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COMPLEX LANDSCAPE ECOTONE ANALYSIS ON THE BORDERLINE REGION OF TWO LANDSCAPES IN THE SOUTH GREAT PLAIN (HUNGARY)

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Summary – Landscape ecotones are transitional zones between landscapes, having greater geodiversity and therefore greater biodiversity and many natural values. The study examines two microregions of the South Great Plain, the Dorozsma-Majsa Sand Ridge and the Szeged Plain, the latter of which has not been regarded as an independent landscape previously. It analyses the surface deposit-morphology-soil-vegetation relations system on the landscape border, and studies its transitional character with regard to landscape ecological factors and their connections. The Dorozsma-Majsa Sand Ridge is characterized by sandy steppe-grasslands on humic sand soils of sandy elevations and residual ridges; Molinia fens, alcali-sodic meadows, and other alcali-sodic habitats on meadow and alcali-sodic soils of wind-furrows and deflational hollows. On the loess area of the Szeged Plain, the typical habitats of the natural vegetation are loess steppe-grasslands on chernozem soils and alcali-sodic berm zonation on the alcali-sodic soils of abandoned riverbeds and their surroundings. In the landscape ecotone, widespread alcali-sodic soils and habitats are found. Their types and pattern cannot be explained with the salinization mechanisms of the two microregions. The surface deposits with special physical and chemical character, the rising groundwater and increasing salinity are important factors in the salinization of the landscape borderline region. The landscape ecotone has several floristic values. The last chapter of the study surveys the necessary actions needed to protect the biotic and abiotic values of the study area.

Key words: landscape ecotone, surface deposit-morphology-soil-vegetation connections, salinization, Dorozsma-Majsa Sand Ridge, Szeged Plain

1. INTRODUCTION

Ecotone is a transitional zone on the borderline region of two vegetation associations or two land use types, with species from both areas. From a nature conservation viewpoint, such places often serve as refugiums of rare and protected species (Láng 2002). In the previous decades several studies have dealt with the role of ecotones in the flow of materials, in the spreading of valuable and invasive species, as well as with the connection between ecotones and global climate change (Risser 1995). There has been a demand in the Hungarian and international scientific literature to expand the ecotones to several spatial scales, leading to the establishment of the concept of landscape ecotone (Gosz 1993, Csorba 2008). According to this concept, the landscape ecotone is a transitional zone between two landscapes (not only from the point of view of the vegetation), controlled mainly by mesoclimatic, geomorphologic and soil factors (Gosz 1993). Exploring the functional connections of the landscape ecosystems is one of the main tasks for landscape ecology (Finke 1986), and is essential for optimal land use planning. The microregions of Csongrád

County were analysed from the point of view of this concept (Deák 2009) and the present analysis of the landscape ecotone is based on these results. The aim of our work was to determine:

(i) How broad is the transitional zone in the case of each landscape ecological factor? What is the character of this transition?

(ii) How do the surface deposit-morphology-soil-vegetation relations of the homogenous landscapes change in the landscape ecotone?

(iii) What kind of land use and protection actions are needed to preserve the functional relations of the landscape (border) ecosystem?

2. MATERIALS AND METHODS

2.1. The study area

The study area of the landscape ecotone is situated in the triangle of the settlements Kiskundorozsma, Szatymaz and Zsombó. Within this area, the transition of the natural-seminatural vegetation in the landscape ecotone can be observed only at the „Hosszúhát" area. The eastern part of the Dorozsma-Majsa Sand Ridge is surrounded by the settlements Kiskundorozsma, Ruzsa, Üllés, Forráskút, Kömpöc, Kistelek, Ópusztaszer and Sándorfalva. The western border of Szeged Plain is the line connecting Röszke-Subasa-Rottkút dülő-Hosszúhát-Szatymazi kisfekete-Belső-Szatymaz-Sándorfalva, whereas the eastern border is the Southern Tisza Valley.

2.2. Data and methods

We assessed the pattern of surface deposits based on the works of Kuti and Rónai (1972), Rónai (1975) and Miháltz (1966). The soil conditions were analysed with the help of 1:100000 agrotopographical maps (Szabó and Pásztor 1994), a genetic soil map of Csongrád County (Takács 1989), and the maps and profile data of the Digital Kreybig Soil Information System (DKSIS) – Pásztor et al. 2002, 2006, Szabó et al. 2005). The relevant soil profiles were revisited during our field works of vegetation mapping and conservationist supervision of the laying down of natural gas pipelines in the study area. The natural-seminatural vegetation was classified according to the official category-system (mm-ÁNÉR) of the MÉTA (Hungarian Biotope Map Database) programme (Bölöni et al. 2003). The agricultural and urban biotopes were classified according to the Modified General National Habitat Classification System (m-ÁNÉR – Molnár et al. 2000). The biotope maps were made during field visits, and are based on the 1:25000 Gauss-Krüger topographical maps (MH 1991-1992), the State Forestry Service's forest management plans (ÁESZ 1998a), maps (ÁESZ 1998b) and SPOT-4 satellite images (CNES 1998). The border of the Szeged Plain as an independent landscape was verified with the help of maps of the 1st military survey (HMT 1764-1787). Spatial analysis was carried out with GIS technology, using ArcView GIS 3.2 software.

3. RESULTS AND DISCUSSION

3.1. Surface deposit-morphology-soil-vegetation connection system in the eastern part of the Dorozsma-Majsa Sand Ridge

The Dorozsma-Majsa Sand Ridge is part of the Danube-Tisza Interfluve region belonging to the Great Hungarian Plain (Marosi and Somogyi 1990). The matrix of the landscape is formed by sandy elevations and residual ridges built, in the eastern part of the landscape, of lower Holocene and upper Pleistocene blowing sand. The network of patches is formed by deflational wind-furrows and hollows containing deposits of upper Holocene lacustrine limestone, lacustrine dolomite and carbonate silt (Kuti and Rónai 1972, Rónai 1975).

The soil types follow the morphological forms and show a very similar pattern. The sandy elevations and the residual ridges have, according to the genetic soil type maps, humic sand or blowing sand soils. The DKSIS puts the sandy soils of the landscape into a single category characterized by poor water retention, very high permeability and infiltration rate – Fig. 1, dominantly neutral or slightly alkaline pH, saturated with calcium carbonate – Fig. 2. The sandy soils of the Dorozsma-Majsa Sand Ridge are rich in carbonate, have high capillary lift value and soil organic C content (Pásztor et al. 2002, 2006, Szabó et al. 2005). The genetic types of the soils of deflational wind-furrows and hollows are (carbonated) meadow soil, (carbonated) solonchak, solonchak-solonetz or solonetzic meadow soil. The DKSIS regards these soils uniformly as salt-affected soils (Fig. 1) and puts them, based on chemical attributes, into the categories of a) salt-affected soils, suitable for plough, the topsoil dominantly acid, rootable depth more than 50 cm, b) salt-affected soils, slightly suitable for plough, rootable depth between 30 and 50 cm c) permanently wet areas (Fig. 2). The patches suitable for plough are equivalent to the solonetzic meadow soils having the highest salt content in the B-layer, and the patches slightly suitable for plough correspond to solonchak or solonchak-solonetz soils with higher salt content and surface salt accumulation. The patches of permanently wet areas can be correlated with meadow or moory meadow soils (with fen vegetation), or with the solonchak and solonchak-solonetz soils of the lake beds regularly drying up.

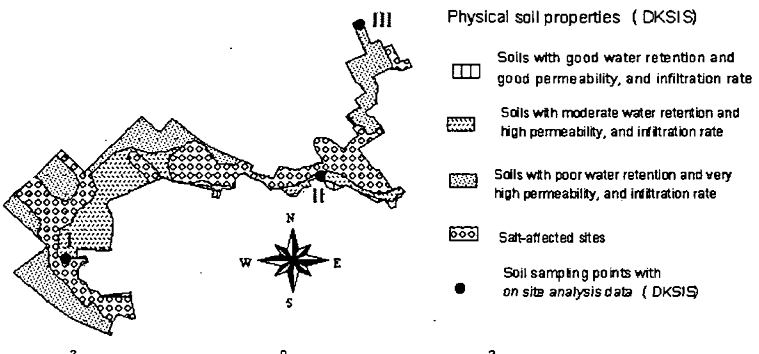

Fig. 1 Physical soil properties in the study area and three soil sampling points with on-site analysis data (based on DKSIS – Pásztor et al. 2002, 2006, Szabó et al. 2005)

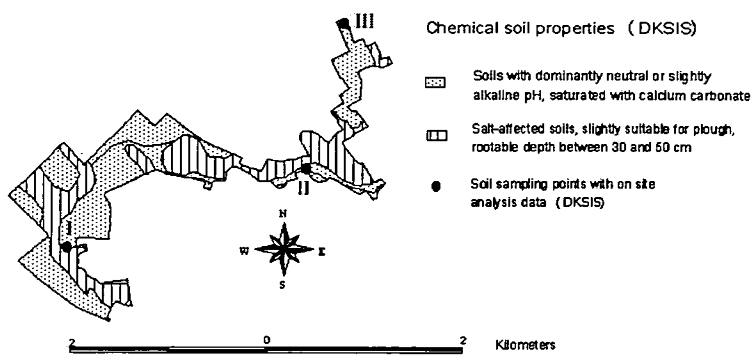

Fig. 2 Chemical soil properties in the study area and three soil sampling points with on-site analysis data (based on DKSIS – Pásztor et al. 2002, 2006, Szabó et al. 2005)

The pattern of the vegetation follows the morphological forms and soil types: the sandy-elevations and residual ridges with sandy soils are covered with different types of sandy steppe-grasslands. The Dorozsma-Majsa Sand Ridge also has, besides the „classical" sandy steppe-grasslands *(Astragalo austriaceae-Festucetum rupicolae),* sandy pastures *(Potentillo arenariae-Festucetum pseudovinae)* and Galium verum-dominated associations *(Galio veri-Holoschoenetum vulgaris)*, Chrysopogon gryllus- Botriochloa ischaemum- and Dactylis glomerata-dominated sandy steppe-grasslands. The habitats of the wind-furrows and hollows are Molinia-fens (mainly *Succiso-Molinietum hungaricae*), alcali-sodic cape vegetation *(Lepidio crassifolii-Puccinellietum limosae),* blind alcali-sodic vegetation *(Lepidio-Camphorosmetum annuae),* alcali-sodic swamps (Bolboschoenus maritimus-dominated or alcali-sodic reeds – *Bolboschoeno-Phragmitetum*) and alcali-sodic meadows *(Agrostio-caricetum distantis)*. The Molinia fens are dominant habitats on (carbonated) meadow soils. The alcali-sodic cape vegetation, the alcali-sodic swamps and salt pioneer swards can be found on solonchak or solonchak-solonetz soils. The alcali-sodic meadows are dominant habitats of solonetzic meadow soils. These habitats are situated in the wind-furrows and hollows according to a well-defined pattern: the northwest side of the wind-furrow is mainly dominated by Molinia fens (non-alcali sodic vegetation), whereas the southeastern part of the same depression is covered with alcali sodic vegetation („fen head-alcalisodic foot pattern" – Deák and Keveiné Bárány 2006).

3.2. Surface deposit-morphology-soil-vegetation connection system in the Szeged Plain

The area referred to in this work as Szeged Plain belongs, according to the present landscape classification (Marosi and Somogyi 1990), to the Southern Tisza Valley of the Lower Tisza Region. The landscape laying west of the Tisza between the settlements of Sándorfalva and Röszke has, however, several landscape ecological attributes (surface genetics, surface deposits, geomorphology, genetic soil types, natural vegetation, land use, past and present hydrological conditions), which are significantly different from those of the Tisza Valley, and it is reasonable to treat it as an independent landscape.

The matrix of the Szeged Plain is formed by upper Pleistocene loess-elevations with typical, sandy and infusional loess. The network of patches is formed by abandoned salinizated riverbeds. Their surface deposits are lower Holocene alcali-sodic silt, loess-silt and sand-flour; upper Holocene carbonate silt, sporadically lower Holocene (e.g. „Fertő-laposa", „Gyevi-fertő") or upper Holocene (e.g. „Maty-ér") clayey aleurite or Pleistocene alcali-sodic loess („Hosszú-dűlő" and „Sárosvölgy-dűlő" in Röszke, „Hattyas-telep" and „Kecskés-telep" in Szeged) (Rónai 1975).

The texture of soils in Szeged Plain is loam. It clearly distinguishes this area from the Dorozsma-Majsa Sand Ridge, which is characterized by sandy soils, and from the Southern Tisza Valley, which has clay or clayey loam soils (Szabó and Pásztor 2004). The genetic soil type of the loess elevations are chernozem with lime deposit and meadow chernozem. Because of the relatively high (1-2 m) groundwater-level, the area close to the Dorozsma-Majsa Sand Ridge is dominated by meadow chernozems. The DKSIS classifies these soils, based on chemical attributes, as soils with dominantly neutral or slightly alkaline pH, saturated with calcium carbonate (Fig. 2). The physical attributes of these soils are not homogenous in the Szeged Plain according to the DKSIS. The soils close to the Dorozsma-Majsa Sand Ridge can be described as having moderate water retention, high permeability and infiltration rate, while in other parts of the Szeged Plain the soils are characterized with good water retention, good permeability and infiltration rate (Fig. 1). The soils of alcali-sodic hollows are mainly solonchak-solonetz, but there are meadow solonetz (callous, medium) and solonetzic meadow soils as well. In the DKSIS, all of the soils of alcali-sodic hollows belong to the salt-affected physical category here as well (Fig. 1), while the chemical character of them can be 'not suitable for plough' or 'slightly suitable for plough' with rootable depth between 30 and 50 cm (Fig. 2). These types can be correlated with the solonchak-solonetz genetic type in this microregion.

The vegetation of the Szeged Plain has changed a lot during the past centuries because of the intensive human impact, and the area of the natural-seminatural vegetation has decreased. Loess steppe-graslands *(Salvio-Festucetum rupicolae)* can be found on the chernozem soils of loess-elevations, these habitats have very small undisturbed stands nowadays. The abandoned riverbeds of the lower and upper Holocene and their edges are covered with primary alcali-sodic berm vegetation: the hard soils lead to an increase of the importance of surface waterflow and linear erosion in the alcali-sodic brooks and abandoned riverbeds (e.g. in the „Maty-ér", which takes its source in the landscape ecotone). The fragmentation of the loess-elevations forms a zonation with micro-level habitats. These habitats are (from the loess-elevations to the local erosion-bases, following the gradient of salt content, groundwater-level and surface water cover): loess steppe-grassland *(Salvio-Festucetum rupicolae)*, Artemisio-Festucetum alcali-sodic grassland *(Artemisio-Festucetum pseudovinae)*, blind alcali-sodic vegetation *(Lepidio-camphorosmetum annuae)*, alcali-sodic cape vegetation *(Lepidio-Puccinellietum limosae)*, alcali-sodic meadow *(Agrosio-Alopecuretum pratensis)*, Bolboschoenus maritimus-dominated alcali-sodic swamps *(Bolboschoenetum maritimi)*. The presence of Artemisio-Festucetum alcali-sodic grassland clearly separates this zonation from the parallel habitats of sandy and alluvial landscapes. We mapped the alcali-sodic berm zonation as a habitat-complex, because of the micro-level habitats.

The landscape ecological character of the Szeged Plain is similar especially to the Kiskunság Loessland, but in many aspects also to the Csongrád Plain and to the loess residual plains of the alluviums of the Tisza and Maros rivers. In the maps of the 1st military survey (HMT 1764-1787) the Szeged Plain was unflooded: the rich soils had been ploughed by the end of the 18th century, so it is improbable that these soils were regularly flooded by average-level floods. This fact supports the distinction of the Szeged Plain from the alluvial landscapes.

3.3. Surface deposit-morphology-soil-vegetation connection system in the landscape ecotone

There is a 200-1000 meter wide transitional zone, where, besides the transition of the landscape ecological factors of the two microregions, a qualitatively new factor appears: the salinity on landscape borderline. This can be explained with relief and hydrological factors: the groundwater flows according to the slope direction, from the central areas of the Dorozsma-Majsa Sand Ridge to the southeast (to the lower Tisza Valley). Reaching the Szeged Plain, the groundwater level rises, in some places even breaks to the surface, due to the much lower permeability of the loess (the permeability, which is measured with the clay and silt content, decreases to twenty percent in the landscape borderline (Rónai 1975). The groundwater flowing from the Sand Ridge here rises near the surface, supplying surface waterflows in some places (e.g. Maty-ér). The high groundwater-level is one of the most important factors in salinization. This process is strengthened by the surface deposits of the landscape ecotone: in a part of the borderline zone, there is clayey loess, instead of infusional loess, which is characteristic in most of the Szeged Plain. In the Dorozsma-Majsa Sand Ridge, the alcali-sodic soils and habitats are lying mainly in a NW-SE direction, according to the position of wind-furrows. In the study area, however, there is a wide-spread area with alcali-sodic soils and habitats, lying in W-E direction. This proves the role of the landscape border in the salinization. Another factor which plays an important role in the process is the presence of upper Holocene carbonate silt lens in the western part of the study area, near the road between Kiskundorozsma and Zsombó (Miháltz 1966). This, as an impermeable deposit, forces the groundwater level up and therefore results in the appearance of alcali-sodic soils and habitats.

Table 1 Measured data from the DKSIS of on-site analysis of the soil profiles in the landscape ecotone (Pásztor et al. 2002, 2006, Szabó et al. 2005). The numbers of the profiles on the nr. 5464/3 sheet of DKSIS are shown in brackets.

Number of the soil profile	Upper border of the soil layer (cm)	Lower border of the soil layer (cm)	Color of the soil layer	Granulation	Morphological structure	Watery pH measured on site	$CaCO_3$ - analysis on site (strength of sparkling)
I (40)	0	20	light grayish brown	fine sand	hardly sandy	9.00	+++
	20	50	light gray	sandy loam	hardly crumbly	9.30	+++
	50	150	yellow	loam	compact	9.20	++
II (133a)	0	20	dark brown	fine sand	sandy	8.30	++
	20	40	brown	loam	compact	8.90	+++
	40	100	light gray	alcali-sodic sandy loam	without structure	9.00	+++
	100	150	light yellowish gray	alcali-sodic loam	without structure	8.30	+++
III (87)	0	40	brown	coarse-grained sand	sandy	7.00	0
	40	110	yellow	coarse-grained sand	sandy	7.20	0, +
	110	150	dark brown	coarse-grained sandy loam	hardly sandy	8.30	+++

The surface deposits' transition is not direct, under the lower Holocene sand there is the Pleistocene loess, its depth increasing with the distance from the landscape border towards the Sand Ridge. This can be easily recognized in the data of the soil profiles on the landscape border: under the surface sandy layer, there is the loess layer with different carbonate content and pH (Table 1), as could be verified during field visits in the area where the gas pipelines were laid down in the northern part of Hosszúhát (Fig. 3). The alcali-sodic soils of the landscape ecotone zone belong to the category of alcali-sodic soils slightly or conditionally suitable for plough in the DKSIS, thus based on the chemical soil properties, they can be correlated with the alcali-sodic soils of the Dorozsma-Majsa Sand Ridge, rather than with those of the Szeged Plain (Fig. 2).

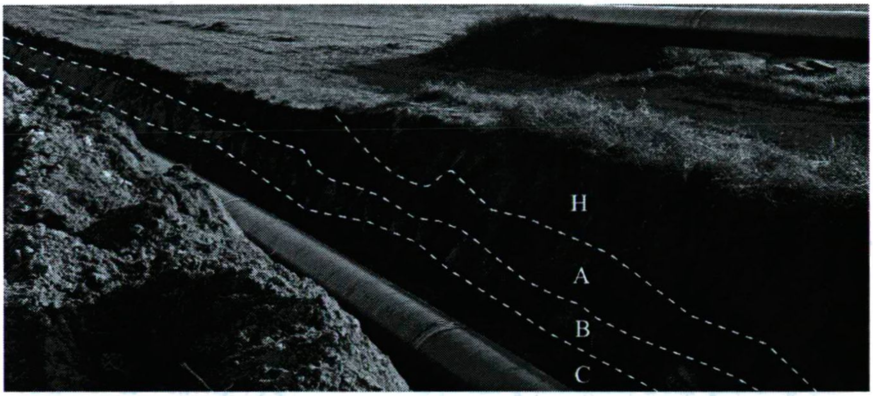

Fig. 3 Transition between soil types with buried humic layers at the II. soil profile
H: Humic sand soil; A: A-layer of meadow chernozem soil; B: B-layer of meadow chernozem soil; C: C-layer of meadow chernozem soil

The dominance of habitats indicating rich water supply and high salt content as well as the unique species separate the vegetation of the landscape ecotone clearly from the two microregions. The semi-natural habitats are dominated by alcali-sodic meadows, in the area closer to the Dorozsma-Majsa Sand Ridge sandy steppe-grasslands and Molinia fens, while closer to the Szeged Plain alcali-sodic berm mosaics are frequent as well (Fig. 4). The vegetation borderline between the two landscapes is part of the „Újszász-Szeged-line", which was defined by Rajmund Rapaics in 1930 (Rapaics 1930), and which separates the Crisicum and Praematricum flora districts within the Eupannonicum flora area. The transition is not sudden in the of case the vegetation either, the presence of certain species and associations indicate the transitional zones among the habitats: in alcali-sodic meadows *Agrostis stolonifera* is more frequent closer to the Sand Ridge, while moving towards the Szeged Plain *Alopecurus pratensis* is becoming more frequent. In the Artemisio-Festucetum alcali-sodic grasslands, *Artemisia santonicum* is less frequent closer to the Sand Ridge – there are stands without Artemisia santonicum near the landscape border –, while in the cape vegetation and Lepidio-Camphorosmetum alcali-sodic marsh vegetation of alcali-sodic berm zonations, *Lepidium crassifolium* is more and more frequent towards the Dorozsma-Majsa Sand Ridge.

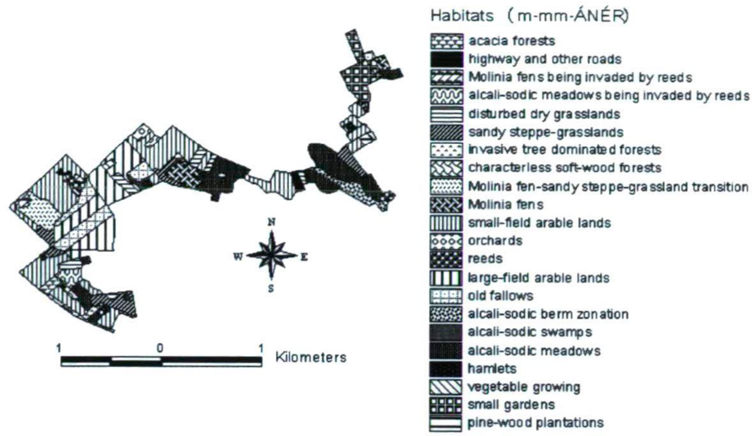

Fig. 4 Actual vegetation map of the landscape ecotone

On the surface deposits of the landscape ecotone, the landscape ecological factors' connection system defined in homogenous microregions breaks down and qualitatively new species- and habitat-compositions appear. The upper Holocene carbonate silt lens in the western part of the study area results in rich water and salt supply. As a result, Molinia fen patches can be found on positive morphological forms (on residual ridges), and the high salt content indicated by the frequent occurence of *Limonium gmellini*, which is characteristic for Crisicum-type solonetzic alcali-sodic habitats, but here, it appears in clearly Praematricum-type habitats, e.g. in sandy steppe-grasslands or sandland-type alcali-sodic meadows. In the „Hosszúhát" grass-complex of W-E direction in the middle of the study area, Crisicum-type alcali-sodic meadows and cape vegetation show transitions to their Praematricum-type stands on clayey loess supeficial deposit and loamy soils. The Artemisio-Festucetum alcali-sodic grasslands are often without *Artemisia santonicum*, and sandland-type habitats (Molinia fens, sandy steppe-grasslands) can appear – the latters often form transitional stands with loess steppe-grasslands – which can indicate thin burying of blowing sand.

According to the above-mentioned complex landscape ecological surveys, the border of the Dorozsma-Majsa Sand Ridge and the Szeged Plain can be drawn along the line defined by the settlements Röszke-Subasa-Rottkútdűlő-Hosszúhát-Szatymazi-kisfekete-Belső-Szatymaz-Sándor-falva (Deák 2009).

The grasslands situated along the landscape border have several protected or rare plant species, because both landscape types can serve as propagulum source. According to our field survey and some data of previous observations (Gaskó 2008), these are (*: protected, **: strictly protected): *Allium sphaerocephalon**, *Astragalus asper**, *Centaurea sadleriana**, *Cirsium brachycephalum**, *Crocus reticulatus**, *Iris pumila**, *Iris spuria**, *Ophrys sphegodes***, *Orchis coriophora**, *Orchis laxiflora subsp. palustris**, *Scutellaria hastifolia*

3.4. Land use optimization proposal

The grass-complex in the landscape ecotone is not under any kind of territorial protection. However, based on the observed floristical and faunistical values (Gaskó 2008, Lajkó 1997), that would be necessary. Risk factors present for years are farming, change of land use, melioration, and, during the last years, the track of the M5 highway. In the „Hosszúhát" grass-complex, a large *Iris spuria*-stand was destroyed because of the area occupation and the execution process. To the south, there is an extensive wetland habitat, which was planned to be a water reservoir. This would have been constructed because of the aridification of the microregion and the Great Plain. In contrast, the highway has been led through this wetland, and the point of junction of the M43 and M5 highways has been built here as well. Drains have been constructed to conduct surface and ground water under the road-bed, but these structures are not kept in good condition, therefore they are often blocked by deposits. This may cause change in the flow of these waters, transforming the soil characteristics of the semi-natural vegetation's residual stands. On basis of all this, it would have been better to lead the highway 100-200 meters to the east. The laying down of natural gas pipelines in 2008 was conducted under conservationist supervision, thus a significant stand of *Allium sphaerocephalon* has been preserved, apart from the damage in the building site. On the reserved area, all of the natural values must be preserved, which should include the preservation of the abiotic characteristics, thus maintaining the processes of the landscape (border) ecosystem: no more groundwater-drains should be constructed, and in the existing ones water retention should be preferred. In this way, there would be a growing grass yield, which could have economic importance. There are good examples for this in the Dorozsma-Majsa Sand Ridge (Deák and Keveiné Bárány 2006). On the alcali-sodic grasslands, grazing is the best land use, since the treading by animals is necessary for preserving the micromorphology of the alcali-sodic berm complexes (Deák 2009). The speciality of the sandy steppe-grasslands in the study area is that most of them developed only some years or decades ago, after the abandonment of the arable land as indicated by the frequent occurence of *Dactylis glomerata*, a characteristic species of young fallows. On these sandy habitats, grazing is still the best method to help the spreading of grass (Rév et al. 2008). If landscape-alien, invasive species settle, mowing is proposed.

4. CONCLUSIONS

We found that landscape ecotones are important elements of landscape heterogeneity. This is indicated by the special connection system of landscape ecological factors and by the floristical and coenological values. Landscape-level biotope-mapping and the parallel analysis of surface deposits, geomorphological forms and soils are useful methods for analysing the landscape ecotones' structure and functioning. These studies can form the basis of land use optimization. We would like to propose this study to serve as a model for the analysis of borderline regions of landscapes using a complex, systemic way of studying nature.

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