cseres-tölgyes avarprodukciójára és talajdinamikai folyamataira (The effect of climate changes on leaf-litter production and pedological processes of sessile oak-turkey oak forests at Síkfőkút). In: *Talajvédelem* (Suppl.), pp. 543-554.

Tóth, T. (2002). *Szikes talajok tér és időbeli változatossága* (Spatial and temporal variability of saline soils). MTA Phd Thesis. Budapest, Hungary.

Varga-Haszonits, Z. (2003). Az éghajlatváltozás mezőgazdasági hatásának elemzése, éghajlati szcenáriók (Analysis of the agricultural effects of climate change, climatical scenarios). *„Agro-21" Füzetek* 31. pp. 9–28.



Climate Change - Geophysical Foundations and Ecological Effects
Edited by Dr Juan Blanco

ISBN 978-953-307-419-1
Hard cover, 520 pages
Publisher InTech
Published online 12, September, 2011
Published in print edition September, 2011

This book offers an interdisciplinary view of the biophysical issues related to climate change. Climate change is a phenomenon by which the long-term averages of weather events (i.e. temperature, precipitation, wind speed, etc.) that define the climate of a region are not constant but change over time. There have been a series of past periods of climatic change, registered in historical or paleoecological records. In the first section of this book, a series of state-of-the-art research projects explore the biophysical causes for climate change and the techniques currently being used and developed for its detection in several regions of the world. The second section of the book explores the effects that have been reported already on the flora and fauna in different ecosystems around the globe. Among them, the ecosystems and landscapes in arctic and alpine regions are expected to be among the most affected by the change in climate, as they will suffer the more intense changes. The final section of this book explores in detail those issues.