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A HUNGARIAN LANDSCAPE UNDER STRONG NATURAL AND HUMAN IMPACT IN THE LAST CENTURY

Zsuzsanna LADÁNYI, János RAKONCZAI & Áron József DEÁK
Department of Physical Geography and Geoinformatics, University of Szeged, POB 653, Szeged H-6701, Hungary
zsuzsi@ geo.u-szeged.hu, J.Rakonczai@geo.u-szeged.hu, aron@geo.u-szeged.hu

Abstract: Many places in the world show spectacular landscape changes caused by the consequences of climate change and anthropogenic effects in the last decades. Most of them are due to the rapid alteration of natural water-cycle. In Hungary the Danube-Tisza Interfluve has been facing to a continuous groundwater table sinking process since the 1980s. The problem of the hydrological regime is emphasised in the Hungarian environmental and nature conservation strategies. In the dry year of 2003, the groundwater table decrease has almost reached the amount of the total annual Hungarian water-use, which can be observed not only in the degradation of natural areas, but it also became a social and economic problem. Moreover, the climate scenarios for the Carpathian Basin predict warmer summers and the further decrease of precipitation, which can play role in the further degradation of environmental and climate sensitive landscapes.

This paper presents one of the most affected part of the Danube-Tisza Interfluve (Illancs microregion). It shows its land-cover changes in the last century, analyses the causes and consequences of water shortage, shows the state of its natural areas and examines the socio-economical relations of the problem. The question to be answered in the region is how the natural, environmental, social and economic processes can be reconcile with each other considering the potential innovations and investments. The success of these projects is doubtful without the comprehensive evaluation of historical and actual processes in the landscape which is aimed to be done in this paper.

Keywords: landscape change, climate change, hydrological regime, human impact

1. INTRODUCTION

Consequences of climate change and human impact on landscape cause spectacular landscape changes all over the world (for example the decrease of Lake Chad (Olivry et al. 1996) and the Aral Sea (Aladin et al. 1995)). The revealing of the causes and consequences of these alterations became important element of scientific research in the 21st century (Küstler, 1999; Rackham, 2000; Biró et al., 2007; Molnár, 2007), as the potential and effective nature conservational and environmental management requires the knowledge of the ongoing processes in the landscape. This statement is particularly true in the case of environmentally sensitive areas where the environmental impacts cause rapid changes, even in few decades.

Among the Hungarian landscapes the Danube-Tisza Interfluve faces the most significant environmental problem nowadays. The land-use changes intensifying from the 20th century have contributed to the alteration of landscape (Bíró, 2003), the natural areas became degraded and fragmented. The problem is worsened by the melioration in the middle of the 20th century, the growing water consumption of inhabitants (drinking water, communal water use and irrigation), the increasing number of arid years (Pálfai, 2000) and the water-uptake of forests extending in the region. Due to these factors, a significant groundwater-table sinking process has been recording since the 1980s in the area (Pálfai, 1994). The water-shortage around the millennium has almost reached 5 billion m^3 which amount is equivalent with the total annual Hungarian water-use (Rakonczai, 2007). Many studies tried to prove the role of the factors playing role in this process in the last 30-40 years. At the beginning of the 1990s it was found that the natural and anthropogenic factors were responsible for the changes in equal proportion (Pálfai, 1994). Later model calculations proved that the role of natural factors (the precipitation shortage due to climate change) is more significant (Szanyi & Kovács, 2009), especially in the highest part of the Danube-Tisza Interfluve. The regionality of the problem comes from two facts. On one hand, the Danube-Tisza Interfluve is located between two big rivers forming a ridge. Surface or underground water-afflux from the surroundings is not possible so precipitation is the only source of groundwater. Secondly, the area is covered by loess and sand piled up by aeolian transport, vertically and horizontally in changing extent, in which a continuous water-flow system was formed.

On the highest part of the area the consequences of groundwater table sinking appear the most significantly, which is now not only a hydrological and nature conservational problem, but has social and economical relations as well. This paper aims to show the present state of the most affected microregion (Illancs) with the help of landscape factors, analyse the scale of the changes and their consequences related to water-shortage.

2. STUDY AREA AND METHODS

Illancs microregion is located in the south part of the Danube–Tisza Interfluve (Figure 1/a). The highest point of the ridge can be found here (Ólom-hegy, 172 m). Its western border towards the Danube-valley is the Kecel–Baja bluff. The northern, southern and eastern border is not determined similarly in the literature (Marosi & Somogyi, 1990; Keresztesi et al., 1989; Mezősi, 1989; Bíró et al., 2007). In our analysis the border published in the Hungarian microregion catasther (Marosi & Somogyi, 1990) and modified by the authors is used.

The examined microchore is situated on the alluvial fan of the river Ancient-Sárvíz (Borsy, 1989), which is covered by aeolian deposits – loess, sand and their mixed varieties – in different extent and width (Miháltz, 1950). Its detailed quaternary statigraphy is known for the upper 10 metres based on the mapping drills of the Geological Institute of Hungary (Kuti, 1982, 1991) (Figure 1/b.). Deep drilling data are available only in one place in this microchore (in Jánoshalma) and one in the neighbour microregion (in Felsőszentiván). The thickness of aeolian sediments increases eastwards. The surface is mainly covered by sand. The main winds with northwest-southeast direction made typical sand-forms like parabolic dunes, hummock dunes, longitudinal dunes, deflation hollows. Its natural habitats are open sand grassland and sand steppe-grasslands.

Military survey maps (HIM, 1806-1869), Kreybig soil science maps (Kreybig, 1930-1940), Gauss-Krueger maps (MNH, 1955), topographical maps of the 1980s (EOTR, 1982), Corine Landcover (CLC 50) (FÖMI, 2000) and ortophoto series from 2005 (FÖMI, 2005) were used for evaluating the land-use changes in the last century. For the geoinformatical analysis ArcMAP 9.3 software was used. For the habitat mapping the categories of the Hungarian National Habitat Classification System were applied (Bölöni et al., 2007).

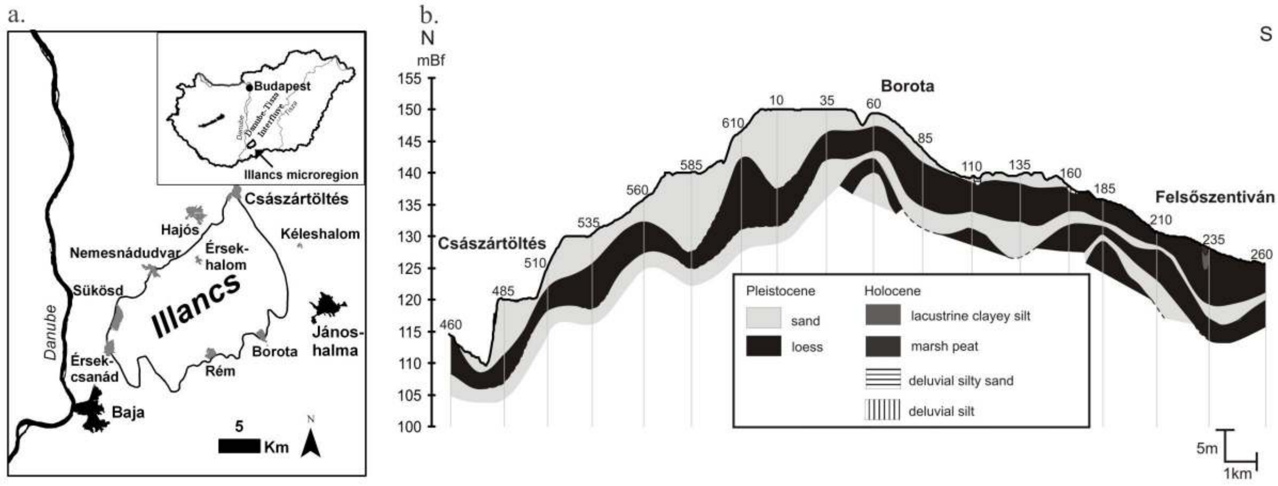

Figure 1. A. Location of the examined microregion; B. North-south cross-section of Illancs microregion (edited by Zs. Ladanyi and L. Kuti based on the data of the Geological Institute of Hungary).

3. RESULTS

3.1. Aridification

Based on the evaluation of the two main climate elements (precipitation and temperature), the climate of Hungary seems to warm up and getting drier (Mika et al., 1995, Szász, 1997, Szalai & Szentimrey, 2001), which tendencies are confirmed by the IPCC Scenarios. The attributes of landscapes determine how people experience the changes. The observed alterations in the Danube-Tisza Interfluve make this microchore more climate-sensitive. It is shown in the FAO predictions, where this semi-arid area is presented among the areas affected by improper agrarian management and climate changes (Kovács, 2006).

Due to the data of the closest meteorological station (Kiskunhalas) of the examined microregion, the last decades are determined by increasing number of years with drought according to the Pálfai Aridity Index (PAI) (Figure 2.) (PAI is developed and applied predominantly in Hungary, counted from the quotient of the mean temperature from April to August and the weighted precipitation sums from October to August, improved with several correction factors (Pálfai, 1989)). The most serious drought occurred in 2003, when the annual precipitation has hardly exceeded 400 mm. The smallest annual precipitation was observed in 2000 (319 mm), but due to the previous humid year and to the other climate factors, the drought proved to be less serious.

The role of precipitation in Illancs microregion is much more important. The region has no natural watercourse, the hydrological regime of its sandy soils is wrong. The annual average precipitation of the period between 1931 and 2009 is 586 mm/year with highly variable distribution, so water is a limiting factor of biomass production. Our previous research proved that biomass production of forests and precipitation are in stronger relation in this sensitive microregion compared to other microregions where groundwater is easily available for vegetation (Rakonczai et al., 2009). By analysing planted pine and locust forests it is proved that precipitation fallen between Marc and June determines basically the annual biomass, which can be confirmed by the wrong soil attributes and the hardly available groundwater (compared to soils with good water-storing capacity and higher groundwater-level, where winter precipitation can be influential as well).

3.2. Groundwater table changes

The first detailed mapping of groundwater-level happened between 1950 and 1954 in the Great Hungarian Plain (Rónai, 1961) had already showed deeper groundwater in the examined microregion (Kuti et al., 2002) which can be explained by the higher elevation of the microregion. In spite of that, a lot of digged wells supplied drinking water until the 1970s near to the border of Illancs, which can be seen still in the garden of the hamlets (with 4-5 meter depth). In the 1980s it became obvious that the Danube-Tisza Interfluve faces a regional hydrological problem, a continuous groundwater-level sinking process. The data of the groundwater-observing wells were evaluated by many researchers in the last decades (Pálfai, 1994; Liebe, 2000; Rakonczai & Bódis; 2002, Kuti et al. 2002; Rakonczai, 2007; VITUKI, 2005; Szalai & Nagy, 2006; Völgyesi, 2006) who confirmed the negative tendency for the region (Figure 3/a.).

Before the 1990s, there were only a few groundwater-wells in the microregion, but as the level of groundwater has reached their bottom a more detailed monitoring system with more new groundwater-wells was established. Until 2003 5-7 metres groundwater sinking happened in this microregion, which was a quite arid year, compared to the 1970s (Figure 3/a.) (Rakonczai, 2007). On the highest elevated places the groundwater table was 15-20 metres under the surface (Figure 3/b, and 4) in 2007, while its depth is somewhat higher towards the border of the microregion (5-8 metres).

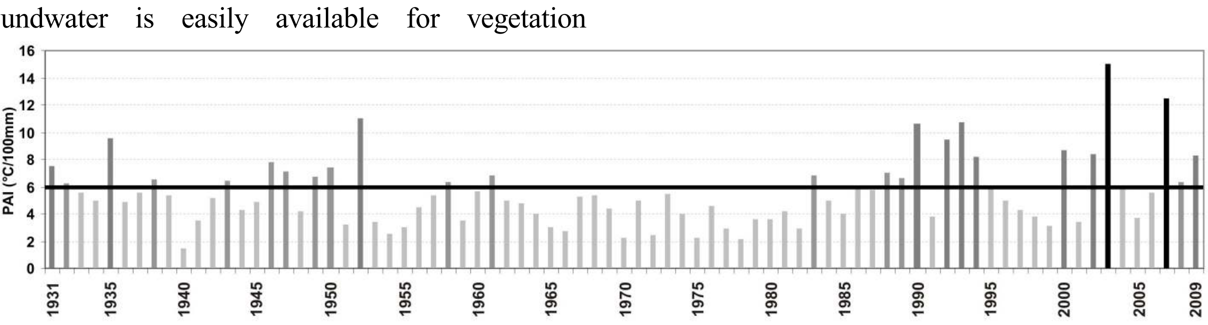

Figure 2.Values of Pálfai Aridity index for Illancs microregion, based on data from Kiskunhalas meteorological station (PAI<6 no drought; 6<PAI<8 moderate drought; 8<PAI<10 medium strength drought; 10<PAI<12 serious drought; PAI>12 quite serious drought (Pálfai, 2000))

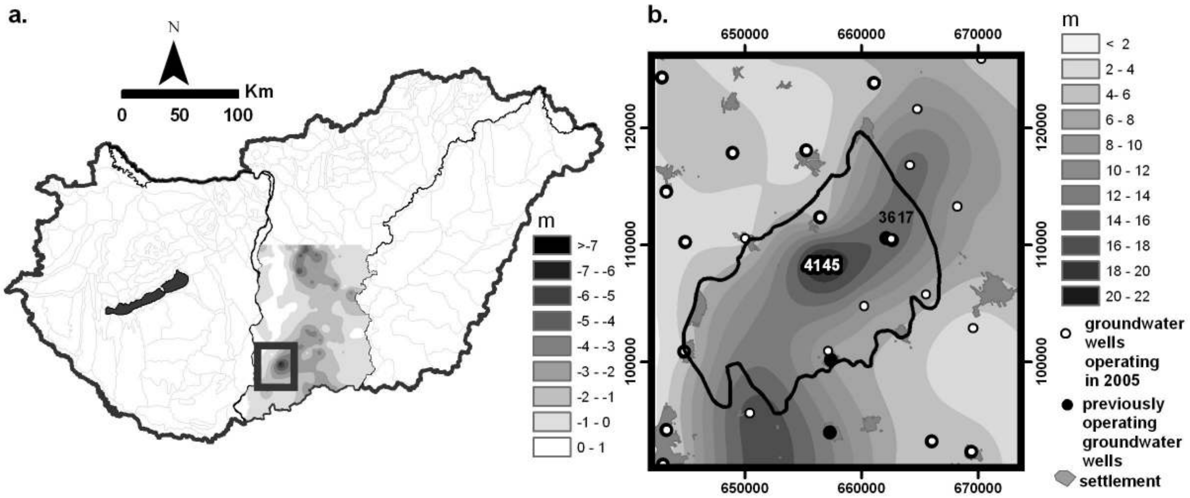

Figure 3. A. the degree of groundwater table sinking in the Danube-Tisza Interfluve in 2003 related to the 1970s; B. the depth of groundwater table under the surface in the microregion and in its environment in 2007

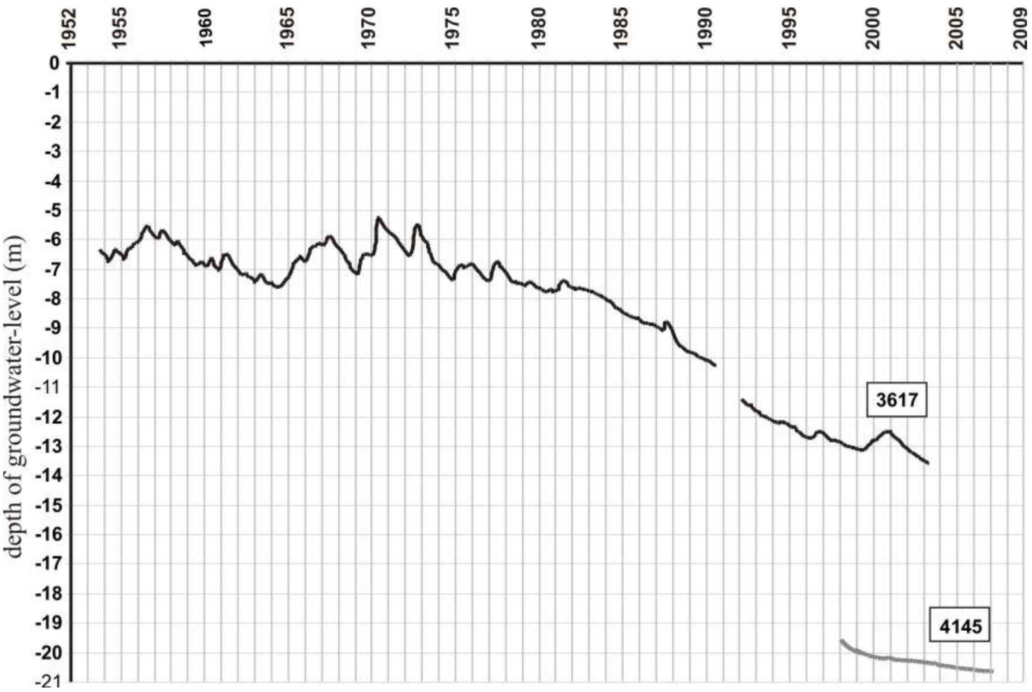

Figure 4. The changes of groundwater table based on the data of groundwater wells (Nr. 3617and 4145)

3.3. Land-cover changes

According to the maps of the 18th century (HIM, 1764-1787), the Danube-Tisza Interfluve was mainly covered by sand grasslands. At that time open sand grasslands covered the 78% of the southern part of the Danube-Tisza Interfluve (Bíró, 2003), so Illancs was characterised also by this habitat on the moving sand dunes. The ratio of woodlands was around 3.5% on choric level then (Bíró, 2003), while the proportion of grasslands could exceed the 90%. At the time of the second military survey (HIM, 1806-1869) 15% of Illancs was covered by forests (Fig. 5.). At the end of the 19th century forests have been planted in order to stop sand movements, with initially few but afterwards more success. By the middle of the 20th century forestation became more intensive. Now they are the dominant habitats covering 60% of the area. The economical aims became more important, so mainly locust and pine, more rarely poplar was planted. At the end of the 20th century aridification made the plantation of poplar very difficult because of its great water-demand. In the 1990s a serious scientific debate developed between forestry and hydrologists about the water-uptake of forests and its impact on groundwater-sinking process. Latter research figured the role of forests around 10% (Pálfai, 1994).

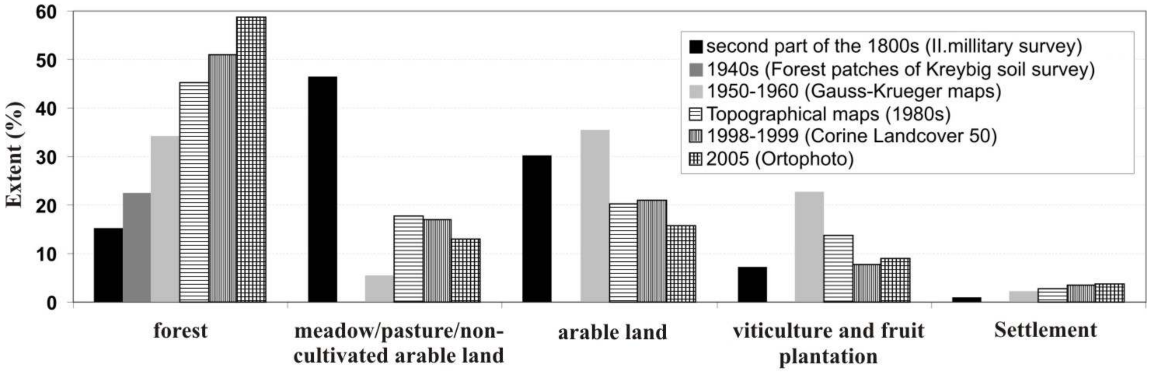

Figure 5. Land-use changes of the last century in Illancs microregion

Cultivation of sand grasslands started during the 18th and 19th century in the Danube-Tisza Interfluve (Bíró, 2003). Their extent decreased significantly to the 1950s, they covered only 5-6% of the microregion beside the huge grape and fruit plantations, and the extending arable lands (Figure 5.). Later their extension increased to 15% as a result of abandonment of arable lands with the regression of collective farming. After the millennium, negative tendency occurred again. Wetlands located in the deflation hollows dried out, so their cultivation became possible, especially at the southeast edge of the microregion (for example west from Borota) near to the border of Bácska Loess Plateau.

Arable lands have already occurred in the loess covered edge of the microregion along the Kecel–Baja bluff in the 18th-19th century (HIM, 1806-1869) (Fig. 5.). The military survey maps prove that the depressions among the dunes were cultivated in many places too. The reason for this could be their better soil-fertility, hydrological regime or just the subsistence of people. Their maximum extent is strongly connected to the period of collective farming and agricultural cooperatives, but during the socialism their extent decreased due to the forestations, extending viticulture and fruit plantations. This land-cover is also significant nowadays, mainly on loess, sandy loess and loessy sand areas, especially along the Kecel-Baja bluff. Viticultures and fruit plantations also occurred at the end of the 18^{th} century, mostly in the northwestern edge (Baja, Nemesnádudvar) of the microregion and near Jánoshalma. By the end of the 19^{th} century they covered more places on the microchore-borders (e.g. Rém, Borota), but after the phylloxerian infection of vineyards (last third of the 19^{th} century) plantations extended towards the centre parts on sandy soils. The maximum extension was reached in the middle of the 20^{th} century (Figure 5.). Nowadays many of the plots are abandoned because of the collapse of agricultural cooperatives, the EU legislations, depopulation of hamlets and the increasing water shortage. Due to deeper groundwater the vineyards, the fruit plantations, and the forests are damaged: their resistance for diseases, air pollution and frost decreased (Harmati, 1994).

The population of the northwestern part of Illancs was significant in the 18^{th} century, but the southwestern region became well-populated by the 19^{th}-20^{th} century too. The extent of settlements continuously increased during the 20^{th} century, however hamlets on higher elevation and in remote places were depopulated in the 1980s, because of the lack of communal infrastructure. The greater demand for drinking and irrigation water also contributed to the water-shortage.

Due to the above mentioned facts native vegetation (open sand grasslands, poplar-juniper steppe woodlands) remained in small extents and they are fragmented. The extent of regenerating non-used arable lands is significant, but they are strongly infected by invasive species (*Asclepias syriaca, Robinia pseudoacacia*). However, the naturalness of these meadows can be improved by grazing (see for example in Borota).

3.4. Anthropogenic effects on surface geomorphology

As a result of the main wind directions (northwest-southeast) typical sand dune forms formed in Illancs. Parabolic dunes, hummock dunes, longitudinal dunes, deflation hollows, blow-outs dominate the surface (Figure 6.) In the accumulation zone the piling up of hummock dunes can be occurred. The differences in sand dune forms are influenced by different wind power, wind direction and the vegetation cover. The land and forest management of the 20th century destroyed these typical aeolian forms on many places of the microregion. Peasants cultivated all the land they could in their small plots making even level the surface. During the period of collective farming more hectare of planning became possible by motorised tools (Fig. 7).

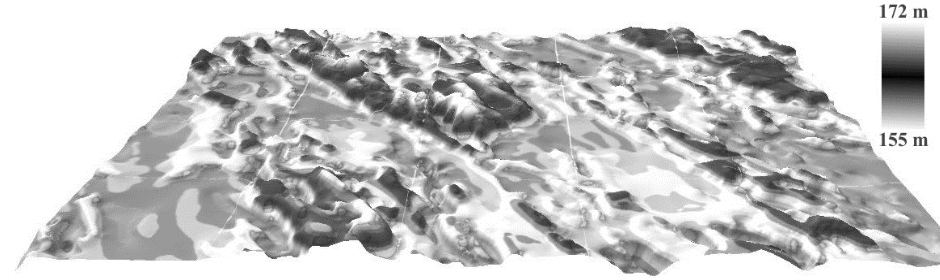

Figure 6. The highest point of Illancs microregion (Ólom-hegy, 172 m) and its environment

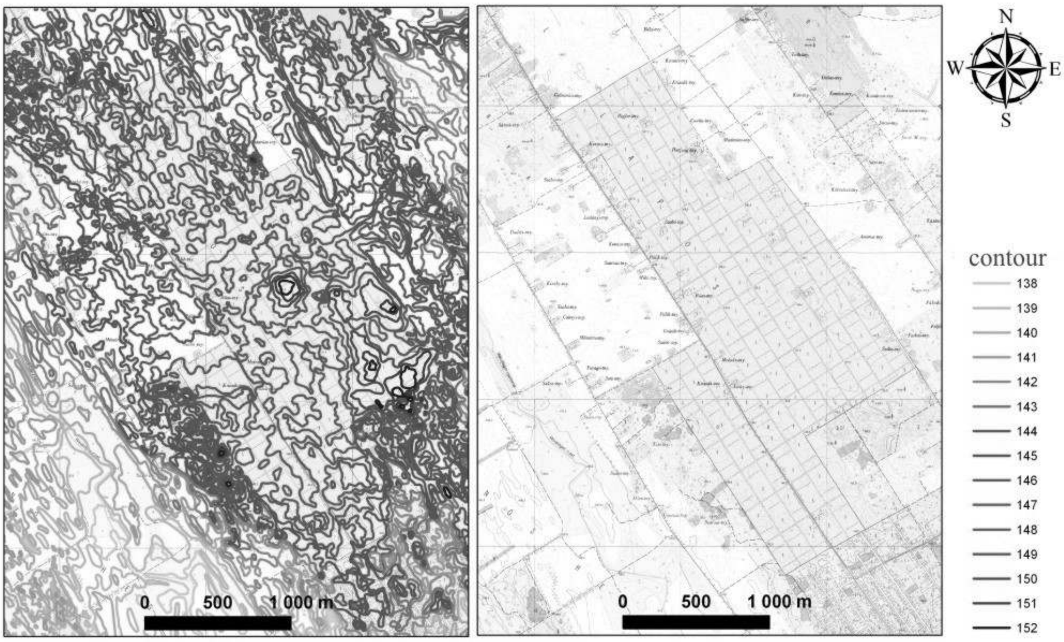

Figure 7. The marks of planishing on Illancs microregion (based on EOTR (1982) maps. See the differences in density of contours in case of cultivated areas (viticultures and arable lands) and their surroundings

3.5. Changes of wet and dry natural habitats

The most spectacular changes of natural vegetation can be observed in the wet habitats of Illancs located in the depression hollows between the fields of sand dunes. Their melioration begun in the 1940s and the precipitation shortage due to climate change significantly decreased their extent. Such habitat dominated depressions can be found in the southeastern edge of the microregion, which were much wetter according to the historical maps until the 1970s (HIM, 1764-1787; HIM 1806-1869; Kreybig, 1930–1940; MNH, 1955). Figure 8/a. shows the habitat map of the blow-out located west from Borota. On the sample area the fen head – saline bottom habitat pattern could be identified described by Deák (2006) from the southeastern Danube-Tisza Interfluve, meaning that in the northwestern part of the depressions fens, whereas in their southeastern parts saline habitats occur. Nowadays wet habitats can be found only in the deeper depressions of the sample area and the marks of the steppification process can be identified on the stands. In the northern part of the area the remains of fen habitats (Molinia fens, sedgefields) are more frequent - indicating groundwater up-wellings coming from the middle part of Illancs. The aridification is shown by the increasing number of Crataegus monogyna on Molinia fen and the shift of vegetation zones (Ladányi & Deák, 2009): the sand steppe grassland took the place of the Molinia fen in the deflation hollows, whereas the Molinia fen moved into the channel intersecting the sample area. The dried, steppe-like, degrading varieties of saline meadows – last remains of the former saline vegetation – can be recognised only in the middle part of the sample area. These consist of Festuca arundinacea, Agrostis stolonifera but their ratio is exceeded by Dactylis glomerata and Festuca pseudovina referring to steppification. Leaching of these saline meadows is shown by Agropyron repens and Poa angustifolia. The other parts of the sample area are covered by typical sand steppe grasslands. The former water covered parts with better soil conditions became cultivated.

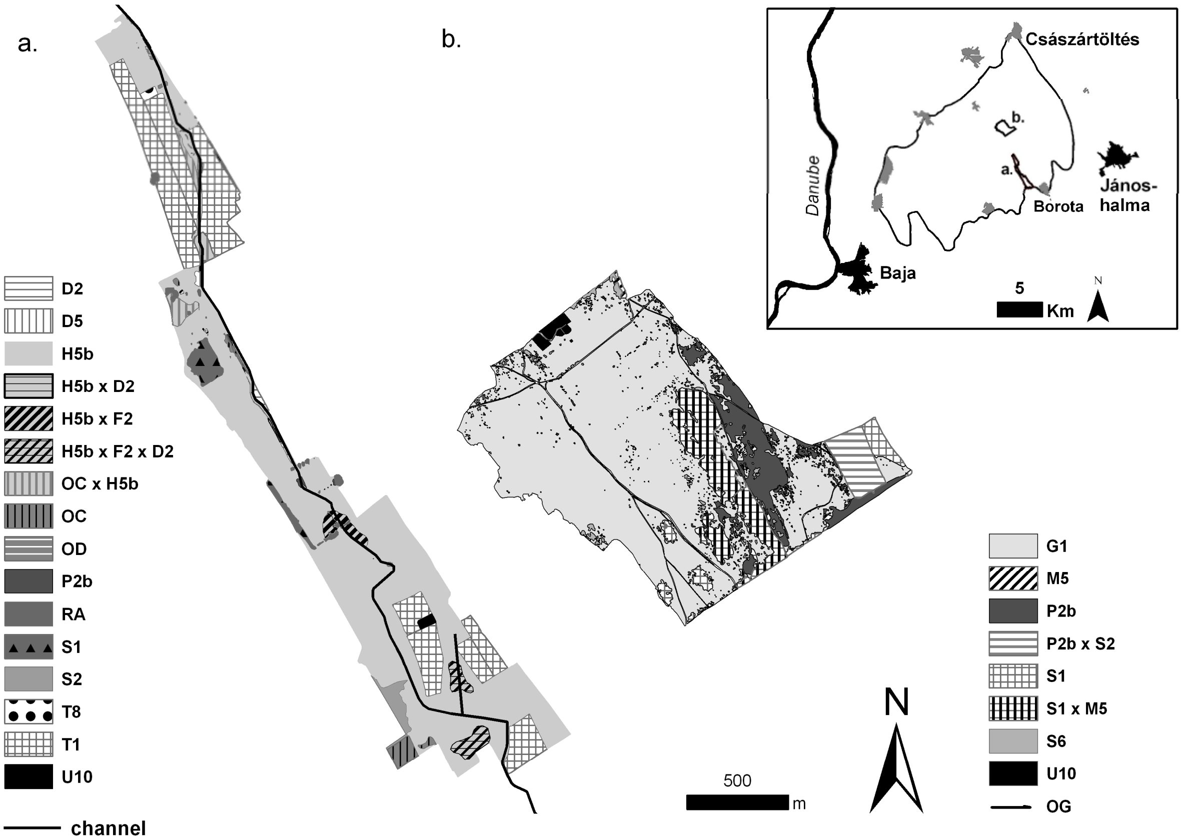

Figure 8. Habitat maps of dry and wet habitats. A. a former wetland westwards from Borota settlement; B. Hajósi Homokpuszta Nature Reserve. Habitat categories: D2- Molinia fen; D5- Fen tall herb community; F2- Salt meadow; G- Open sand grassland; H5b- Sand steppe grassland; M5- Poplar-juniper steppe woodland; OC- Weedy dry grassland; OD- Soft-stem invasive vegetation; OG- Trodden weed community; P2b- Dry shrub; RA- Tree-groups of native species; S1- Locust tree forests; S2- Cultivated poplar forest; S6-Invasive tree-species dominated spontaneous forest; T8- Small viticulture and fruit plantations; T1- Arable land; U10- Hamlet; H5b x D2: Former Molinia fen became a sand steppe grassland; H5b x F2: Former saline meadow became a sand steppe grassland; H5b x F2 x D2: Former transition between Molinia fen and saline meadow became a sand steppe grassland; OC x H5b Highly weedy sand steppe grassland; P2B x S2- Mixture of dry shrub and cultivated poplar forest; S x M5- Transition between locust tree and poplar steppe woodland.

Quite a few natural dry habitats remained in this microregion. Grasslands with the highest naturalness are protected, like Hajósi Homokpuszta Nature Reserve (Figure 8/b), which is inserted among planted pine and locust forests. This territory preserves the natural dry vegetation of sand dunes. The steep dune sides and the peaks are characterised by open sand grasslands, while between the dunes closed sand steppe grasslands occur. The territory has steppe physiognomy. The poplar-juniper steppe woodlands are absent, just *Crataegus monogyna* dominated dry shrubs can be observed spreading on valuable sand grasslands. That's why active management of nature conservation is needed. The marks of the former viticulture are shown by higher ratio of *Asclepias syriaca* and by network-like pattern of *Crataegus monogyna.* The grassland is characterised by protected and strictly protected species like *Dianthus serotinus*, *Alkanna tinctoria*, *Stipa borysthenica*, *Iris arenaria*, *Adonis vernalis*, *Crocus reticulatus, Onosma arenaria, Tragopogon floccosus.*

3.6 Society

Changes of nature also affect society (farmers) which is facing to increasing difficulties. According to our field interviews the farmers blame the channels, the oil research drillings of the 1980s and the droughts for the formation of water shortage. Presumably, the oil research drillings of the 1980s were made when the water-shortage started to increase, but due to previous research it had no significant role in this process (Pálfai, 1994). On a forum for farmers a questionnaire was made (23 farmers from the region). As a result of it farmers on sandy soil (in settlements of Borota, Jánoshalma and Rém) feel the problem of water shortage more serious and they could estimate the degree of the changes with the highest accuracy. Farmers on more

Table 1. Questions of the questionnaire made on an agro-forum (Europe through the eyes of farmers) in Jánoshalma (Illancs microregion) and their positive answers (2009.02.26.)

Question	*Farmers cultivate sandy soils in Illancs microregion*	*Farmers cultivating soils with better soil attributes in the surrounding microchores*
Were you forced to change cultures in farming in the last decades?	*26,6%*	*0 %*
Does water shortage cause damages or additional charges in agricultural production?	*100%*	*75 %*
Have you experienced that people stopped cultivating arable lands or moved to other regions due to crop failures caused by water shortage?	*60%*	*25%*
Are you irrigating?	*13,3%*	*0%*

fertile soils outside the border of Illancs see the problem less serious and farmers in the Duna-valley (Császártöltés) don't feel even the consequences of climate changes (precipitation shortage, increasing temperature). Modern technologies (e.g. drip irrigation) make possible the adaptation to the changed water conditions but the costs of these systems can't be beard by all farmers (Table 1.). Farmers on sandy soils have significant damages respect to water shortage but change in the type of farm produce can be carried out by few of them. Those who changed stands, chose cereals or forestation instead of cultures with high water demand (e.g. horticulture).

The water supplement of the examined microregion and the Sand Ridge of the Danube-Tisza Interfluve have engaged the attention of researchers, politicians and hydrologists since decades. However, the feasibility of water supplement for agriculture is made doubtful by the consideration of economical respects (the water should be press upwards by 40-60 metres compared to the level of River Danube). Keeping life-stocks and grazing is still significant on the remained grasslands nowadays, and farmers try to keep in step with the standards of EU.

4. CONCLUSIONS

The Danube-Tisza Interfluve faces to one of the most significant hydrological problems of the Great Hungarian Plain. The water shortage can be felt in farming beside the degradation of natural areas in the last decades. This paper aims to have a comprehensive report on the changes of the most affected microregion of this landscape. The last century brought significant changes in land-use: a region with open sand grasslands and moving dunes became mostly forested. The majority of the microregion became cultivated as arable land or forest as a result of the extreme land-use of the 1950s. Nowadays fruit production and viticulture have smaller role than in the middle of the 20th century, and arable land farming is profitable only on loess covered regions. The anthropogenic and natural processes of the 20th century have significant effect on natural vegetation. The dry habitats were mainly damaged by the land-use changes resulting the decrease of their areas, their fragmentation. Significance of water- shortage is proved by the spectacular aridification of depressions at the southern edge of the microregion and between the fields of dunes, which resulted the changes of soils and vegetation. Nowadays wet habitats occur only in the deepest parts of the blow-outs, they turned into steppificated subdivisions or became totally dry sand steppe grasslands. The abandonment of hamlets around the villages and the spread of invasive species contributed to the degradation of landscape too.

The water shortage has been in front of the government many times since the 1990s. Many conferences passed, many studies were born and it was incorporated in national environmental strategies (29/2008), in all National Environmental Programs (83/1997, 132/2003, 96/2009) and government decrees were born (See e.g. 2286/1996, 2271/1999) in order to solve this problem during the last decades.

Based on the above mentioned facts some questions can be made:

1. If mostly climate changes stand behind the water shortage, can we do anything against it? Is it worth fighting against nature?

2. Which solutions could bring success?

3. If water supplement happens, who will bear the costs of that?

The real goals and possibilities of water supplement should be made clear. However, in such environmental and climate sensitive areas living circumstances should be kept in sustainable way, so the decisions and financial supports should help this aim.

5. ACKNOWLEDGMENTS

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