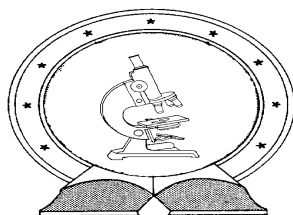


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**LAND USE CHANGES DURING THE LAST 200 YEARS AND LAND
USE EFFECTS ON HABITATS AND GROUND BEETLES**

**KULTÚRTÁJ VÁLTOZÁSA ÉS A KÖRNYEZETI VÁLTOZÓK
HATÁSA FUTÓBOGARAKRA**

Egyetemi doktori (PhD) értekezés

Varga Katalin

Témavezetők

Dr. Tóthmérész Béla

Dr. Dévai György

DEBRECENI EGYETEM
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a jelölt aláírása

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HATÁSA FUTÓBOGARAKRA**

Értekezés a doktori (Ph.D.) fokozat megszerzése érdekében
a Természettudomány tudományágban

Írta: **Varga Katalin** okleveles biológus-ökológus
Készült a Debreceni Egyetem **Juhász-Nagy Pál doktori iskolája**
(**Kvantitatív és Terresztris Ökológia programja**) keretében

Témavezető: Dr. Tóthmérész Béla
Dr. Dévai Görgy

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Papers included

1. Varga K., Dévai Gy., Tóthmérész B. 2013: Land use history of a floodplain area during the last 200 years in the Upper-Tisza region (Hungary) – Regional Environmental Change, DOI: 10.1007/s10113-013-0424-8
2. Varga K., Szabó Sz., Szabó G., Dévai Gy., Tóthmérész B. 2013 : Increase accuracy of automated vegetation and land cover mapping using archive aerial photos and moderate resolution remote sensing data - Environmental Earth Sciences, Major Revision.
3. Varga K., Gerisch M., Agostinelli V., Scholz M., Lengyel Sz., Tóthmérész B., Dziöck F.: Predictive power of vegetation structure, plant traits and abiotic variables for the composition of ground beetle assemblages in floodplain grassland - Waiting for submission

1 Introduction

1.1 Importance of floodplain and land use changes on this area

Since the beginning of the 20th century, the landscape has undergone important changes with drastic consequences for the ecosystem. Many studies deal with this problem and all have the common goal of understanding the changes in land cover and land use in landscapes and developing models of past landscape patterns (Riebsame et al. 1994; Olsson et al. 2000; Cousins 2001; Alados et al. 2004; Bender et al. 2005). Factors that affect landscapes can be divided into abiotic (topography, climate, soil), and biotic (organism interaction, ecosystem succession) circumstances as well as human activities (Nagaike and Kamitani 1997). Landscape reflects the long-term interactions between people and their environment (Moreira et al. 2001; Gingrich et al. 2012), especially in a country where great historic changes have occurred. These changes in land cover and land use have taken place over long periods of time as a result of many factors but also because of changes in human population. These factors include changes in traditional land use, farming intensification, irrigation, pesticides, fertilizers, machinery, etc. Most of these changes have occurred so quickly that the natural environment has not been able to adapt to the new conditions and as a result habitat fragmentation has increased dramatically over the last century (Alados et al. 2004; Antrop 2004; Saunders et al. 1991). Since cultural landscape changes have serious ecological consequences such as fragmentation and loss of habitats, specific knowledge about the background of disadvantageous processes is fundamental for the success of nature conservation (Metzger et al. 2006; Costanza et al. 1997; de Groot et al. 2010).

In the same way, in Hungary we hardly find any region which has not been modified by human activity. The land-use history includes extensive disturbance by agriculture and timber extraction and subsequent natural reforestation, beginning in the mid-1900s and continuing as in other parts of Europe (Verburg et al. 2006b). The land use is a crucial factor for the development of the actual state of vegetation. Traditional land use activities such as forests, orchard and meadows have shaped the Hungarian floodplain landscape for centuries. On the floodplains of the River Tisza and its tributary streams the backwaters of different ages and succession states are parts of Europe's semi-natural and special water-influenced habitats (WWF 2002). Nevertheless, the water-influenced natural systems have suffered the most through anthropogenic effects. Earlier floods passed through wide flood-basins along the Tisza and along other rivers, but these were reduced due to river regulation works and nowadays the area is flooded only between the dams on the present floodplains every year, or more frequently. The natural habitats have been able to survive primarily on these reduced floodplains due to the permanent flooding of the river.

Thus the area of natural habitats has considerably decreased and become fragmented on floodplains not only as a result of floodplain protection works and drainage of marshes, but also cultivation (WWF 2002; Dollar et al. 2007; Lóczy et al. 2012).

The floodplain area is of great importance because it provides a transition between aquatic habitats and terrestrial biotopes. Floodplains have a significant function in ecological and nature preservation as they create ecological corridors for animals and plants between different types of regions. Floodplains of most European rivers are under strict hydrological control to prevent damaging floods and provide water supply for agriculture, industry and communal purposes (Dynesius and Nilsson 1994). The existence of threatened wetland habitats explains the unique status and outstanding importance of floodplains. The continuity of natural habitats in these relatively small areas is not adequately guaranteed (Haslam 2008). For this reason floodplains have become the most endangered areas. Furthermore, any modification in natural water regime, or in agricultural and forestry practice, could cause changes in soil texture, soil nutrient balance and soil moisture regimes, threatening the natural habitats (Hobbs 1993; Priess et al. 2001; Van Dessel et al. 2009).

1.2 Satellite images or aerial photographs and accuracy of technique

Recently the use of remotely sensed data and techniques for land cover change detection has attracted greater attention than ever. Landscape parameters can be quantified with a variety of modern techniques and landscape indices (Szalai 1998; Negrón-Juárez et al. 2011; Ashraf et al. 2012; Wu et al. 2012). Nowadays, the rapid development of land surface detection and analysis techniques motivate researchers to find a simple objective method to quantify the changes of land cover and the effects of changes on the pattern and structure of landscapes (Van Dessel et al. 2009; Mi et al. 2011; Miettinen et al. 2012). Spatially explicit information about land cover and vegetation cover, both in small and large scales, are increasingly sought by biodiversity modellers and by management and restoration programs (Egbert et al. 2002; Wulder et al. 2004; He et al. 2005). Furthermore, assessing and monitoring the state of the Earth's surface is a key requirement for global change research (Research and Council 1999; Lambin et al. 2001; Wulder et al. 2004).

Remote sensing technology extends possible data archives from the present time to decades in the past and the data archives are continuously updated. Archive images are important for long-term time series research, and in historical ecology, but they do not offer accurate and detailed information as compared to the results obtained through modern images (Moran et al. 1994; Rocchini et al. 2006; le Polain de Waroux and Lambin 2012). Altogether, the capture of high quality information

about vegetation across a large and impenetrable area is usually difficult. Another useful option is the application of aerial photographs coupled with a relatively small area of the ground which typically gives a detailed picture of the earth's surface (Alados et al. 2004; Chalmers and Fabricius 2007; Terzioglu et al. 2009). Although, aerial photographs are only available for a few periods or only once a year, satellite imagery can solve this problem in most cases, and already many large resolution (as aerialphotos) satellite images are available. Several studies have focused on comparisons of satellite images and aerial photographs and their accuracy, since ability to monitor land surface or vegetation cover accurately is important (Minick and Shain 1981; Mosbech and Hansen 1994; Hyypä et al. 2000; Palandro et al. 2003). Modern remote sensing imagery offers a practical and economical means to study land and vegetation cover changes and present valuable information for understanding natural and man-made environments, especially over local to global scales at a given time or over a continuous period (Xie et al. 2008; Ganguly et al. 2010). For example the Shuttle Radar Topography Mission (SRTM) data is a high quality surface model which is widely utilized in many studies, in geography (Gorokhovich and Voustianiouk 2006), in geomorphology (Hancock et al. 2006; Siart et al. 2009) and to estimate vegetation height across the landscape (Kellndorfer et al. 2004; Hofton et al. 2006). Improvements using SRTM could help to separate the land cover classes; taken together some aspects can modify the absolute accuracy of SRTM (Gorokhovich and Voustianiouk 2006, Higgins et al. 2012). It is the first near-global spaceborne mission which provides high resolution estimates of three-dimensional forest structure across the Earth's land surface (Baker 1989; van Zyl 2001; Walker et al. 2007). The vertical accuracy of SRTM is widely analysed by testing the differences between SRTM and Digital Elevation Models (DEMs) (Baker 1989; Rodríguez et al. 2006). Mapping of remotely sensed data is based on image classification which may be achieved by either manual or automated, computer-aided analysis. Numerous automated and semi-automated methods can help to identify and map land cover using remotely sensed data (Schott 2007). These automated and semi-automated mapping techniques are gradually replacing classical techniques due to the increasing availability of high resolution digital topographic data (Anders et al. 2011). The characterization of areas traditionally involves either expensive manual interpretation of aerial photographs or field investigation.

1.3 Ground beetles on floodplain

Active floodplains are among such relatively unaltered habitats that are important as refuge landscapes for native biota (Amoros and Petts 1993). Floodplains are also characterized by a diverse and specialized vegetation and fauna which are strongly adapted to flooding disturbance and habitat turnover (Januschke et al. 2011). Insects

are a highly suitable group to monitor changes in habitats. Also insects are the most diverse animal group on the planet and they are highly susceptible to human interventions (Dunn 2005). For example the ground beetles (Coleoptera: Carabidea) are one of the ecologically most sensitive groups to hydrological conditions, disturbance intensity, habitat structure and management (Lövei and Sunderland 1996, Boscaini et al 2000, Dunn 2005, Gerisch et al 2006, Koivula 2011). They are especially suitable for studying the effect of habitat modifications at different scales and the influence of land cover structures (Dufrene and Legendre 1997, (Magura, Tóthmérész et al. 2004). Also, the composition of carabid assemblages indicates their strong specialization to a wide range of habitats, as well as their various behavioural, morphological and physiological adaptations (Luff et al 1992, Bonn and Schroder 2001; Rainio and Niemelä 2003). More publications proved that ground beetles are one of the ecologically most sensitive groups to hydrological conditions, disturbance intensity, habitat structure and management (Koivula 2011, Lövei and Sunderland 1996). They are good indicators and highly suitable group to monitor change in habitat (Dunn 2005, Gerisch et al 2006, Schanowski et al. 2009). In many studies were published that several abiotic and biotic factors affect the composition of ground beetles, for example: soil moisture, land use, soil type and soil organic matter, temperature etc. (Irmeler 2003, Pétilion et al. 2008).

In addition, the structural complexity of habitats could have a large influence on population dynamics and trophic organization of terrestrial arthropods because the physical structures in the habitat create more microhabitats and allow the coexistence and persistence of predators and their prey (Price et al 1980; McCoy and Bell 1991; Siemann 1998, Siemann et al 1998, Antvogel and Bonn 2001).

Nevertheless, our knowledge is poor about direct, mechanistic relationships between vegetation structure and composition of carabid assemblages (Tews et al. 2004). In a meta-analysis of experimental studies manipulating habitat structural complexity by adding or subtracting leaf litter, straw or mulch as structure. Langellotto and Denno (2004) found clear density responses of several insect groups to structural changes. Structural complexity can thus have a large effect on trophic interactions. Furthermore, some studies found evidence that carabids are more strongly associated with habitat and vegetation structure than with vegetation composition or with any plant species (e.g. McFerran et al 1994; Jukes et al 2001; Brose 2003; Aviron et al 2005, McCoy and Bell 1991; Langellotto and Denno 2004). For example, Gardner et al (1997) found a clear separation of carabid assemblages between tall and short vegetation. However, other studies have established some kind of association between vegetation composition and insect assemblages, supporting the view that vegetation composition may also play a role in shaping carabid assemblages (McCracken 1994; Sanderson et al 1995; Cherrill et al 1997; Foord et al 2003). A more recent study by Schaffers et al (2008), using an analytical technique to

consider the entire plant community, found that plant species composition had a much larger effect on carabid beetles and six other arthropod groups than vegetation structure and environmental conditions combined. It is difficult to disentangle the roles of vegetation structure and composition for several reasons. Vegetation structure and composition are not independent because the identity of plant species is linked to the physical properties of the plants. The relative roles of vegetation structure and composition vary by the spatial scale of the study. Habitat structure can vary from simple to complex at several spatial scales relevant for carabids, i.e., at the landscape-scale, the habitat level, or at individual plants or plant parts. It is plausible, that at larger scales vegetation composition, the differences among habitat types or land cover units or plant beta diversity become more important than vegetation structure. Vegetation structure may be measured and interpreted in various ways making the comparisons among the studies is difficult (Tews et al 2004).

Why could be so important the research of the plant and vegetation structure beside other environmental factors for ground beetles? As vegetation structure may also interact with other habitat factors. For example, the composition of ground beetle assemblage is strongly influenced by vegetation structure because vegetation structure determines microclimatic conditions (Antvogel and Bonn 2001). Microclimatic conditions may in turn be related to plant species, so ground beetles can have an indirect association to vegetation composition on small scales (Antvogel and Bonn 2001). One way to disentangle the roles of vegetation structure and composition in explaining carabid assemblages is to move the scale of inquiry down to smaller scales and to quantify the vegetation at the scale at which carabids perceive their environment (i.e, level of leaves, stems, ground surfaces etc.).

2 Aims of study

I.) To extract improved results from satellite images and aerial photographs using ancillary data sources about a floodplain area and to test the reliability of satellite images in the automated analysis in cases when dense and impenetrable vegetation does not allow information to be extracted from the vegetation if the fieldwork is not possible. Test, how the accuracy of automated vegetation mapping could be increased in both cases. Study that the automated methods on remote sensing data sources (with and without SRTM) which can give an accurate and useful opportunity for the analysis. Test whether the SRTM could help us to interpret better the vegetation on a flat area and whether there could be give differences between the beginning and end of summers. Investigate whether seasonality or a short time period has an effect on the results of the automated analysis of vegetation cover on

satellite images. Furthermore, test whether better results could be gained for vegetation and land cover classification by merging two aerial photographs.

II.) This part of my research was to examine the historical land use, land cover changes in land use context from 1784-2005 on floodplain area of the Upper-Tisza-Region in Hungary using repeated aerial photographs and topographical maps. Analyse the extension of wooded area and the changes the grasslands and wetlands on floodplains. Make a class and landscape level analysis to explore and understand the development of landscape structure on this area between 1784 and 2005. Study how large was the fragmentation and how far are the small semi natural habitats to each other. Furthermore, demonstrate that similar floodplain areas are developed along a very different pathway during the last 200 years depending on the human influence.

III.) Test the correlations between carabid assemblages and some environmental factors; furthermore find out which factor has a stronger effect on carabid composition. Study the carabid assemblages related to the architectural structure of individual plants (vegetation structure) and in what amount. Study plant density and light availability whether correlated to habitat choice of different species of carabids. Compare the predictive value of relevant environmental factors on ground beetle assemblages in a floodplain area managed by mowing and grazing. Test which biotic or abiotic environmental factors were more relevant on carabid assemblages in managed floodplain area.

3 Data and Methods

3.1 Study areas

3.1.1 Study area of satellite- and aerial photos accuracy analysis and land use change analysis

The study area was a floodplain area on the Upper-Tisza-Region in North-Eastern Hungary near to the border where the Tisza River enters the country (Fig. 3.1.1a). The study area is located on the right and left bank of the river, in the vicinity of four villages (Jánd, Gulács, Olcsvaapáti, Panyola). The study area was a part of the active, adjacent floodplain areas on the Upper-Tisza-Region in north-east Hungary. It was selected after a large flood catastrophe in 2001 in the Upper-Tisza Region. Annual floods of the Tisza and anthropogenic effects are of great importance on this floodplain area. A part of these floodplains has conservation priority and also part of Natura-2000 site within the Hortobágy National Park (48°4'58"N, 22°24'6"E), because of its considerable riparian bird communities and their special wetland

habitats. Several valuable species live or forage here e.g. *Castor fiber*, *Alcedo atthis*, as well as migrating and wandering heron species (*Ixobrychus minuses*, *Botaurus stellaris*). (see Natura 2000). Furthermore, the area is an important migration area for *Ciconia nigra* and here can be found the largest sand martin (*Riparia riparia*) population in Central Europe. The study area located at 104-111 m altitude above Baltic sea-level. The geological substrate is a Quaternary loess strata with alluvial silt. The climate is continental (mean annual temperature above 9-10 °C, annual precipitation of 600-700 mm), cool and dry temperate. On this area floods were/are frequent; as result large river channelization and floodplain drainage were attempted between 1846 and 1880. There are some backwaters and some marsh patches in the studied area. Today a large portion of the area is arable land, orchard, riparian forests and economic plantation.

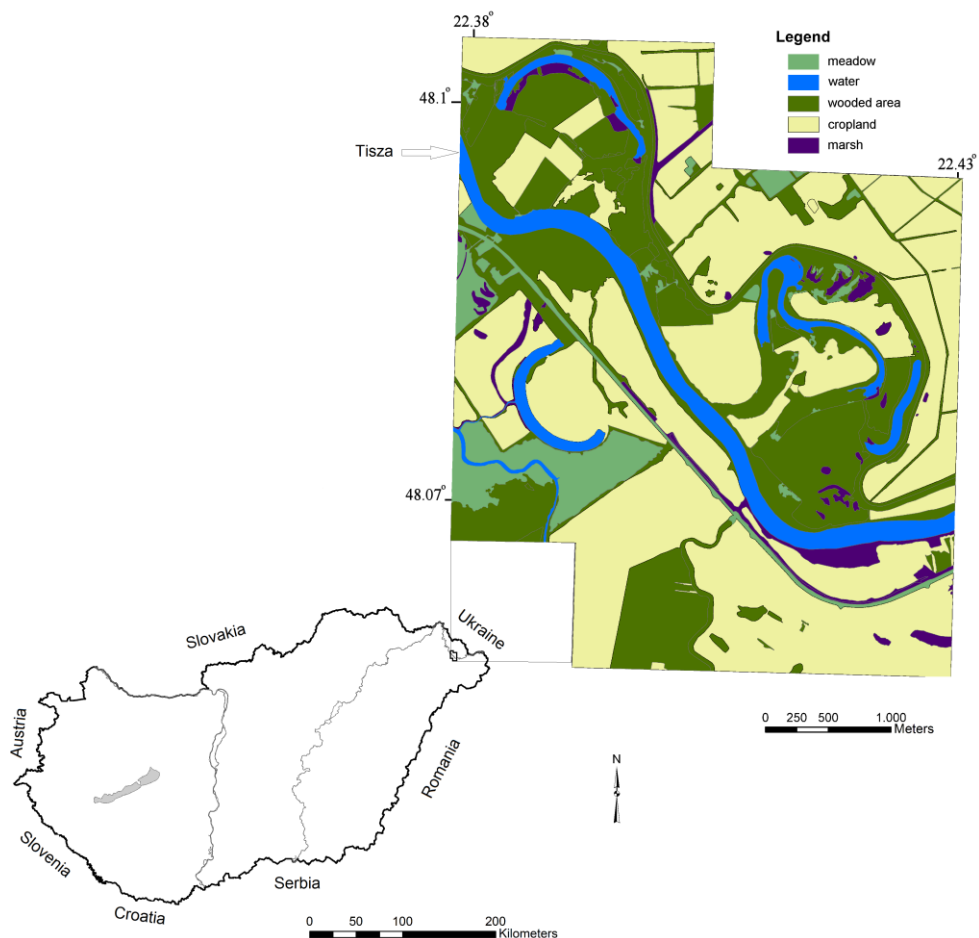


Fig. 3.1.1 Location of the study area in Hungary, Boroszló-kert and Foltos-kert (Upper-Tisza Region)

3.1.2. Study area of study of environmental factors predictive power for ground beetle assemblages

Three sites were selected in the frame of the RIVA project in Natura 2000 protected areas in the floodplain of Elbe River in Saxony Anhalt, Germany (Henle et al 2006). The study areas located “Wörlitz” and “Steckby” near Dessau and the third near “Sandau”, 100 km downstream in the UNESCO Biosphere Reserve “Middle Elbe/Elbe River Landscape”. The sampling plots were selected with a stratified random design in each study site to represent hydrological conditions (Henle et al. 2006, Scholz et al. 2009) (Fig. 3.1.2). There are seasonally flooded grasslands with typical small-scale relief features, including bayous and higher and lower-lying areas with corresponding variable inundation and groundwater level. The intensity of farming was medium and consisted of biannual mowing of elevated areas. The vegetation types included flood-channels, depressions and ditches, wet and dry grassland close the river, and dry grassland distant from the river (Henle et al 2006). A total of 60 sampling plots were established in the three study areas (Wörlitz: 12, Steckby: 36, Sandau: 12) and have been monitored for invertebrates, vegetation and a range of hydrological and soil parameters (Henle et al. 2006). All field data that we have used in this study came from the RIVA project.

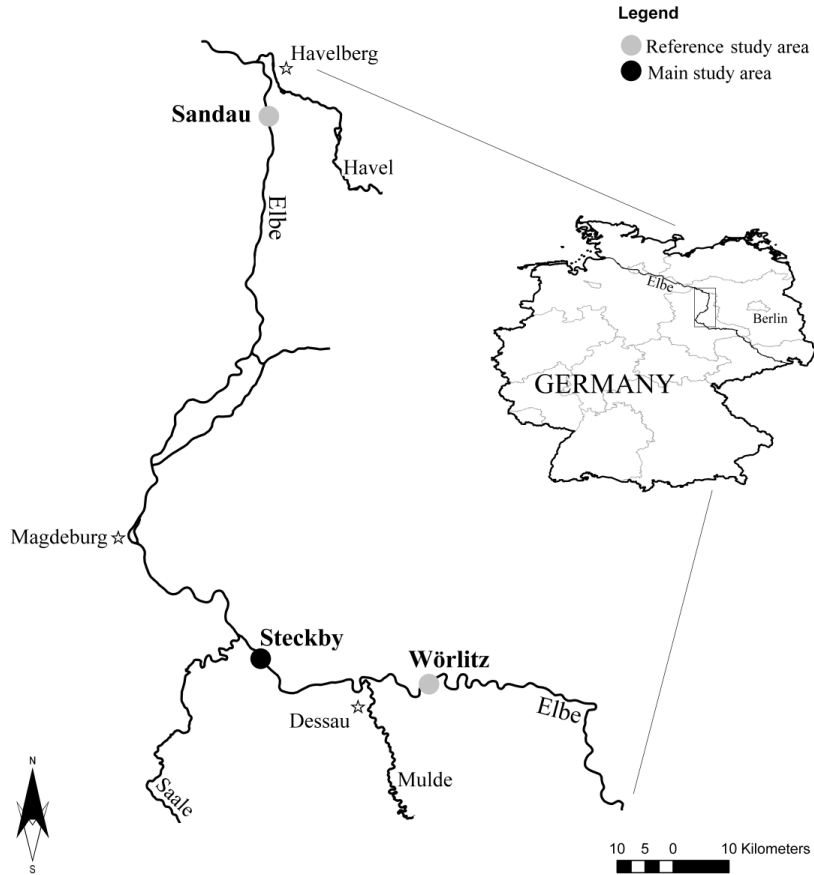


Fig. 3.1.2 Location of study areas along the Elbe River in Saxony Anhalt, Germany

3.2 Data and methods

3.2.1. Satellite images and aerial photographs to accuracy analysis

The first type of data set was LANDSAT7 Enhanced Thematic Mapper (ETM+) images which were used from two dates June and August of 2000 (NASA Landsat Program). The spatial resolution of LANDSAT7 ETM+ was 28.5 meters. A colour composite (RGB) was generated from bands 4 (near-infrared), 5 and 7 (mid-infrared ranges of the electromagnetic spectrum). This combination was ideal for detecting healthy green vegetation and the water-land border-line. There were no clouds or stripes on the images; therefore, we were able to use them without any limitation or need of post processing. The SRTM surface model was added to satellite images. This elevation data was generated using the most complete high-resolution digital elevation data of the Earth, which was made with the Interferometric Synthetic

Aperture Radar (InSAR). The sensitivity of the radar can be attributed to the relatively short wavelengths of the C- (5.6 cm), and X-band (3.1 cm) interferometer. A 225 km swath was allowed at the C-band and was limited to 45-50 km at the X-band (van Zyl 2001, Farr et al. 2007, Bolch et al. 2005).

Furthermore, two aerial photographs from 2004 and 2005 were used from the National Hungarian Mapping Agency. A Leica RC20, RC30 aerial camera was employed when acquiring aerial photographs and for field work. These photos were also used to obtain detailed land cover information of the floodplain. The original resolution of the aerial photos was 0.63 m, and the resolution never reached an accuracy of 0.5 m, so the original resolution was applied to produce orthophotos. During our data processing, the 0.63 m resolution resulted noisy and unusable results; to improve (i.e. to remove/decrease noise from) the outcomes resolution resampling was implemented using the nearest neighbour method. Thus a resolution of 2 meters was used. Aerial photos in the visual spectral range were separated into RGB channels and used for automatic evaluation. Thus thematic maps could be extracted from the satellite images. With the use of the two orthophotos we had six ($2 \times \text{RGB}$) channels to use in the automatic evaluation. Supervised classification methods were applied based on training sites and provide real information categories. Several possibilities using the six bands was tested: only the bands from 2004, only the bands from 2005, and from 2004 and 2005 together without modification, from 2004 and 2005 together but with bands multiplied (a pair wise multiplication of each band), from 2004 and 2005 together with stretched values (linear stretch with 1% saturation). It is not common to use altered values in the analysis; however, these aerial photos did not have radiometric correction. Thus, this procedure can increase contrast and, potentially, improve the classification.

3.2.1.1 Manual interpretation of aerial photographs

A habitat map of the study area was created in 2005 to present the vegetation cover and type of these regions of Hungary. Vegetation was classified using the Hungarian General National Habitat Classification System (Á-NÉR) (Fekete et al. 1997) and the nomenclature of Simon (Simon 2000) was used for identify the vascular plants in each habitat. The habitat types were estimated in units of $20 \times 20\text{m}$; the similar adjacent patches were merged. Aerial photos were used as reference information for these most accurate thematic map variants. Nevertheless, the categories of the Hungarian General National Habitat Classification System were useless for automated mapping of satellite images and aerial photographs because of the similarities of the classes (e.g. forest and orchard). Therefore, their number was reduced into five easier-to-handle classes which were recognizable in this area with automated classification (meadow, water, wooded area, croplands, and marshes) so

simpler land cover maps were created for automatic satellite image classification (Table 3.2.1.1). The simplified manual vectorized maps (MVM) of 2000, 2004 and 2005 were converted into a stratified random point map with the values of the land use codes and used them as the reference in the accuracy assessment. All details of the vegetation and land cover maps could be control because the area had a manageable size and field observations were performed between 2003 and 2005 to rectify our MVMs (vegetation type, land cover classes). The manual vectorized maps of current vegetation in the different years were created with ArcGIS 9.3.

Table 3.2.1.1 Current vegetation cover and type on the study area

Land cover classes	Á-NÉR (National Habitat Classification System of Hungary)
Cropland	Arable land (T1, T2 (forage plantation))
Meadow	Mesotrophic meadow (D4), Tall herb meadow (D6), Ruderal and semiruderal vegetation on floodplain and marsh (O3), Semiruderal vegetation on floodplain (O4),_Seminatural grassland on fallow (O11), Seminatural vegetation on dike (O10), Dirt road vegetation (O13).
Water (Tisza, backwaters)	Standing water (U9), Running water (U8)
Wetlands	Standing water vegetation with <i>Trapa</i> , <i>Lemna</i> , <i>Salvinia</i> and <i>Ceratophyllum</i> (A1), Floating vegetation of <i>Utricularia spp.</i> and <i>Stratiotes sp.</i> (A2), Submers or emerse rooted pioneer plant communities with <i>Potamogeton spp.</i> and <i>Nymphoides sp.</i> (A3), Marshy vegetation with <i>Thypha spp.</i> , <i>Phragmites spp.</i> (B1), Assemblages of <i>Glyceria maxima</i> , <i>Sparganium erectum</i> and <i>Schoenoplectus lacustris</i> (B2), The water-fringing helophyte assemblages with <i>Butomus sp.</i> , <i>Eleocharis spp.</i> and <i>Alisma spp.</i> (B3)
Wooded area	Riverine willow scrub (J3), Riverine willow-poplar woodland (J4), Riverine oak-elm-ash woodland (J6), Spontaneously afforested (P2) Lands forest with non-native wood, shrub and grassland level (R2), Locust tree plantation (S1), Poplar plantation (S2), Large orchard (T7), Little orchard (T8), Abandoned orchard (O12)

3.2.1.2 Automated image classification

IDRISI Taiga software was used for land cover classification and for comparison of the accuracy of assessment. In case of satellite images, spectral bands were analysed with maximum likelihood classifiers (separately in each date). This supervised classification method was based on training sites and provided real information categories. The training samples for land cover classification were obtained from the simplified MVM. All training samples were the most appropriate for that cover

class. Due to the spectral differences between aerial photos and satellite images, different land cover types were applied in these analyses.

The accuracy assessment of satellite images was estimated using 200 points chosen with the stratified random method to represent different land cover classes of the area with the same probability. The distribution of random points had the same spatial proportion among the land cover classes. The accuracy of classification results from the satellite images were compared by using the cross tabulation matrix in all compared pairs (Table 3.2.1.2). The cross tabulation matrix was applied to calculate the error of omission [PA], the error of commission [UA]) and the Kappa Index of Agreement (overall and per categories), and Chi-square and Cramer's V to estimate the spatial distribution of different vegetation and land cover classes. PA showed the ratio of pixels where the classification was successful concerning the omissions (e.g. pixels claimed to be water surface are classified as water). UA showed the rate of accuracy concerning the commissions (e.g. what are the pixels actually classified as water) (Lunetta et al. 1991). Cross-classification was also run which showed multiple overlaps of all combinations (Fig. 3.2.1.2). Through the overlay process, areas which were misclassified in the cropland, wooded area, wetlands and water classes were relabelled into the correct classes using the manual interpretation layer.

Table 3.2.1.2 Combinations to cross tabulation matrix in the analysis of satellite images
Notation: MVM - manual vectorized map

	MVM	03.06.2000	03.06.2000 +SRTM	22.08.2000	22.08.2000 +SRTM
MVM		vs.	vs.	vs.	vs.
03.06. 2000+SRTM			vs.	vs.	vs.
03.06.2000				vs.	vs.
22.08.2000+SRTM					vs.

For aerial photographs two different images were used and needed a control layer that showed the same land cover information in both years (Lowe 2004). A stratified random sampling was defined and was overlapped with the land cover maps based on aerial photos and field observations. A cross tabulation image showed the points where the land cover type was the same in 2004 and 2005. This layer was reclassified to a Boolean image showing only the pixels where the land cover coincides in both years (Fig. 3.2.1.2). Whereas the study area had non-regular shape and the random point generation produced sampling points to the whole area; furthermore, there were some land cover differences between the dates, so the original 1000 points were decreased to 609 due to differences and the fact that those were omitted that were outside the study area. In accuracy assessments was updated

providing a point layer with land cover data. This layer was used as a ground truth image in the verification procedure. The classification results of aerial photos were also controlled by using the confusion matrices (error of omission [PA], error of commission [UA]) and Kappa Index of Agreement (overall and per categories) (Lunetta et al. 1991). A ground truth image was created using the map based on field observations.

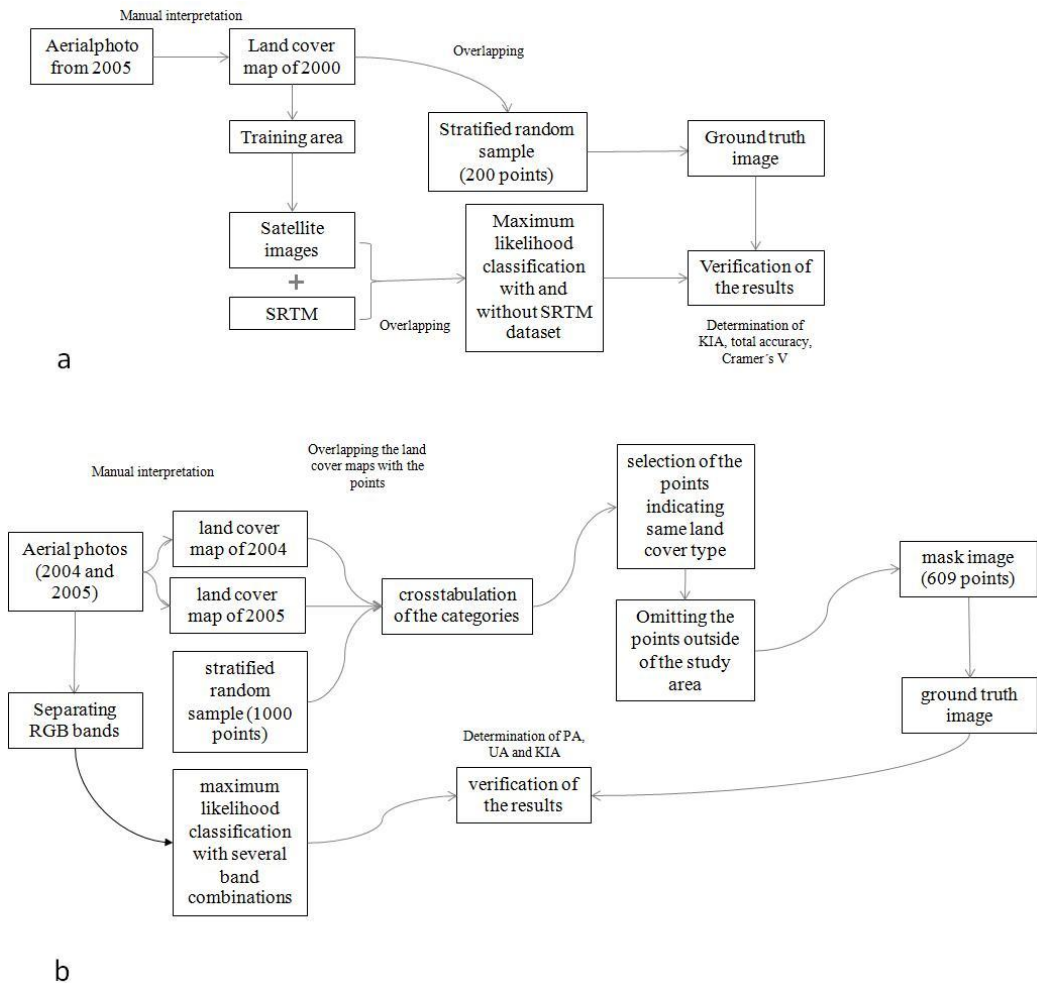


Fig. 3.2.1.2 Scheme of delineating the mask image for the accuracy assessment, a) analysis of satellite images, b) analysis of aerial photographs

3.2.2 Maps and aerial photos to analyse land use changes

The analysis of land use change was based on topographic, historical maps and aerial photographs. The change of the land use over time was described by four topographical maps (firstly military maps (1784) at a 1:28 800 scale, secondly military maps (1858) at a 1:28 800 scale, and thirdly military maps (1884) at a 1:25 000 scale and, from 1985, at a 1:25 000 scale). The first military map was not surveyed uniformly but rather built up as separate surveyed parts of countries, regions and autonomous provinces. The recording method was also not consistent, varying from country to country and with circumstances, according to the most appropriate method. The recording was not based on a strong geodetic base and the work process was defined by the threatened or expected directions of eventual military attacks. In the 19th century, due to technical developments and social pressure it was necessary to create increasingly accurate maps of the countries (II. and III military maps). Beside the military maps and topographical map nine aerial photographs from the floodplain of Boroszló-kert (1944, 1956, 1966, 1975, 1988, 1995, 1997, 2000, 2002, 2004, 2005) and four aerial photographs from the floodplain of Foltos-kert (1944, 1995, 2000, 2005) were used to study the land use changes in the area. The first, second and third military maps were provided by the Military History Museum Maps Gallery. A topographic map from 1985 was provided by the National Hungarian Mapping Agency. The digital ortophotos from 1966, 1975, 1988, 1997, 2000, 2002, 2004 and 2005 were obtained from the National Hungarian Mapping Agency, and those from 1944 and 1956 were obtained from the Department of Hydrobiology and from 1995 from the Environment and Water Resources Research Institute Ltd. (VITUKI Rt.).

After the projection of all maps in the national map projection (“Hungarian Datum 1972 - Unified National Projection System” (EOV)) with IDRISI Kilimanjaro, vegetation cover was digitized from the projected maps and aerial photographs. Layers were constructed for each time period that we investigated (first, second and third military surveys, 1944, 1956, 1966, 1975, 1985, 1988, 1995, 1997, 2000, 2002, 2004, 2005), beginning with the most recent and most accurate aerial photograph, and working backwards in time to the earlier layers.

3.2.2.1 Characterization of land cover

The analysis of land use changes based on an intensive field work beside of manual photo interpretation. In this way all thematic maps and aerial photographs were transferred into vector format where the information is defined by polygons. All layers were prepared with ArcView 3.2, ArcGIS 9.3.1. Polygon maps of land use changes were created one after another by intersecting the various temporal layers

according to categories of change, beginning with the oldest layer. Then it became possible to visualize the changes between any two temporal layers e.g. a patch of marsh disappearing from one temporal layer year by year. The spatio-temporal data model enables us to quickly generate land cover statistics for any given time step. This is necessary to obtain a general insight into the most decisive land cover/use changes in the study area. Unfortunately, the quality of the aerial photographs from earlier years does not allow the subdividing of habitat classes into more detailed land cover types. The topographical maps only served to identify the changes. Their distortions and simplified mapping of the land cover and survey do not allow consideration of their patch area by land use change analysis. They represent only approximate values and the direction of land use changes.

Land cover was classified into 12 groups to historical analyses which could be easily recognized in each time period on the maps and aerial photographs. In some case categories were very difficult to distinguish in the aerial photographs because of the quality and scale of photographs (wooded area and orchard or wooded area and water surface or cultivation area or grassland, etc.). The simplified habitat categories which were used for the evaluation of land cover were (1) backwater, (2) cropland, (3) dam, (4) economic plantation (5) grassland, (6) marsh, (7) meadow, (8) orchard, (9) other, (10) river, (11) wood clearing and (12) woodland (Table 1).

Land cover composition data were analysed using FRAGSTAT software (McGarrigal and Marks 1995). We used the Effective Mesh Size (MESH) and Degree of landscape division (DIVISION) to characterize the fragmentation of the study area. Furthermore, with the Distance Matrix script of ArcView 3.2 and vLATE extension of ArcGIS we calculated the Nearest-Neighbor Distance (NNDist). With these methods we established the distance between the semi natural habitats (backwater, grassland, marsh, meadow) (Table 3.2.2.1). In some cases, this was not applicable because some marsh patches were located in the same backwater; they were connected and thus the distance was not interpreted.

3.2.3 Data to analysis of environmental factors predictive power for ground beetles assemblages

Data sets that address carabid composition, different environmental data and data from vegetation and composition has been collected in the RIVA project in 1999. This data were analysed during my DBU scholarship (Deutsche Bundes Stiftung Umwelt) in Germany.

3.2.3.1 Ground beetle sampling

Sixty sampling plots were established in the three study areas (Wörlitz: 12, Steckby: 36, Sandau: 12). Carabids were sampled using pitfall traps filled with a 7% solution of acetic acid and detergent to reduce surface tension. Traps were exposed bi-weekly from the end of April until the end of October 1999 and also the environmental variables were measured on each plot in 1999. All adult ground beetles were identified to species-level.

3.2.3.2 Plant and vegetation measurements

On each sampling plot the number and cover (in %) of vascular plant species was recorded in 10x10m levers according to Braun-Blanquet (1964). Species identification was based on Klapp and Opitz von Boberfeld (1990), Wisskirchen and Haeupler (1998), and Rothmaler et al (1999). We have used vegetation and plant data both from spring (begin of May until begin of June) and autumn (begin of September until begin of October) 1999 for our analyses.

To characterize the vertical structure of vegetation we used information on the estimated density of the vegetation by measuring light intensity at different heights above the ground (starting from 3 cm and then in 10 cm steps until 100 cm aboveground). Measurement was carried out by carefully inserting a vertical 1 m² white board into the standing crop and measured illumination intensity with two types of sensors: a radial sensor and a pole sensor (LICOR LAI 189 Quantum/Radiometer/Photometer with SA-Sensor, LI-COR Inc.). The radial sensor in the vegetation and the pole sensor were inserted on the ground simultaneously. The radial sensor was used to calibrate the readings from the pole sensor. Then the relative intensity of illumination (%) was calculated from these two values to eliminate potential biases caused by varying cloud cover that can influence the absolute value. The intensity of illumination was measured in micromol and lux/klux, respectively. Relative light intensity was standardized by choosing the data under 80% because above this height the vegetation density is already negligible and light is not shaded by the vegetation. For clarity, the reciprocal values of the standardized light intensity were used to express vegetation density, i.e. a low value of reciprocal light intensity refers to higher vegetation density and vice versa.

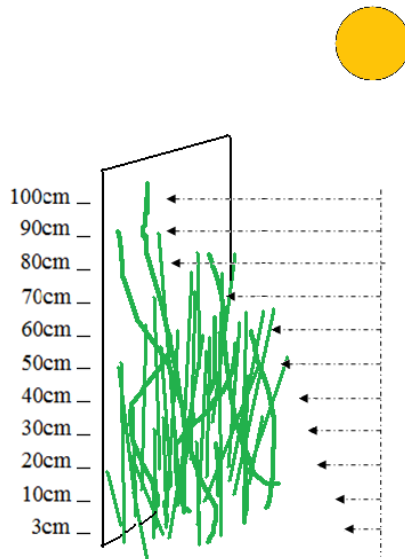


Fig. 3.2.3.2 Measuring light intensity at different heights to characterize the density of vegetation

To obtain a fine-scale characterization of vegetation architecture as vegetation density that can be related to the movement and microsite selection of carabids, we used two leaf traits of the vascular plant species recorded. Each plant species has its own specific architecture arising from the shape of their leaves and the leaves are on for only a certain time period which was called leaf longevity. Leaf longevity provides a temporal aspect for physical complexity, which may be an important additional factor to leaf shape in the fine-scale habitat selection of carabid beetles. For estimating leaf shape, 13 leaf traits were used (see Table 3.2.3.2). Leaf longevity was estimated by classifying plant species into four categories: spring green, deciduous, overwintering green, persistent green (Table 3.2.3.2). Data on both leaf shape and longevity were obtained from the BIOFLOR database (Klotz et al. 2002).

Table 3.2.3.2 Variables characterizing leaf traits (shape and longevity) used in the study. Categories followed the BIOFLOR database (Klotz et al 2002).

Variable	Levels	Number of plant species recorded
Leaf shape	bipinnate	6
	digitate	1
	ensiform	1
	full	21
	grass-like	31
	lobate	4
	long-leaf	29
	palmate	8
	pinnate	16
	pinnatifid	18
	scale-like	2
	simple	24
	tubular	2
	no marking	2
	Leaf longevity	spring green
deciduous		94
overwintering green		16
persistent green		49
no marking		4

Two indices, created by us, were applied to measure the correlation between carabids and leaf traits. For the leaf shape index (*lsci*) was calculated as:

$$lsci = \sum_{i=1}^n f_i \cdot lsi,$$

where f_i is the mean value of cover of plant species i , lsi is the leaf shape value of species i (Table 3.3.2.3.1) and n is the number of plant species.

The leaf longevity complexity index (*llci*) was calculated as:

$$llci = \sum_{i=1}^n f_i \cdot lli,$$

where f_i is the mean value of cover of plant species i , lli is the leaf longevity of species i (Table 3.2.3.2) and n is the number of plant species.

3.2.3.3 Environmental variables

We used the following environmental variables for analysis: groundwater level during the vegetation period (in m), pH (H₂O) and mean clay content of the soil (%), management type (categorical), human disturbance level and habitat type (Table 3.2.3.3).

Table 3.2.3.3 Predictor variables in the study of ground beetles. Variables in bold were selected for the more detailed analyses.

Type of variable	Variable	Measurement
Vegetation	Vegetation density	Light intensity measured at 11 heights between 3 to 100 cm in the vegetation, both in spring and autumn
	Vegetation height	Maximum height of vegetation, both in spring and autumn
	Cover	Percentage plant cover according to Braun-Blanquet (1964) on each area, both in spring and autumn
	Leaf shape	Leaf shape complexity index (<i>lsci</i>), both in spring and autumn
	Leaf longevity	Leaf longevity complexity index (<i>llci</i>), both in spring and autumn
Hydrology	Groundwater level	Mean and maximum
	Duration of inundation	Number of days inundated
	Maximum inundation height	Inundation height (m)
Soil	pH	H ₂ O delogarithmical (H ⁺ concentration)
	Mean clay content	% particles in clay size range
	Mean sand content	% particles in sand size range
Land use	Management type	Floodplain, mowed once, grazed twice, grazed partially, not managed
	Disturbance level	Categorized as none, little, medium, or high
	Habitat type	Habitat categorisation based on homogenous units with similar vegetation structure, abiotic site conditions or morphology etc. (Scholz et al 2009)
River part	Place	Place of the plots categorized as Wörlitz, Steckby, Sandau

3.2.3.4 Statistical analysis

The aim of this study was to explain the species composition of ground beetles by vegetation structure and environmental factors. We were interested in the relative strength of these relationships and in the joint explanatory effect of these two sets of predictor variables. Canonical correspondence analysis was used to study the

relationships between predictor and response variables. Many of the predictor variables were suspected to show correlations and we reduced such redundancy in the dataset in two ways. Spearman's rank correlations were calculated between all possible pairs of the 16 numerical vegetation and environmental variables to identify large correlations and we eliminated variables that showed large ($\rho > 0.8$) correlations with any other variables in the same variable group (Table 3.2.3.3).

Canonical correspondence analysis (CCA, ter Braak 1986, 1987) was used to explore the relationships between ground beetle species composition and vegetation structure and environmental variables. We further aimed to evaluate how well the composition of species was explained by the different sampling seasons, to predict the possible differences between spring and autumn. For this, data from spring and autumn were separated. Canonical correspondence analysis was carried out using Canoco 4.14 (ter Braak 1987).

Variables were assigned to one of three groups of biotic and abiotic factors to explain carabid species composition. Set 1 consisted of variables describing vegetation structure (vegetation density, height, cover, leaf shape, leaf longevity). Vegetation structure set was dissolved into two main groups: vegetation architecture and vegetation density. Vegetation architecture included leaf shape, leaf longevity and vegetation cover, whereas vegetation compactness included total vegetation density and vegetation density at 3 cm. Set 2 included environmental variables (soil mean clay content, soil pH, mean groundwater level), and set 3 included land use variables (management, disturbance, habitat type) (Table 3.2.3.3). We searched for the best performing subset of variables within each predictor set to evaluate how large effective the single variables of each subset were at explaining the carabid composition. To do this, we applied variation partitioning on the ground beetle data; based on both, the predictor set and the single response variables. The function partitions the variation in the table of the response variable with respect to two, three or four tables of explanatory variables using redundancy analysis (RDA, Oksanen et al 2010). Vegan package (Oksanen et al. 2010) of R (R DevelopmentCore Team 2011) was used to perform the variation partitioning analysis.

4 Results and discussion

4.1 Analysis of satellite images and aerial photographs accuracy

4.1.1 Automated classification of satellite images

The evaluation of the classification (or accuracy assessment) of satellite images showed small differences between the comparing pairs (Table 4.1.1a). The total accuracy (TA) for reclassified images and MVM (derived from the habitat map) was between 76 and 77% compared to the satellite images. The lowest accuracy gave the

comparison of MVM and satellite image from 22.08.2000 with SRTM. In addition, when results of satellite maps with SRTM and without SRTM were compared a larger accuracy of 94.4% was obtained at the beginning of the summer (03.06.2000). The comparison of two date point agreements with and without SRTM did not give differences.

Table 4.1.1a. Accuracy statistics of reclassified images for the classifications Notation: MVM - manual vectorized map

	Total Accuracy	ChiSquare	Cramer's V	Kappa
MVM vs. 03.06.2000+SRTM	77.18	4011.22	0.57	0.63
MVM vs. 03.06.2000	77.27	4106.23	0.58	0.63
MVM vs. 22.08.2000+SRTM	75.94	3899.658	0.56	0.62
MVM vs. 22.08.2000	77.5	4024.92	0.57	0.64
03.06.2000+SRTM vs. 03.06.2000	94.36	8830.44	0.85	0.91
22.08.2000+SRTM vs. 22.08.2000	88.72	7638.62	0.79	0.81
03.06.2000 vs. 22.08.2000	80.89	4883.30	0.63	0.69
03.06.2000+SRTM vs. 22.08.2000+SRTM	81.06	4699.78	0.62	0.68

However, details of single class accuracy for all compared pairs showed that the SRTM presented higher accuracy by a comparison of MVM and reclassified images from 03.06.2000 in various land cover classes (Table 4.1.1b). The matching of interpretations was higher at 03.06.2000+SRTM, 03.06.2000 comparing pairs than between 22.08.2000+SRTM and 22.08.2000 (see Kappa Index of Agreement in Table 4.1.1b). The interpretation showed greater similarity at 03.06.2000+SRTM vs. 22.08.2000+SRTM than between 03.06.2000 and 22.08.2000.

Table 4.1.1b. Accuracy statistics of reclassified images estimated to various land cover classes. Notations: MVM - manual vectorized map; UA - User's Accuracy; PA - Producer's Accuracy; KIA - Kappa Index of Agreement

	MVM vs. 03.06.2000+SRTM			MVM vs. 03.06.2000			MVM vs. 22.08.2000+SRTM			MVM vs. 22.08.2000		
	PA	UA	KIA	PA	UA	KIA	PA	UA	KIA	PA	UA	KIA
meadow	71.43	32.08	0.30	32.62	84.72	0.31	42.24	48.24	0.39	43.3	45.5	0.40
water	81.12	77.69	0.76	74.61	82.2	0.73	76.9	83.7	0.75	77.3	86.6	0.75
wooded area	75.81	73.06	0.60	73.84	74.72	0.61	74	77.9	0.62	73.5	80.78	0.62
cropland	81.9	90.05	0.79	90.05	81.22	0.78	86.2	80.45	0.71	89.45	79.4	0.77
marsh	12.15	12.38	0.09	14.28	16.13	0.12	4.8	5.5	0.02	6.66	16.28	0.05

	03.06.2000+SRTM vs. 03.06.2000			22.08.2000+SRTM vs. 22.08.2000			03.06.2000+SRTM vs. 22.08.2000+SRTM			03.06.2000 vs. 22.08.2000		
	PA	UA	KIA	PA	UA	KIA	PA	UA	KIA	PA	UA	KIA
meadow	78.57	91.6	0.78	94.51	87.07	0.94	41.46	80.95	0.40	34.83	86.1	0.33
water	92.77	97.88	0.92	89.12	91.8	0.88	86.2	82.73	0.85	84.48	83.05	0.83
wooded area	94.08	91.74	0.91	84.69	88.44	0.78	78.28	77.24	0.68	79.7	73.43	0.70
cropland	97.8	96.99	0.95	93.71	89.16	0.86	89.54	87.3	0.77	87.2	88.62	0.72
marsh	59.8	68.82	0.59	31.87	67.44	0.31	18.68	15.89	0.16	30.23	13.98	0.28

Five categories (meadow, water, wooded area, croplands, and marshes) were identified with varying success through the automated mapping technique. Through the overlay process, areas which were misclassified in the cropland, wooded area, marshes and water classes were relabelled into the correct classes using the manual interpretation layer. Misclassifications could be explained by the fact that in some cases the croplands were spectrally interchangeable with the meadow class and water areas could be interchangeable with wooded area as well as with some marsh patches.

With the single land cover class accuracies the highest accuracy was for cropland and water by MVM vs. reclassified images and when comparing the two reclassified images from different dates in the same year and season. The lowest accuracy belonged to marsh and meadow.

A post-classification detection technique was implemented with the cross tabulation matrix. Interpretation of the same land cover class by the comparison of different reclassified images resulted in different percentages of the surface area (Table 4.1.1c in appendix). In the same classes, higher percentages were obtained, except for marsh. The identification of land cover classes was better when using the image classification pair of MVM vs. 03.06.2000+SRTM and MVM vs. 03.06.2000 reclassified image (Table 4.1.1c in appendix). The misclassifications were predominantly under or around 10 percent. Higher misclassified values occurred in pairs of marsh and wooded area around 30-40% at MVM and in comparing pairs of reclassified images as well as in marsh and water identification (17-28%) at MVM and in comparing pairs of reclassified images. A high value (38-40%) in meadows – cropland pairs was obtained in the case of MVM and 22.08.2000+SRTM and without a SRTM comparing pair.

4.1.2 Automated classification of aerial photographs

The difference between the two aerial photographs was minimal: Fuzzy Kappa (Van Vliet et al. 2011) was 0.92 using a 10 meter neighbourhood radius (which is about the same as the mistake of georeferencing images), so the similarity was enough for their parallel application. The pixel values were similar even in the case of bodies of water, plough land and wooded area; they all had green toned colours and fine differences were impossible to discriminate accurately (e.g. between trees and bushes) (Table 4.1.2a). The infra-red channels that could help to distinguish the bodies of water were missing in the aerial photos and to take into consideration the soil moisture content or biomass characteristics.

Table 4.1.2a Pixel intensities of RGB bands of the aerial photographs (DN values, mean±standard deviation)

Land cover unit	2004			2005		
	blue	green	red	blue	green	red
Tisza	176.4±33.6	169.0±30.7	166.6±29.3	144.0±10.8	134.9±10.0	109.6±10.7
backwater	144.0±67.7	145.8±65.8	156.3±57.9	107.7±8.5	108.6±8.0	98.2±4.5
forest	79.0±32.2	91.4±35.6	102.4±33.7	90.0±37.4	97.5±35.2	87.5±19.5
arable land	117.9±40.8	129.2±40.8	129.8±32.7	123.8±36.7	124.9±30.9	100.2±17.8
other	118.7±46.0	126.3±44.7	128.5±41.1	129.2±43.7	125.4±36.0	104.7±22.8

If we distinguish only the River Tisza, the backwater, the arable lands and the green wooded area, we obtained an acceptable classification in the case of the river (Tisza), arable lands and wooded area. Wooded area, as the most distinct vegetation type, could be observed, but the difference between an orchard and a wooded area was limited to their similar colour. Their texture was different, but that we could not use by pixel-based classification. Backwaters could not be good differentiated by automated methods. All methods where the two data sources was used together provided better results than the stand-alone tests, but the result was not improved when the raw data was manipulated (e.g. multiplication; Table 4.1.2b).

Table 4.1.2b Accuracy assessment of the classified maps. Notations: UA - User's Accuracy; PA - Producer's Accuracy

Land cover unit	2004		2005		2004 and 2005		2004 vs. 2005		2004 and 2005 stretched	
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA
Tisza	93	49	100	47	93	85	95	59	93	67
backwater	25	6	41	46	16	71	34	20	19	46
forest	68	61	57	66	94	62	82	64	89	63
arable land	52	81	69	66	65	82	64	79	66	79
other	7	29	15	33	20	23	11	35	15	24

4.1.3 Discussion of satellite images and aerial photographs accuracy analysis

The use of ancillary data may be helpful (e.g. maps, field observations) and more than one aerial photograph could also improve the classification accuracy. In the current paper was demonstrated that an optimal scale parameter definition was the key to successful automated and semi-automated mapping. The results can be useful when manual interpretation is too expensive or field investigation is not possible. The automated identification of vegetation patches can be difficult due to their heterogeneity and the sporadic influence of water that can cause spectral

interchanges. Low accuracy could be explained by the fact that the areas were too small and the vegetation appearance (colour composition) led to their misclassifications (e.g. in some cases marsh and meadows pair with wooded area). For example backwaters also had green tones because of the biological processes of the water surface and as a consequence they cannot be good differentiated by automated methods. SRTM was useful in separating the land cover classes on the floodplain area in case of wooded area, but for the other categories did not contribute to the identification accuracy. Furthermore, the analysis of satellite image composition from different dates during the vegetation season showed that both dates give reliable information regarding land cover. Altogether, classification at the beginning of summer could be more accurate, but the differences between the seasons were not considerable. In the case of SRTM the differences were more considerable if it was looked at the land cover types at different dates during the summer. It is well known that the manually vectorized aerial photographs, satellite images allow for a much more detailed classification than any automated computer classification (Harvey and Hill 2001). However, we were able to get more accurate information of vegetation type or land cover with an automated analysis of satellite images than with an automated analysis of aerial photographs. Although we established that the results of the classification could be improved by using a combination of two time close aerial photographs to map vegetation covers. In contrast, automatic image classification of aerial photos was not successful in all categories. Since the spectral information could be obtained by the separation of visible (RGB) bands and had no infra red (IR) bands, possibilities to extract features were limited. While Hyypä et al. (2000) (Hyypä et al. 2000) found that aerial photographs could give comparable results to satellite images, it seems that in some cases this includes more information for forest inventory than satellite radar images (Hyypä et al. 2000). The infra-red channels that could help to distinguish the bodies of water and to take into consideration the soil moisture content or biomass characteristics were missing in the aerial photos.

Many studies deal with accuracy and how better information could be extracted from satellite images, aerial photographs and other remote sensing data sources (Mas 1999, Foody 2002, Wulder et al. 2006). Some studies discuss how classifications of satellite images with automated classification methods could not perform satisfactorily in deriving accurate and reliable classification categories in some cases, but this could be improved. For example Manandhar et al. (2009) also discussed how to improve the accuracy of land cover classification of LANDSAT data and they were able to improve accuracy by incorporating additional data (DEM, spatial texture, NDVI etc.). Improvements using SRTM could help to separate the land cover classes; taken together some aspects can modify the absolute accuracy of SRTM (Gorokhovich and Voustianiouk 2006).

In the same way, it could be seen that several land cover maps and vegetation maps of large projects were created based on satellite images due to the fact that they can cover a large area. For example the International Geosphere-Biosphere Program pioneered a global land cover mapping in the development of the Global Land Cover Characterization (GLCC). Their database was based on 1-km Advanced Very High Resolution Radiometer (AVHRR) in 1992 (<http://edcns17.cr.usgs.gov/glcc/>). It must be mentioned that the Global Land Cover 2000 (GLC2000) (<http://www-gvm.jrc.it/glc2000/>) and other smaller scale programs were also developed such as the Pan-European Land Cover Monitoring project and Corine Land Cover (CLC50) which is based on the photo interpretation of SPOT4 images. Besides, the aerial photographs also give useful information regarding the location of vegetation and land cover. In addition many examples show that these techniques are used in parallel (Cakir et al. 2007; Terzioglu et al. 2009).

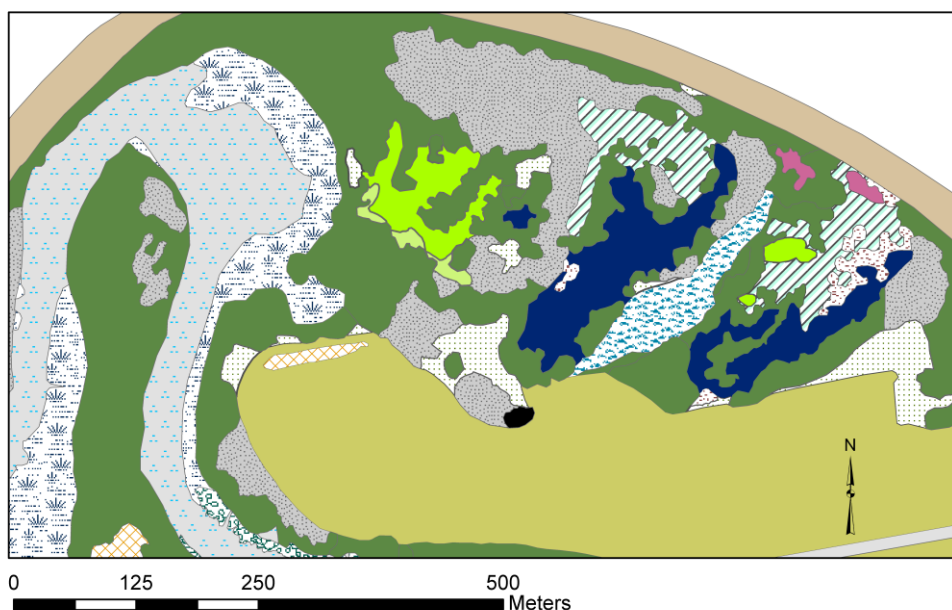
4.2 Land use change analysis during the last 200 years

4.2.1 Vegetation cover and type on the study area in 2005

Field tracking and a habitat map created through the manual interpretation of aerial photographs gave a general idea of the vegetation cover in the study area in the research period (Fig. 4.2.1a). We transformed the Á-NÉR categories to the Corine Biotops which is well-known in Europe, we found 35 categories (Table 4.2.1 in appendix). We created the Á-NÉR habitat map of active floodplain based on aerial photograph of 2005 and field work in examined region (Boroszló-kert, Foltos-kert) (Fig. 4.2.1b in appendix, Fig. 4.2.1c in appendix). There were 29 habitat categories, in which was also recorded the vegetation, in the research period. In marshes and backwaters there were six categories recorded which formed large mosaics. One of these was the standing water vegetation with *Trapa natans*, *Lemna spp.*, *Salvinia natans* and *Ceratophyllum spp.* (A1). Another category was floating vegetation of *Utricularia spp.* and *Stratiotes sp.* (A2). Furthermore, it could be found submersed or emergent rooted pioneer plant communities with *Potamogeton spp.* and *Nymphoides sp.* (A3). *Thypha angustifolia*, *T. latifolia* and *Schoenoplectus lacustris* made up the marshy vegetation with some *Phragmites australis* (B1). In addition, large assemblages were recorded of *Glyceria maxima* and *Sparganium erectum* (B2). Moreover, the water-fringing helophyte assemblages (B3) were characterized by *Eleocharis palustris*, *Alisma plantago-aquatica*, *Butomus umbellatus* and *Sagittaria sagittifolia*. The open water surface could be classified into two categories: running water (U8) and standing water (U9). Near the semi-natural water could be found uncharacteristic marshes (O1) caused by human activity.

The open but higher terrain was characterized as mesotrophic meadows (D4) and tall herb meadows (D5). In addition, the categories of ruderal and semi-ruderal

vegetation on floodplain and marshes (O3, O4) also occurred in the area as semi-natural vegetation on dikes (O10) and semi-natural grasslands on fallow (O11). Forested and shrubby areas were separated into eight categories. These were the following: riverine willow scrub (J3), riverine willow-poplar woodland (J4), riverine oak-elm-ash woodland (J6), forest with non-native wood, shrubby grassland level (R2), locust tree plantations (S1), poplar plantations (S2), non-native forests and shrubs (S6), and tree lines, hedges and small woodlots (S7). The natural, semi-natural categories of forests and shrubs were characterized by *Populus alba*, few *P. nigra*, *Salix spp.*, some *Alnus glutinosa*, *Fraxinus spp.*, *Quercus spp.*, *Ulmus spp.* and *Cornus sanguinea*, *Sambucus nigra*, *S. ebulus* etc. Besides this the non-native and planted species were the *Robinia pseudo-acacia*, *Populus spp.* and *Acer negundo* etc. Spontaneously afforested lands (P2) could also find. Furthermore, the following economic areas or areas with intensive human activities also occurred in the area: arable land (T1, T2 (forage plantation)), large orchards (T7), small orchards (T8), abandoned orchards (O12), and dirt road vegetation (O13).



Legend

 A2-A3-B2	 B2-B3	 O10	 T1
 A3	 B3	 O4	 T2
 B1	 D4	 R2	
 B1-B2	 J3	 S1	
 B2	 J4	 U9	

Fig. 4.2.1a. A section of the vegetation types map in accordance with Á-NÉR on the study area. Notations: A2 - Floating vegetation of *Utricularia* spp. and *Stratiotes* sp., A3 - Submers or emerse rooted pioneer plant communities with *Potamogeton* spp. and *Nymphoides* sp., B1 - Marshy vegetation with *Thypha* spp., *Phragmites* spp., B2 - Assemblages of *Glyceria maxima*, *Sparganium erectum* and *Schoenoplectus lacustris*, B3 - The water-fringing helophyte assemblages, D4 - Mesotrophic meadows, J3 - Riverine willow scrub, J4 - Riverine willow-poplar woodland, O4 - Semiruderal vegetation on floodplain, O10 - Seminatural vegetation on dikes, R2 - Forest with non-native wood, shrubby grassland level, S1 - Locust tree plantations, T1 - Arable lands, T2 - Arable land (forage plantation), U9 - Standing water

Analysing these habitat maps we found that the type and numbers of habitat patches were different in the two neighbouring central region of the study area. In Boroszló-kert were separated 32 different types of habitat so long in Foltos-kert were identified 28 Á-NÉR categories. We calculated the ratios of naturalness of different habitats in 2005. In Boroszló-kert were close-to-nature habitats 39%, agricultural and degraded habitats represent 43%, secondary habitats 14% and economic plantation 4%. Naturalness ratios of the different habitats were in Foltos-kert the follow: close-to-nature habitats 38%, agricultural and degraded habitats 6%,

secondary habitats 33% and economic forests 23%. We established that the poplar plantations and the riverine willow-poplar woodlands had the most extension on the active floodplain. The riverine woodlands were in a bad condition and spread only edge of active floodplain and with many invasive plant species.

4.2.2 Land use change analysis during the last 200 years

The spatio-temporal photo-interpretation revealed the most decisive land cover changes in the neighbouring floodplain areas on the Upper Tisza Region (Fig. 4.2.2). The characteristic land cover of this countryside also changed markedly from the recording of the first military map. The three military maps were produced during the Austrian and Austro-Hungarian Monarchy. The first military map creation began in 18th century, after the time that Hungary had been part of Ottoman Empire (1541-1699). During the period of the second and third military mapping the regulation of rivers and draining of marshes started, but large changes could not yet be observed on this area. In the late 18th century the area of wooded area and grasslands decreased continuously on the floodplain area. The land use types that were mostly responsible for the partitioning of the landscape were arable land, economic plantations and orchards.

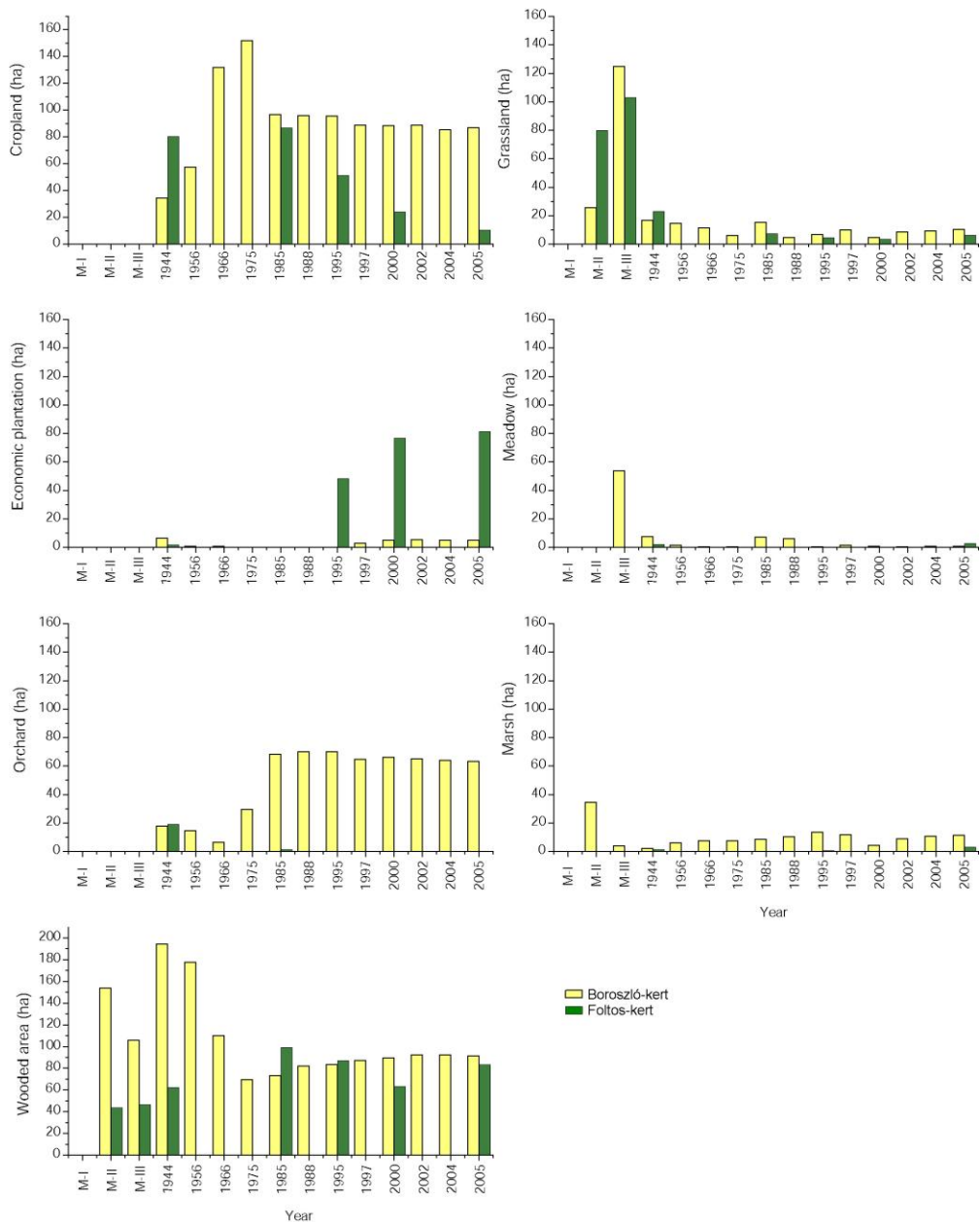


Fig. 4.2.2 Results of the spatio-temporal photo-interpretation of seven important habitat categories, from the 8 (Foltos-kert) and 15 (Boroszló-kert) time point (M-I: 1784, M-II: 1858, M-III: 1884).

4.2.2.1 Land use changes in Boroszló-kert

Gallery forests, grasslands and marshes were common in this region in the 18th century; one backwater and marsh were found there. In the first, second and third military maps no arable land nor were orchards found. There were two marsh areas in the second military map and a larger backwater evolved in these years. This backwater already had no contact with the river by the second part of the 19th century due to river regulation works, except at high water. In these years the gallery forest probably contained typical species of riparian forests (*Populus nigra*, *Populus alba* and *Salix* ssp.) but after the regulation works their species composition degraded more and more and *Robinia pseudo-acacia*, *Acer negundo*, *Solidago gigantea* appeared. In 1944 more than 58% (199 ha) of the area was already covered with gallery forest. Drastic decreases in gallery forest can be identified between 1966 and 1975. The area of woodland was the lowest - 69 ha (21%) - in 1975; forest decreased considerably on this part of the floodplain. Parallel with the decrease of considerable sections of forest, the extension of arable land and orchards increased. In larger area orchards were planted about 1985, because it occurred on the area in this year. Economic plantations (black locust and poplar) were again planted in the area in 1997 (1%, 3 ha). Marshes occupied the largest area at the time of the first and second military maps; after these periods their area fluctuated between 2 and 4% (6-13 ha). The grasslands were also the largest (ca.140 ha, 39%) in the 18th century; after 1884 it decreased considerably (1-5%, 5-16 ha) (Fig. 4.2.2.1a-d in appendix, Table 4.2.2.1a in appendix, Table 4.2.2.1b in appendix).

The landscape structure data for Boroszló-kert shows that the minimum number of land use types was six and the average was above nine (Table 4.2.2.1c). The value of Effective Mesh Size (MESH) showed that this floodplain area was more fragmented after 1956 than before this date. The degree of landscape division (DIVISION) showed the same trend as the mesh size. From results of Nearest-Neighbour Distance it could be established that the distance between grasslands, marshes and meadows changed considerably. The shortest distances between nearest neighbour grasslands occurred in 2005 (NNDist: 7.3 m) and the longest distance was recorded in 1988 (NNDist: 139 m). The areas of these grassland patches decreased after the third military map and fluctuated from 0.02 to 1.12 ha. The marsh habitat type first appeared on the second military map (1858). We observed the longest distance between two marsh patches at this time (NNDist: 1147 m). Following that, the distance of this patch type decreased considerably. Two outstanding values could be found in 1985 and 1997. In case of meadows, the largest value (NNDist: 1136 m) of the nearest neighbour distance was recorded in 1944 and it decreased after 1966 (Table 4.2.2.1d).

Table 4.2.2.1c Landscape subdivision analysis in Boroszló-kert from the first military map to 2005 (PR: Class type number, DIVISION: Degree of landscape division, MESH: Effective Mesh Size)

Boroszló-kert			
Year	PR	DIVISION	MESH
1784	6	0.8642	48.2970
1858	6	0.7860	66.7942
1884	7	0.8789	38.8808
1944	10	0.6201	126.5834
1956	10	0.6788	104.6967
1966	11	0.812	60.7238
1975	10	0.8854	37.4964
1985	10	0.9014	31.445
1988	10	0.8733	41.556
1995	10	0.8712	41.6342
1997	11	0.8777	39.4221
2000	11	0.85	48.4474
2002	11	0.8633	45.114
2004	11	0.885	37.4941
2005	11	0.8687	42.6899

Table 4.2.2.1d The Nearest-Neighbor Distance (NNDist) and the Farthest-Neighbor Distance (FNDist) between separated habitats in Boroszló-kert (NN Area1, NNArea2 the area of the two nearest habitat patch)

Boroszló-kert					
	lccat	NNDist(m)	NN_Area1 (ha)	NN_Area2 (ha)	FNDist(m)
1784	grassland	89.88	43.24	51.67	491.62
	marsh	0	2.58	2.58	0
1858	marsh	1147.2	23.72	10.81	1147.2
1884	grassland	48.09	47.90	16.02	1564.11
	marsh	190.18	1.06	0.49	1169.84
	meadow	146.78	6.20	3.51	1238.89
1944	grassland	45.90	0.24	0.13	1566.32
	marsh	67.55	0.13	0.76	1396.24
	meadow	1135.77	0.66	1.04	1135.77
1956	grassland	104.93	1.12	2.29	1623.22
	marsh	79.36	0.89	0.81	1263.86
	meadow	1037.39	0.59	0.97	1037.39
1966	grassland	28.09	0.63	2.78	1498.72
	marsh	86.81	0.42	0.74	997.77
	meadow	103.78	0.06	0.27	103.78
1975	grassland	24.14	0.09	1.78	1399.67
	marsh	5.22	0.06	1.02	1101.46
	meadow	7.76	0.03	0.19	156.55
1985	grassland	18.75	0.12	0.33	2141.45
	marsh	35.92	1.11	0.18	1499.62
	meadow	16.67	0.61	0.11	1297.69
1988	grassland	139.02	0.60	0.68	1646.86
	marsh	11.78	0.38	0.69	1493.08
	meadow	295.48	5.39	0.37	958.96
1995	grassland	6.39	0.22	0.70	1904.16
	marsh	9.73	0.79	1.24	1367.6
	meadow	533.07	0.07	0.06	742.7
1997	grassland	5.82	0.09	1.06	1883.45
	marsh	40.22	0.08	0.51	1152.83
	meadow	335.77	0.45	0.92	962.2
2000	grassland	21.64	0.07	0.07	1665.84
	marsh	13.70	0.04	0.05	1445.54
	meadow	6.57	0.02	0.04	1073.36
2002	grassland	21.51	0.14	0.75	1878.28
	marsh	16.46	0.05	0.77	1293.34
	meadow	36.01	0.03	0.12	878.97
2004	grassland	13.64	0.94	1.00	1837.71
	marsh	9.67	0.70	0.10	1447.45
	meadow	119.09	0.03	0.18	1067.39
2005	grassland	7.29	0.02	0.10	1839.35
	marsh	15.30	0.07	1.82	1380.8
	meadow	8.34	0.03	0.05	1109.31

4.2.2.2 Land use changes in Foltos-kert

There were no arable lands and orchards on the first three military maps. Woodlands, grasslands and marshes were also frequent along the river on the active floodplain. The backwater had not appeared on the third military map yet. In 1944 more than 34% (80 ha) of the active floodplain was already agricultural land but this later decreased to 4% (11 ha). At this time 26% (63 ha) of the area was covered with gallery forest, the wooded area had the lowest coverage at this time, in the 19th century and in 2000 (27%, 64 ha). Orchards (plum) were not characteristic on this part of the floodplain area. We found 8% (12 ha) from that in 1944 which decreased to 0.07% (0.17 ha) by 2005. On the other hand economic plantations (black locust and poplar) developed considerably by 1995 and remained characteristic of the appearance of Foltos-kert (35%, 81 ha) until 2005. The middle region of the backwater silted up, resulting in the division of the backwater into two parts. In 2000 the silted part of the backwater was dredged. The marsh area of Foltos-kert was not extended, so it depended on the water content of the backwater, because marshy areas were mainly found at both ends (0.2-1%, 0.5-3 ha). The largest area of grassland was registered in the 19th century; after 1884 this decreased considerably, the greatest extent was 48% (larger than 80 ha) and the lowest was 2%, 4 ha in 2000 (Fig. 4.2.2.2a-c in appendix, Table 4.2.2.2a in appendix, Table 4.2.2.2b in appendix).

The landscape structure data shows that the minimum number of land use types was four and the average was above seven in this part of our study area (Table 4.2.2.2c). In this case the value of Effective Mesh Size and DIVISION showed that the area was maximally fragmented in 1944 and 2000. Fragmentation was similar on the first and second military maps and in 1985. In the case of this floodplain area, we could also establish from the Nearest-Neighbour Distance results that the distance changed considerably between grasslands, marshes and meadows (Table 4.2.2.2d). The Nearest-Neighbour Distance of the grassland was the longest (NNDist: 109 m) on the first military map and it was the shortest (NNDist: 9 m) in 2005. The distance between marsh patches was the shortest in 1944 and also in 2005, NNDist: 8.7 m and 5.5 m. Furthermore, only in these years (in 1944 and 2005) could we find two meadow patches whose distances were similar (NNDist: 1100 m and 1030 m).

Table 4.2.2.2c Landscape subdivision analysis in Foltos-kert from the first military map to 2005 (PR: Class type number, DIVISION: Degree of landscape division, MESH: Effective Mesh Size)

Foltos-kert			
Year	PR	DIVISION	MESH
1784	4	0.6410	52.8056
1858	4	0.6568	59.7250
1884	4	0.8179	38.9381
1944	10	0.9148	20.316
1985	7	0.715	66.3462
1995	9	0.8006	46.9919
2000	10	0.9252	17.5881
2005	10	0.8241	41.4476

Table 4.2.2.2d The Nearest-Neighbor Distance (NNDist) and the Farthest-Neighbor Distance (FNDist) between separated habitats in Foltos-kert (NN Area1, NNArea2 the area of the two nearest habitat patch)

Foltos-kert					
	lccat	NNDist(m)	NN_Area1(ha)	NN_Area2(ha)	FNDist(m)
1784	grassland	108.67	11.94	1.39	108.67
1858	grassland	0	80.16	80.16	0
1884	grassland	17.67	13.13	6.83	2103.137
1944	grassland	52.98	15.24	1.96	1446.33
	marsh	8.64	0.27	0.27	1137.1
	meadow	890.76	1.81	0.39	890.76
1985	grassland	71.56	1.31	1.60	1911.67
1995	grassland	10.08	0.11	0.38	1250.12
	marsh	1100.45	0.38	0.40	1100.45
2000	grassland	48.12	0.60	0.83	2044.77
	marsh	414.73	0.26	0.22	414.73
2005	grassland	9.07	0.05	0.58	2189.98
	marsh	5.52	0.06	0.38	1085.94
	meadow	1030.39	2.73	0.06	1030.39

4.2.3 Discussion of land use change analysis

Our results show that the Upper-Tisza region was mainly exploited under traditional agricultural systems with meadows, orchards and some cereal cultivation. Moreover, the characteristic land use of this countryside has changed greatly during the last 200

years. In Boroszló-kert a drastic decrease in wooded areas was identified between 1966 and 1975. Considerable forest shrinkage was caused by intensified agricultural land use and the agricultural policy of the 1960's, which favoured clear-cutting of forest to increase cultivation areas. In 1997 economic plantations (black locust and poplar) were created once again on this part of the floodplain for the first time since 1966 but this was not such a large-scale development compared to Foltos-kert. In Foltos-kert, croplands and orchards decreased across the time period under consideration and Foltos-kert comprised the majority of economic plantations on this part of the active floodplain. Our study showed that the structure and distance between the habitats of the floodplains changed with great intensity. Furthermore, human activities and floods played a great role in the changes, because in drier years the agricultural areas were larger and in wet years the semi natural habitats were closer. Analysing the habitat maps of 2005 we found that the ratios of naturalness of habitats were different in the two neighbouring central region of the study area, it came from economic using of the areas.

The periods of political and economic development left their imprints on the socio-economic characteristics as well as the land use structure (Kohlheb and Krausmann 2009). The floodplains and also those landscapes in Hungary involved in the industrialization of agriculture during the socialist regime are undergoing major changes due to the political and economic changes, a phenomenon which also supports our results. After the collapse of the socialist regime (1989) the landowners could claim back their original property. In this way large parcels of cooperatives and state farms were split up, resulting in a relatively fragmented land ownership (van Dijk and Kopeva 2006). The unclaimed land was abandoned or converted to extensive rangeland or to forest (Van Dessel et al. 2009).

In 2004 Hungary joined the European Union and this provoked an increase in agricultural competition as a catalyst for future land cover changes (Verburg et al. 2006a). Using the flood pulse dynamics and effects on the regulated river floodplain and river margin and the protection of traditional land use and land cover around holiday resorts and agro-tourism farmsteads it was possible to protect habitats successfully. Nowadays these processes are encouraged and they are a developing trend.

The 200 years of history studied here contribute to a more careful and wiser management use the region (backwater-fishing, angling, field-grazing or mowing). Our study has demonstrated general trends in land use over 200 years and how the dynamics of land use have changed the floodplain landscape. The historical information from the 18th and the 19th century cannot be taken as a reference for the future; however, it could be used to evaluate the area's current ecological state, and thus to determine an optimal management of the regions in the future. Previous research has provided a definite answer that most species can be protected by

keeping habitats together successfully. This makes it possible to follow land cover changes in the past, and support decision making in landscape planning and biological conservation management (Gutzwiller 2002; Lambeck and Hobbs 2002; Metzger et al. 2006; Gingrich et al. 2012).

4.3 Predictive power of environmental factors for ground beetle assemblages in floodplain grasslands

A total of 122 carabid species were detected the three floodplain areas. More than 70% belonged only to 13 species. The most frequent species were *Carabus granulatus*, *Clivina fossor*, *Pterostich melanarius* and *Agonum micans*, which were characteristic to wetlands and riparian habitats. *Poecilus versicolor* and *Poecilus cupreus* were also frequent in open and dry habitats.

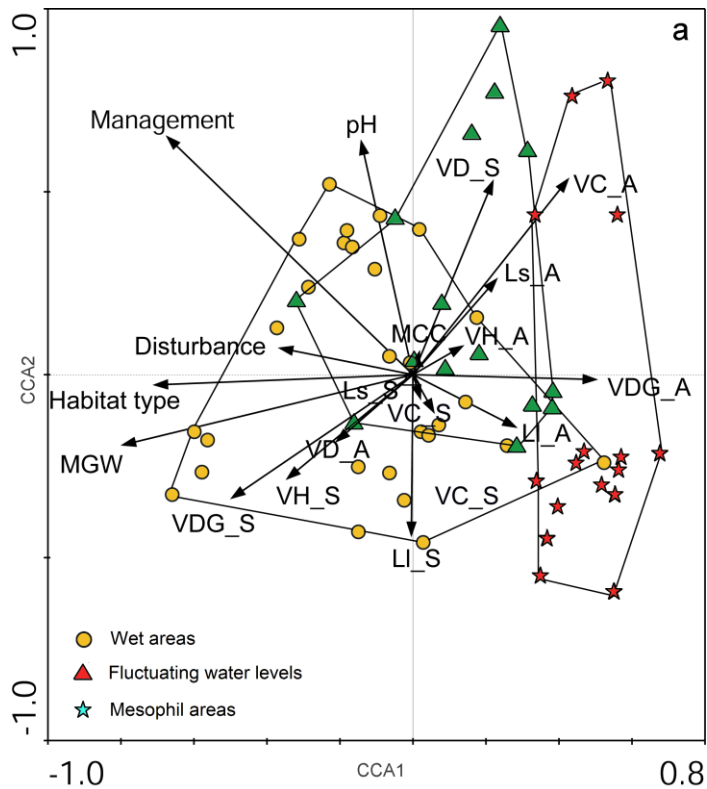
4.3.1 Results of statistical analysis

After variable selection (Table 3.2.3.3) we analysed the remaining predictor variables with canonical correspondence analysis. The CCA suggested that eight variables affected the composition of carabid species: mean groundwater level, management, pH, habitat types, and vegetation cover in the autumn and vegetation density, density at ground level and height in the spring (Fig. 4.3.1a-b). These variables explained 57.75% of the variance of ground beetle composition.

The first four axes together explained 39.43% of the variation. The first axis explained 18.67% of the variation (Fig. 4.3.1a-b) and the second axis explained 9% of the variation of carabid composition. The first axis negatively related to mean groundwater level and habitat type, management and also disturbance. Vegetation density at 3 cm in the spring, vegetation density in the autumn and vegetation height in the spring also showed negative correlations with the first axis, whereas vegetation height in the autumn and vegetation density at 3 cm in the autumn had a positive effect (Fig. 4.3.1a). Furthermore, pH, vegetation cover in the autumn, and vegetation density in the spring had a large positive correlation with the second axis. In contrast, vegetation cover in the spring pointed in an opposite direction with the vegetation cover in autumn. Leaf-longevity in the spring showed a negative correlation with the second axis; in addition, leaf longevity in the autumn had a positive correlation with the first axis. Finally, leaf shape in the autumn had a positive correlation with the second axis, as far as in the spring pointed in a direction opposite from that (Fig. 4.3.1a-b).

We also analysed data from the 13 most abundant species, which occurred in large numbers at the three study sites (Fig. 4.3.1b). The first CCA axis differentiated mainly wetter conditions from drier conditions and stronger land use context from

lower land use context. In addition, these show an opposite gradient of vegetation density at 3 cm. Along this axis associated species with wet areas, e.g. *Bembidion dentellum*, *Bembidion biguttatum*, *A. micans* and *Agonum emarginatum* were opposite to species associated with drier areas such as *P. melanarius*, *P. versicolor*. This axis represented species that preferred dense vegetation at 3 cm and large vegetation cover in autumn (*P. melanarius*, *P. versicolor*) (Fig. 4.3.1b). The second CCA axis differentiated the higher from the lower soil pH and also differentiated the stronger from lower vegetation density in spring, which had an opposite gradient with leaf longevity. *Pseudoophonus rufipes*, *P. melanarius*, *Bembidion guttula*, *P. cupreus* preferred the higher pH and stronger vegetation density in spring. Species opposite to these were *B. dentellum*, *P. versicolor* or *Bembidion gilvipes* (Fig. 4.3.1b).



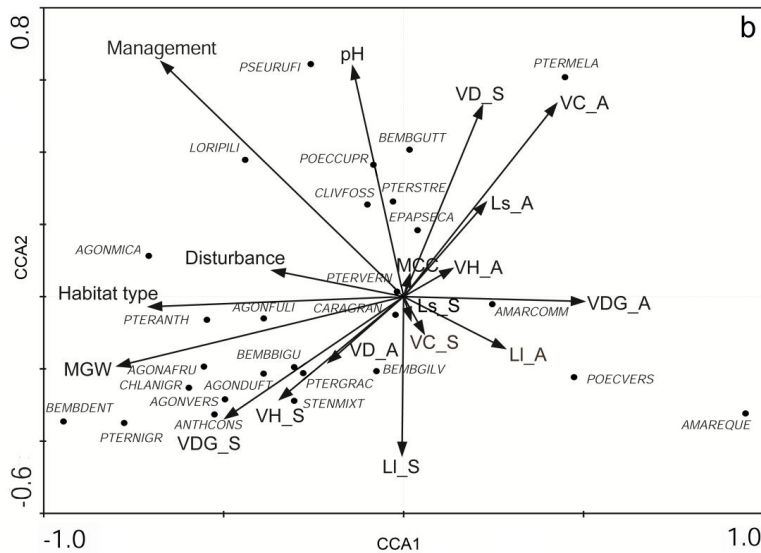


Fig. 4.3.1a-b Biplot by Canonical correspondence analysis of environmental factors and carabid species. The length of the arrow represents the strength of the correlation with the ordination axes. (a) Dots show the sample points with different habitat types.

(MGW=mean groundwater level, MCC=mean clay content, VH_S=vegetation height in the spring, VH_A=vegetation height in the autumn, VD_S=vegetation density in the spring, VD_A=vegetation density in the autumn, VDG_S=vegetation density at the ground in the spring, VDG_A=vegetation density in the autumn, VC_S=vegetation cover in the spring, VC_A=vegetation cover in the autumn, LI_S=leaf longevity in the spring, LI_A=leaf longevity in the autumn, Bf_S=leaf shape in the spring, Bf_A=leaf shape in the autumn, Mgt=management, Dist=disturbance). (b) Carabid species names are 4-letter abbreviations of the genus and species name.

The CCA results suggested that habitat types differed considerably in species composition. Mesophilous grasslands separated well from the areas with fluctuating water levels and from wet areas (Fig. 4.3.1a). The results of seasonal dissociation (variables in spring and autumn) showed negligible differences from the CCA of the total variable set.

We carried out variation partitioning analysis separately and in combination of the three sets of predictor variables (vegetation, abiotic environment including water and soil, and land use). The results show that vegetation structure, environmental variables and land use explained different parts of ground beetle composition (Fig. 4.3.1c). Land use had a considerably higher percent of explanatory power than vegetation structure and environmental variables. Land use variables had a strong effect on carabid species composition, because they explained 17% of the ground beetle data variation. The set of vegetation structure variables alone explained only 3% of the variation in species composition, while the environmental variables alone (set 2) explained only 1%. However, when the variables of vegetation structure were combined with land use variables (set 3), then they explained 9% of the variation.

The combination of the three variable sets explained 8% of the variation in species composition. The marginal effect was in combination of the three variable sets 49%. In addition, we also repeated the analysis within each of the three sets of predictor variables. Combining the single variables did not increase the predictive power of the variable set. Management and habitat type had a stronger effect on carabid species composition than disturbance (Fig. 4.3.1c). Vegetation structure explained 10% altogether. The vegetation architecture besides the vegetation compactness had a stronger effect on carabids. Within vegetation architecture, vegetation cover and leaf longevity had similar effects on ground beetles, whereas leaf shape explained a smaller percentage of the variation. Moreover, within vegetation compactness, vegetation density had the strongest effect on ground beetle species composition, whereas vegetation height explained only 5% alone and 7% in combination with vegetation density (Fig. 4.3.1c).

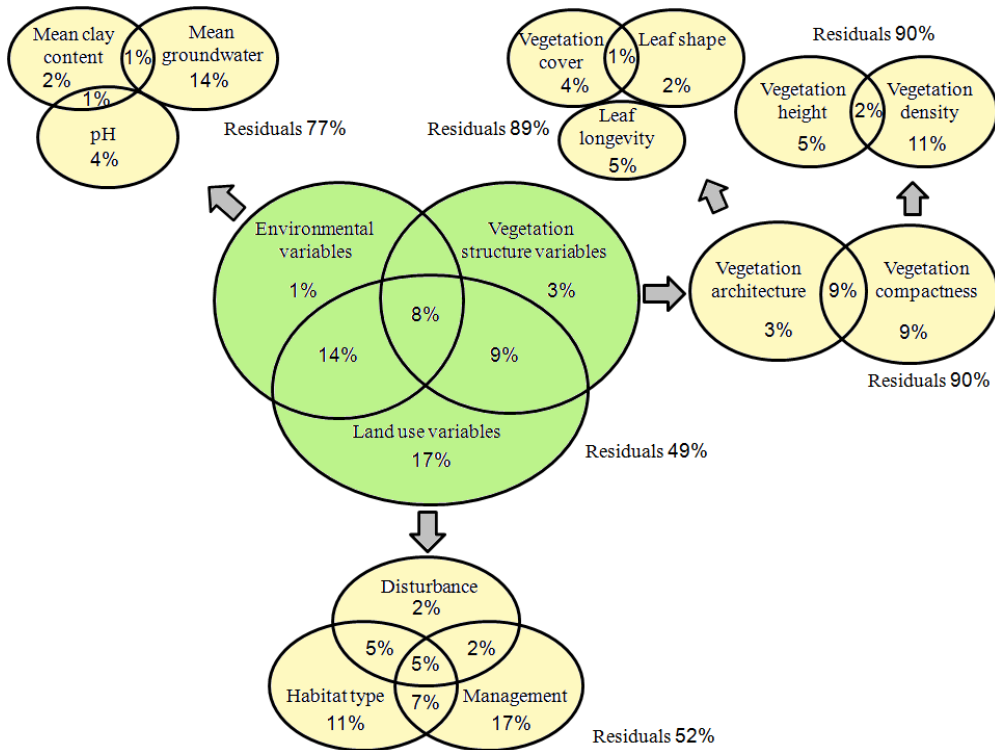


Fig. 4.3.1c Synthetic model of amount of variance between environmental variables and carabid beetle assemblages, based on variation partitioning analysis. (In the middle combination of the three sets, around separately the members of sets)

4.3.2 Discussion of analysis of environmental factors effect on ground beetles assemblages in floodplain grasslands

We identified eight factors that greatly influence the species composition of carabid assemblages in Elbe floodplains and variation partitioning allowed us to establish a hierarchy of explanatory variables based on their influence. In order of decreasing importance, these were land use variables, environmental variables and vegetation structure variables. The environmental variables and vegetation structure showed more negligible effects than landscape variables, although they were identified by CCA as explanatory factors of carabid species composition. Strong correlations were detected between several aspects of vegetation structure and species composition of carabid assemblages.

Variation partitioning analysis showed that the explanatory power of vegetation density was higher than explanatory power of leaf longevity and leaf shape, but that their combination already showed a relatively higher percent. These results suggested that vegetation architecture (leaf shape and longevity) is an important factor when its effect is not separated from vegetation density. The physical complexity of the vegetation (density, height) may thus more directly affect carabid species composition than may the longevity and shape of the leaves of the constituent plant species. The finding that the explanatory power of vegetation architecture (leaf longevity and leaf shape) was low separately but high when it was combined with other sets of predictor variables, indicates that vegetation architecture may have important secondary (interactive or synergistic) effects in combination with other variables. Vegetation density was as important as the height of vegetation, which was a relevant finding considering that many studies used vegetation height as a proxy for vegetation structure, because some species prefer the open and drier ground conditions while others are more strongly associated with shady, vegetated ground conditions (e.g. Gardner 1997, Jukes et al 2001). More over our results suggest that the vegetation density from the vegetation structure variable set was the most important determinant of carabid beetle species composition and that this effect is also relevant in the spring and autumn. These results support the hypothesis that dense vegetation may provide more microsites available for hunting, for the preparation for the egg-laying or for the overwintering of carabid beetles (Epsteins and Kulman 1990; Brose 2003).

Our study provides an insight into the relative importance of different sets of predictor variables (vegetation structure, environmental variables and land use) and their interrelationships with carabid beetles. Our results suggest that land use and environmental variables have a main role shaping carabid assemblages on the Elbe floodplain (Fig. 4.3.1a-b). Irmeler (2003) also reported that the most important factors for carabid species were environmental variables (water and sand content) in grassland sites in the valley of the River Eider. These two factors, in combination with other environmental factors such as soil moisture, soil type and land use projected the pattern of ground beetles. In contrast, our study showed that soil

properties may be less important for ground beetle composition in floodplain grassland than management type, hydrology and vegetation structure.

These findings correspond to those of many other studies that found an overwhelming effect of vegetation structure in determining carabid assemblages (McCoy and Bell 1991, Holmes et al. 1993, McFerran et al. 1994). Vegetation structure determines microclimatic conditions and therefore it is likely to be one of the most important factors determining the distribution of ground beetle assemblages (Magura et al. 2000; Burel 1989). It was previously established that vegetation structure changes the efficiency of different hunting strategies and the vulnerability of prey species (Provencher and Vickery 1988). For instance, large predators may be more efficient in sparse vegetation or vegetation dominated by wide leaves while prey species have more chance of escaping from natural enemies in dense vegetation or under narrower leaves (Morse 1980; Heck and Crowder 1991; Price et al 1980).

Floodplains are fundamentally affected by groundwater fluctuations and that hydrological conditions and vegetation structure affect carabids at different spatial and temporal scales. At large scales, land use and environmental variables may be important, which are expected to vary more in the case of geographically more distant sites as to closer sites. At finer scales, e.g. at the habitat level, vegetation structure and density may be more relevant, whereas at the microscale, i.e., the scale of perception of carabid beetle individuals, plant traits such as leaf shape and longevity may be important.

5 Conclusions of studies

The selections of data and methods are generally determined by different factors: the mapping objective, the cost of images, climate conditions and technical issues regarding image interpretation, environmental factors (Paine and Kiser 2012; Schott 2007; Xie et al. 2008). It was found that the success of vegetation cover detection from imagery depends on the success of the image pre-processing and the classification procedures, regardless of the techniques used. Sensors have different spatial, temporal, spectral and radiometric characteristics. Moreover, the selection of appropriate images is very important for mapping vegetation cover and land cover (Langley et al. 2001; Pohl and Van Genderen 1998). Nevertheless, this is an important element in long-term time series research which needs to analyse archive images and to extract information from vegetation, in cases where field work is not possible. The use of ancillary data may be helpful (e.g. maps, field observations) and more than one aerial photograph could also improve the classification accuracy.

Our findings suggest that correctly rectified old maps can be useful in revealing the direction of land-cover changes. Although historical maps can clearly determine land use types this does not enable accurate conclusions about different types of

grasslands or plant associations. The land use changed considerably on our study area in Upper-Tisza Region during the last 200 years. However land cover of Boroszló-kert and Foltos-kert developed different ways over the years. Boroszló-kert was used for agricultural and Foltos-kert for economic plantation (forestry). The fragmentation increased more in Boroszló-kert as Foltos-kert. We concluded that the data obtained from monitoring land cover and land use changes could reflect habitat types on a rough scale in historical time. Historical studies of floodplains could be useful for the ecological assessment of these areas for large European rivers. Monitoring and survey of floodplains may help to achieve the objectives of European-wide large projects such as the European Water Framework Directive, Natura 2000, and the Ramsar Convention. Furthermore, it could help to reconstruct processes, rehabilitation plans and better land-use scenarios or landscape planning by documenting of effects on habitat of floodplain.

Floods may affect large areas and to different degrees according to the duration and height of the flood, influencing the level of groundwater, the properties of vegetation structure. Their effect may become more important at smaller scales. Investigated the relative effect of environmental factors on floodplain carabid assemblages land use was proved as the most important one, followed by environmental variables (hydrological conditions) and by vegetation structure, in shaping the composition of floodplain carabid assemblages. The relatively large role of hydrological conditions is not surprising considering the regular flooding and the related fluctuations of the groundwater level close to the river in alluvial ecosystems. Our study provides novel insights into the mechanistic level of the relationships between vegetation structure and carabid species composition by demonstrating that the density of vegetation and the longevity and shape of leaves of plant species constituting the habitat can directly influence carabid species composition. The present study show that species composition of plant communities may be deserve more attention in future work on carabid beetles composition. The main conservation implication of our results is that the floodplain areas need to promote a connected network of permanent landscape elements at the landscape scale. Nevertheless it should also focus on increasing the fine-scale diversity of vegetation structure and consider the temporal availability of different structural elements to efficiently protect floodplain biodiversity hotspots. Our studies provide that investigation of land use, land cover changes and management have great importance, since they are determinant for the local fauna. Monitoring of floodplain could help to reconstruct processes, rehabilitation plans and better land-use scenarios or landscape planning by documenting of effects on habitat of floodplain (woodland, backwaters, field, marsh and navy pits along dam).

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Appendix

Table 4.1.1c. Results of image classification technique in percent of surface area. Matching of various land cover classes identification by comparison of different reclassified images. Notations: MVM - manual vectorized map; C - cropland, F - wooded area, MA - marsh, ME – meadow, W – water

Misidentified	03.06.2000	03.06.2000	03.06.2000	22.08.2000	22.08.2000	22.08.2000	22.08.2000+	22.08.2000	
	+SRTM	vs.	vs.	+SRTM	vs.	vs.	SRTM vs.	vs.	
	vs. MVM	MVM	03.06.2000	vs. MVM	MVM	22.08.2000	03.06.2000+	03.06.2000	
Lclass1 as Lclass2			+SRTM			+SRTM	SRTM		
ME	ME	71.43	84.72	91.67	48.17	45.51	87.08	80.95	86.11
ME	W	2.38	1.39	0.00	0.61	0.56	0.00	1.19	0.00
ME	F	7.14	6.94	6.94	9.15	10.67	3.93	4.76	8.33
ME	C	17.86	5.56	1.39	38.41	39.89	8.99	11.90	5.56
ME	Ma	1.19	1.39	0.00	3.66	3.37	0.00	1.19	0.00
W	ME	1.20	0.85	0.00	0.00	0.00	0.00	0.40	0.00
W	W	81.12	82.20	97.88	83.68	86.64	91.81	82.73	83.05
W	F	12.45	12.29	0.85	9.62	9.05	0.00	3.21	5.08
W	C	1.20	0.42	0.00	1.67	0.43	0.43	5.22	7.63
W	MA	4.02	4.24	1.27	5.02	3.88	7.76	8.43	4.24
F	ME	7.76	7.66	1.69	4.24	5.29	0.22	7.35	8.56
F	W	1.43	1.89	0.30	1.24	1.73	0.76	0.61	0.50
F	F	75.82	74.73	91.74	77.87	80.78	88.44	77.24	73.43
F	C	10.92	11.94	2.89	12.41	8.53	8.86	12.24	16.52
F	MA	4.08	3.78	3.38	4.24	3.67	1.73	2.55	1.00
C	ME	2.67	2.71	0.06	3.86	3.20	0.36	1.28	1.81
C	W	1.46	1.32	0.00	1.56	1.78	0.59	0.49	0.42
C	F	11.48	12.28	2.59	11.58	12.74	8.23	9.29	8.55
C	C	81.91	81.22	96.99	80.45	79.38	89.16	87.31	88.62
C	MA	2.49	2.47	0.36	2.55	2.90	1.66	1.64	0.60
MA	ME	3.74	2.15	0.00	5.49	6.98	2.33	1.87	0.00
MA	W	16.82	25.81	0.04	24.18	27.91	20.93	16.82	25.81
MA	F	44.86	30.11	0.02	43.96	32.56	4.65	42.06	30.11
MA	C	22.43	25.81	0.01	20.88	16.28	4.65	23.36	30.11
MA	MA	12.15	16.13	0.15	5.49	16.28	67.44	15.89	13.98

Table 4.2.1. Simplified habitat categories and their potential Corine Biotops categories and Hungarian National Habitat Classification System.

Categories	Corine Biotops	A-NÉR (National Habitat Classification System of Hungary)
Cropland	Field crops (82.11)	Arable land (T1, T2 (forage plantation))
Dam	Ruderal communities (87.2)	Seminatural vegetation on dike (O10), Dirt road vegetation (O13).
Economic plantation	Locust tree plantations (83.324), Poplar plantations (83.321)	Locust tree plantation (S1), Poplar plantation (S2)
Grassland	Eutrophic humid grassland (37.2)	Semiruderal vegetation on floodplain (O4),_Seminatural grassland on fallow (O11).
Marsh	Temporary fresh waterbodies (22.2), Duck weed covers (22.411), Frogbit rafts (22.412), Salvinia covers (22.415), Rooted submerged vegetation (22.42), Rooted floating vegetation (22.43), Shallow-water floating communities (22.432), Common clubrush beds (53.12), Reedmace beds (53.13), Arrowhead communities (53.141), Neglected bur-reed communities (53.142), Erect bur-reed communities (53.143), Sweet flag communities (53.144), Flowering rush communities (53.145), Water dropwort-great yellowress communities (53.146), Water horsetail beds (53.147), Water parsnip communities (53.148), Mareetail beds (53.149), Iris beds (53.14B)	Standing water vegetation with <i>Trapa</i> , <i>Lemna</i> , <i>Salvinia</i> and <i>Ceratophyllum</i> (A1), Floating vegetation of <i>Utricularia spp.</i> and <i>Stratiotes sp.</i> (A2), Submers or emerse rooted pioneer plant communities with <i>Potamogeton spp.</i> and <i>Nymphoides sp.</i> (A3), Marshy vegetation with <i>Thypha spp.</i> , <i>Phragmites spp.</i> (B1), Assemblages of <i>Glyceria maxima</i> , <i>Sparganium erectum</i> and <i>Schoenoplectus lacustris</i> (B2), The water-fringing helophyte assemblages with <i>Butomus</i> , <i>Eleocharis</i> and <i>Alisma</i> (B3)
Meadow	Humid grassland and tall herb communities(37), Pannonic humid meadows (37.263), Lowland hay meadows (38.2)	Mesotrophic meadow (D4), Tall herb meadow (D5)
Orchard	High-stem orchards (83.1), Shrub orchard (83.2), Fallow fields (87.1)	Large orchard (T7), Little orchard (T8), Abandoned orchard (O12)
Other	Ruderal communities (87.2), Lowland tall herb communities(37.1)	Ruderal and semiruderal vegetation on floodplain and marsh (O3)
Backwater	Temporary fresh waterbodies (22.2), Duck weed covers (22.411), Frogbit rafts (22.412), Salvinia covers (22.415), Rooted submerged vegetation (22.42), Rooted floating	Standing water (U9), Standing water vegetation with <i>Trapa</i> , <i>Lemna</i> , <i>Salvinia</i> and <i>Ceratophyllum</i> (A1), Floating vegetation of <i>Utricularia spp.</i> and <i>Stratiotes sp.</i> (A2),

	vegetation (22.43), Shallow-water floating communities (22.432), Common clubrush beds (53.12), Reedmace beds (53.13), Arrowhead communities (53.141), Neglected bur-reed communities (53.142), Erect bur-reed communities (53.143), Sweet flag communities (53.144), Flowering rush communities (53.145), Water dropwort-great yellowress communities (53.146), Water horsetail beds (53.147), Water parsnip communities (53.148), Maretail beds (53.149), Iris beds (53.14B)	Submers or emerse rooted pioneer plant communities with <i>Potamogeton spp.</i> and <i>Nymphoides sp.</i> (A3), Marshy vegetation with <i>Thypha spp.</i> , <i>Phragmites spp.</i> (B1), Assemblages of <i>Glyceria maxima</i> , <i>Sparganium erectum</i> and <i>Schoenoplectus lacustris</i> (B2), The water-fringing helophyte assemblages with <i>Butomus sp.</i> , <i>Eleocharis spp.</i> and <i>Alisma spp.</i> (B3)
River	Running waters (24), (Euhydrophytic river vegetation (24.4), River mud banks (24.5))	Running water (U8)
Wood clearing	Rural mosaics (84.4)	Lands forest with non-native wood, shrub and grassland level (R2)
Wooded area	Lowland, collinar and Mediterraneo-montane willow (44.12), Pannonic willow galleries (44.161), (Ash-alder woods of rivulets and springs (44.31)), Illyrian ash-oak-alder forest (44.431), Pannonic ash-oak-alder forest (44.433), Tree lines (84.1), Small woodlots (84.3)	Riverine willow scrub (J3), Riverine willow-poplar woodland (J4), Riverine oak-elm-ash woodland (J6), Spontaneously afforested (P2) Lands forest with non-native wood, shrub and grassland level (R2)

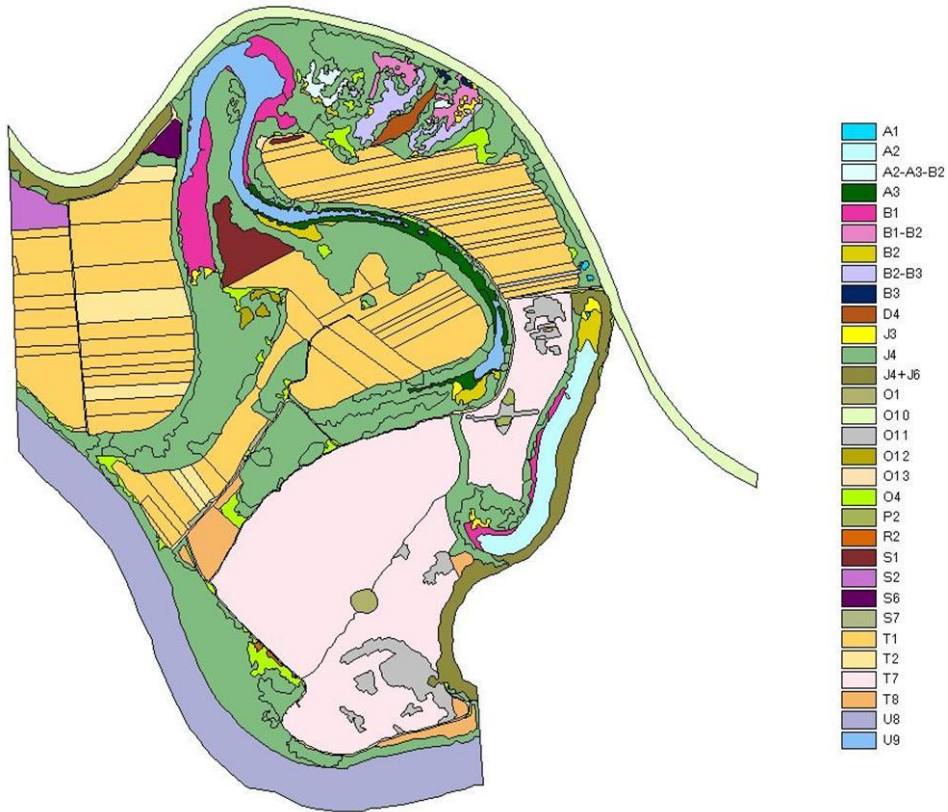


Fig. 4.2.1b. Habitat map of Boroszló-kert according to Á-NÉR classification system.

Notations: *Trapa natans*, *Lemna spp.*, *Salvinia natans* and *Ceratophyllum spp.* (A1); Floating vegetation of *Utricularia spp.* and *Stratiotes sp.* (A2); Submers or emerge rooted pioneer plant communities with *Potamogeton spp.* and *Nymphoides sp.* (A3); *Thypha angustifolia*, *T. latifolia* and *Schoenoplectus lacustris* made up the marshy vegetation with some *Phragmites australis* (B1); Assemblages were recorded of *Glyceria maxima* and *Sparganium erectum* (B2); Water-fringing helophyte assemblages (B3) characterized by *Eleocharis palustris*, *Alisma plantago-aquatica*, *Butomus umbellatus* and *Sagittaria sagittifolia*; Running water (U8); Standing water (U9); Uncharacteristic marshes (O1); Mesotrophic meadows (D4); Tall herb meadows (D5); Ruderal and semi-ruderal vegetation on floodplain and marshes (O3, O4); Semi-natural vegetation on dikes (O10); Semi-natural grasslands on fallow (O11); Riverine willow scrub (J3); Riverine willow-poplar woodland (J4); Riverine oak-elm-ash woodland (J6); Forest with non-native wood, shrubby grassland level (R2); Locust tree plantations (S1); Poplar plantations (S2); Non-native forests and shrubs (S6); Tree lines, hedges and small woodlots (S7); Spontaneously afforested lands (P2); Arable land (T1); Arable - forage plantation land (T2); Large orchards (T7); Small orchards (T8); Abandoned orchards (O12); Dirt road vegetation (O13)

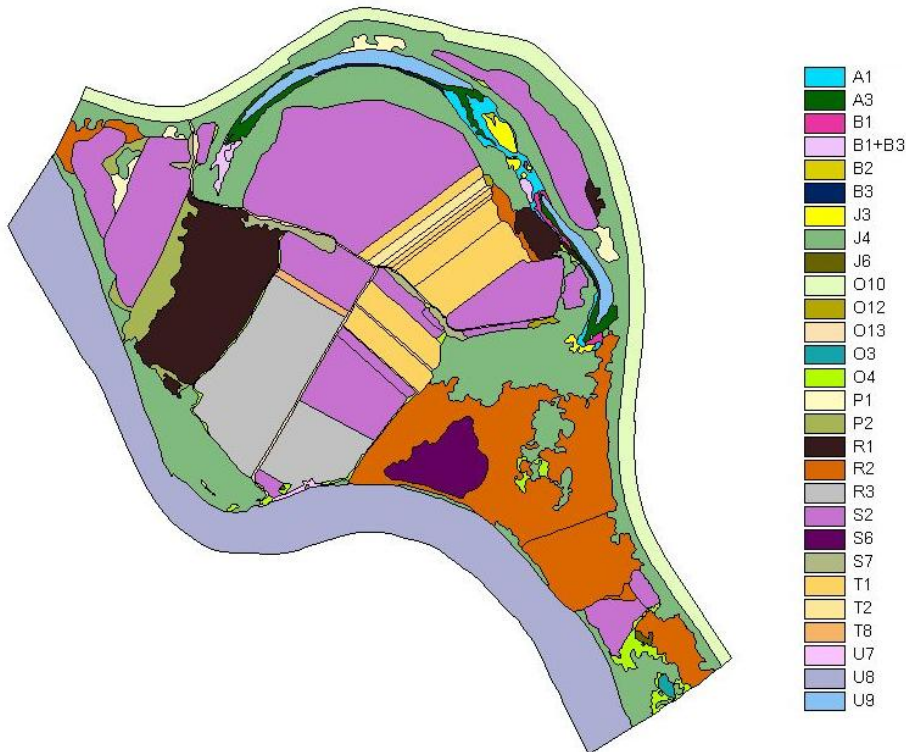


Fig. 4.2.1c. Habitat map of Foltos-kert according to Á-NÉR classification system.

Notations: *Trapa natans*, *Lemna spp.*, *Salvinia natans* and *Ceratophyllum spp.* (A1); Floating vegetation of *Utricularia spp.* and *Stratiotes sp.* (A2); Submers or emerge rooted pioneer plant communities with *Potamogeton spp.* and *Nymphoides sp.* (A3); *Thypha angustifolia*, *T. latifolia* and *Schoenoplectus lacustris* made up the marshy vegetation with some *Phragmites australis* (B1); Assemblages were recorded of *Glyceria maxima* and *Sparganium erectum* (B2); Water-fringing helophyte assemblages (B3) characterized by *Eleocharis palustris*, *Alisma plantago-aquatica*, *Butomus umbellatus* and *Sagittaria sagittifolia*; Running water (U8); Standing water (U9); Uncharacteristic marshes (O1); Mesotrophic meadows (D4); Tall herb meadows (D5); Ruderal and semi-ruderal vegetation on floodplain and marshes (O3, O4); Semi-natural vegetation on dikes (O10); Semi-natural grasslands on fallow (O11); Riverine willow scrub (J3); Riverine willow-poplar woodland (J4); Riverine oak-elm-ash woodland (J6); Forest with non-native wood, shrubby grassland level (R2); Locust tree plantations (S1); Poplar plantations (S2); Non-native forests and shrubs (S6); Tree lines, hedges and small woodlots (S7); Spontaneously afforested lands (P2); Arable land (T1); Arable - forage plantation land (T2); Large orchards (T7); Small orchards (T8); Abandoned orchards (O12); Dirt road vegetation (O13)

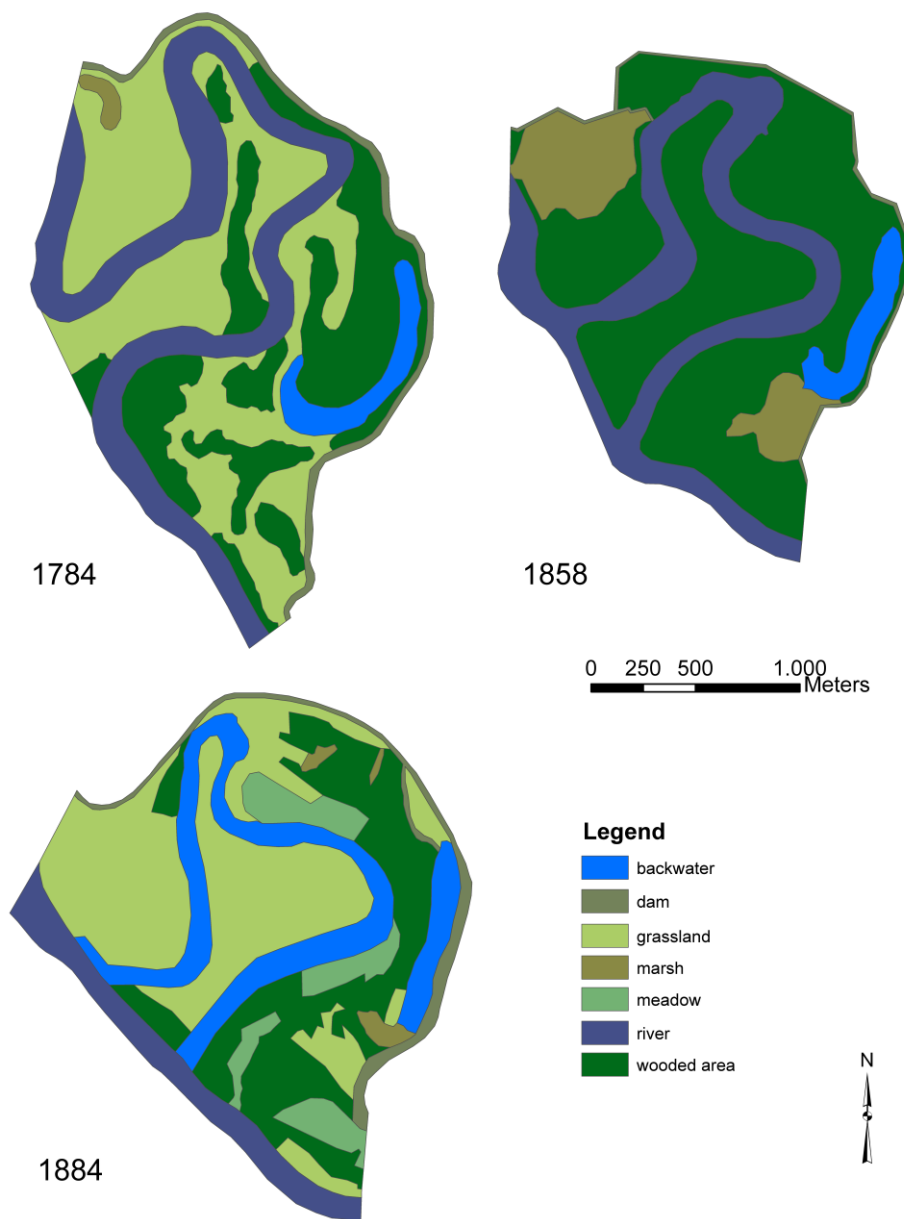


Fig. 4.2.2.1a. Land use changes of Boroszló-kert from the first military map to the third military map.

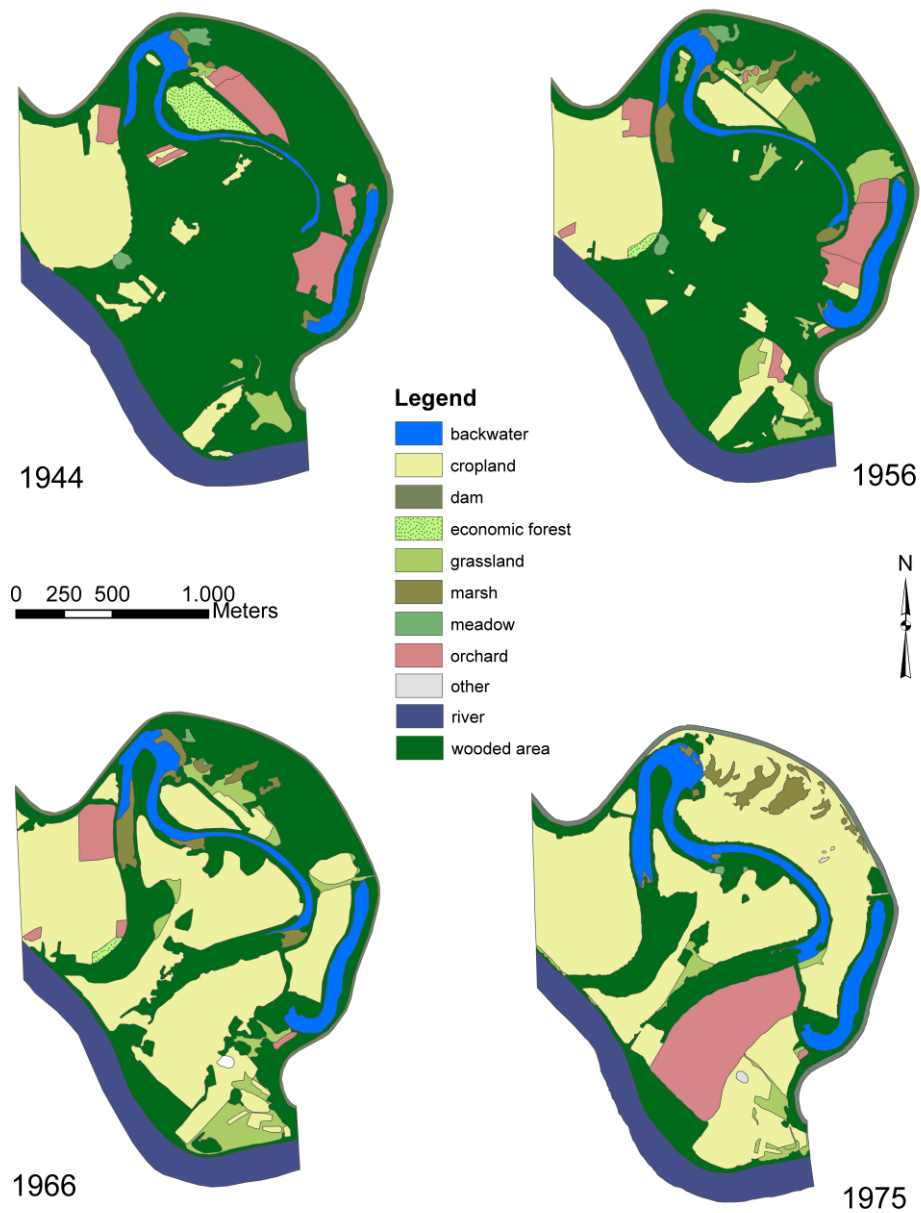


Fig. 4.2.2.1b. Land use changes of Boroszló-kert from 1944 to 1975.

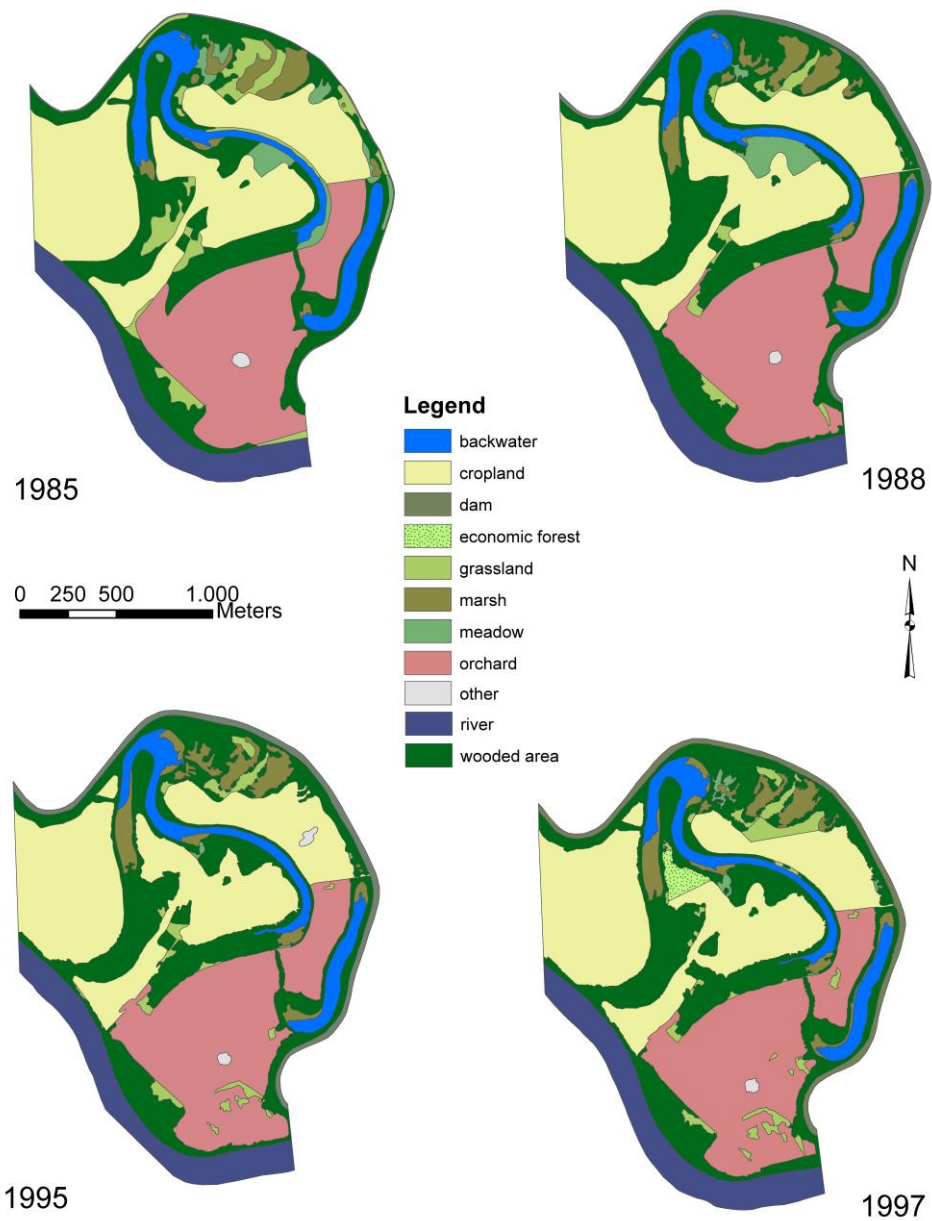


Fig. 4.2.2.1c. Land use changes of Boroszló-kert from 1985 to 1997.

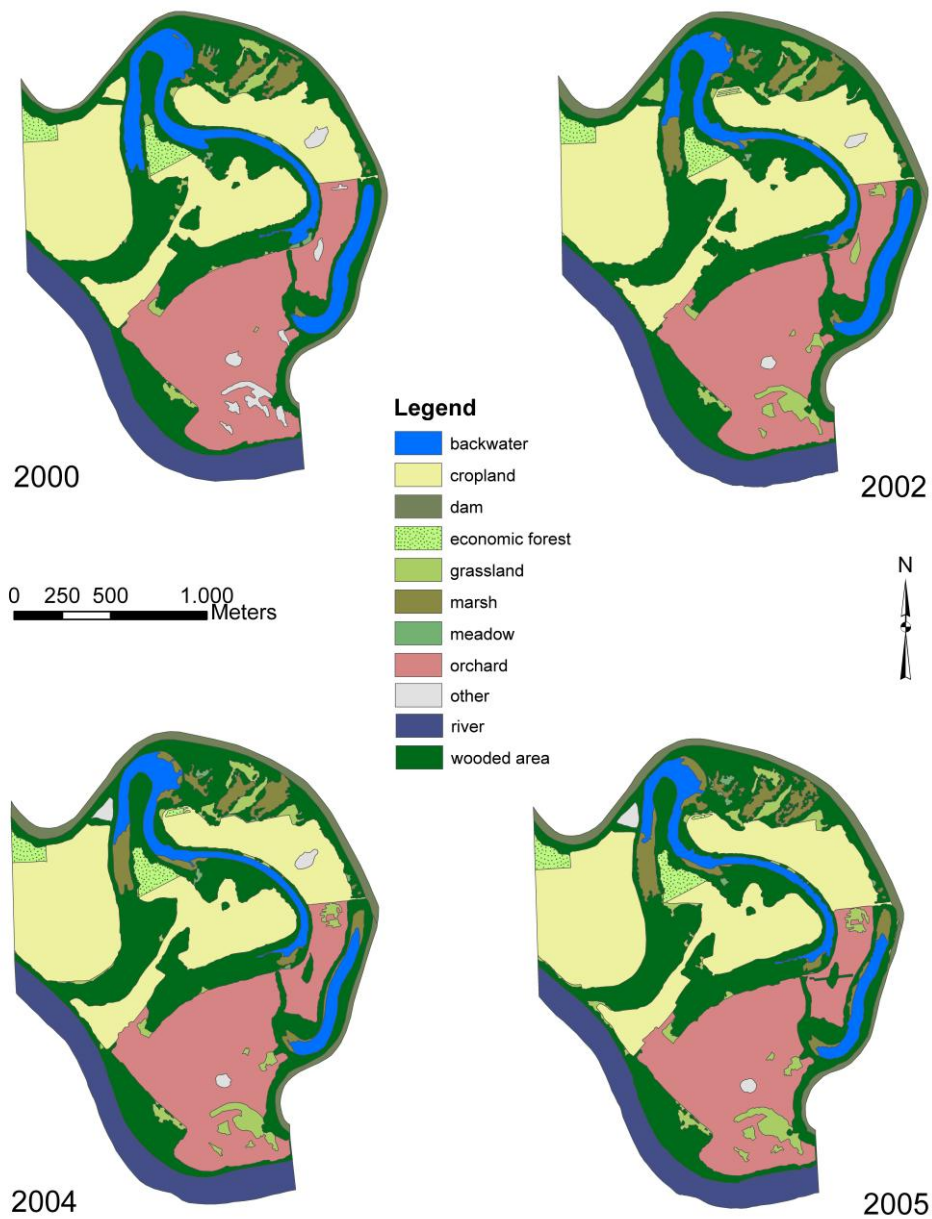


Fig. 4.2.2.1d. Land use changes of Boroszló-kert from 2000 to 2005.

Table 4.2.2.1a. Evolution of land cover categories (lccat) in area percent in Boroszló-kert from the first military map to 2005.

Boroszló-kert lccat	1784	1858	1884	1944	1956	1966	1975	1985	1988	1995	1997	2000	2002	2004	2005
cropland				14	18	41	46	30	29	30	28	27	27	26	27
dam	4	2	5	3	2	2	3	1	3	3	3	3	4	4	4
economic plantation				2	0.3	0.3					1	2	2	2	2
grassland	39	8	38	1	4	4	2	5	1	2	3	1	3	3	3
marsh	1	11	1	1	2	2	2	3	3	4	4	1	3	3	4
meadow			8	2	0.5	0.1	0.1	2	2	0.1	0.5	0.2	0.1	0.2	0.2
orchard				5	4	2	9	21	21	22	20	20	20	20	19
other						0.1	0.1	0.2	0.1	0.3	0.1	1	0.3	1	0.4
backwater	4	4	17	4	5	5	7	6	6	5	5	7	6	5	5
river	25	26	9	9	10	9	9	9	9	8	9	8	8	8	8
woodland	28	57	24	59	54	34	21	23	25	26	27	28	28	28	28

Table 4.2.2.1b. Evolution of land cover categories (lccat) in hectar (ha) in Boroszló-kert from the first military map to 2005.

Boroszló-kert lccat	1784	1858	1884	1944	1956	1966	1975	1985	1988	1995	1997	2000	2002	2004	2005
cropland				48.2	57.4	131.9	151.9	96.5	96.0	95.5	88.7	88.5	88.62	85.5	86.9
dam	13.6	6.1	14.7	9.1	7.7	5.3	9.4	2.1	9.8	10.9	10.6	8.7	14.5	13.7	12.9
economic plantation				6.5	0.8	0.8					2.9	5.1	5.4	5.1	5.1
grassland	140.1		150.5	4.6	14.5	11.4	6.0	15.3	4.7	6.7	9.9	4.6	8.5	9.4	10.5
marsh	2.6	34.5	4.1	2.0	6.1	7.4	7.4	8.7	10.3	13.4	11.7	4.4	8.8	10.7	11.5
meadow				7.3	1.6	0.3	0.3	7.3	5.9	0.4	1.6	0.7	0.3	0.7	0.7
orchard				17.7	14.6	6.4	29.5	68.3	70.2	70.1	64.8	66.1	65.1	63.9	63.4
other						0.4	0.4	0.6	0.4	0.9	0.4	4.3	1.0	1.9	1.4
backwater	14.0	12.4	55.1	13.7	14.9	17.2	23.6	19.8	20.4	16.8	17.0	23.5	18.7	16.2	15.5
river	87.5	81.6	28.1	31.6	31.0	28.8	29.2	27.2	28.0	25.0	27.6	27.4	26.8	26.7	25.9
woodland	97.9	177.5	77.8	198.9	177.4	109.9	69.3	73.3	82.2	83.5	87.2	89.6	92.4	92.3	91.5

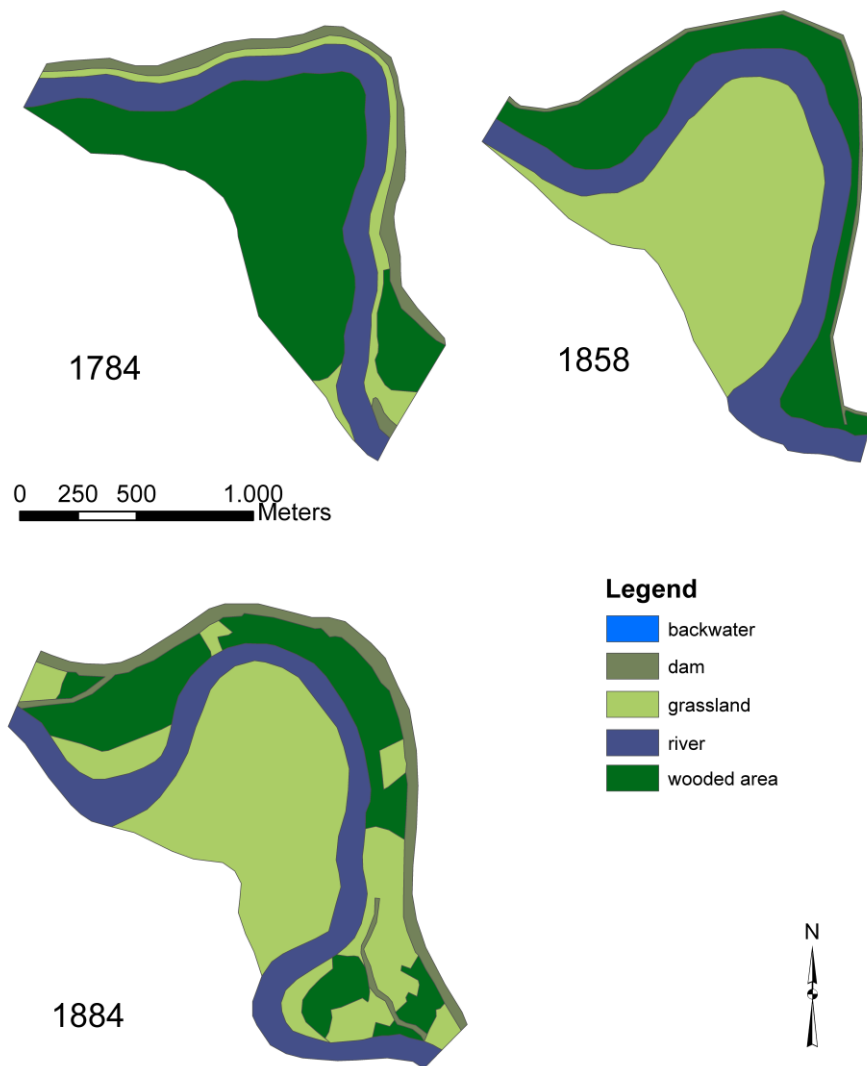


Fig. 4.2.2.2a. Land use changes of Foltos-kert from the first military map to the third military map.

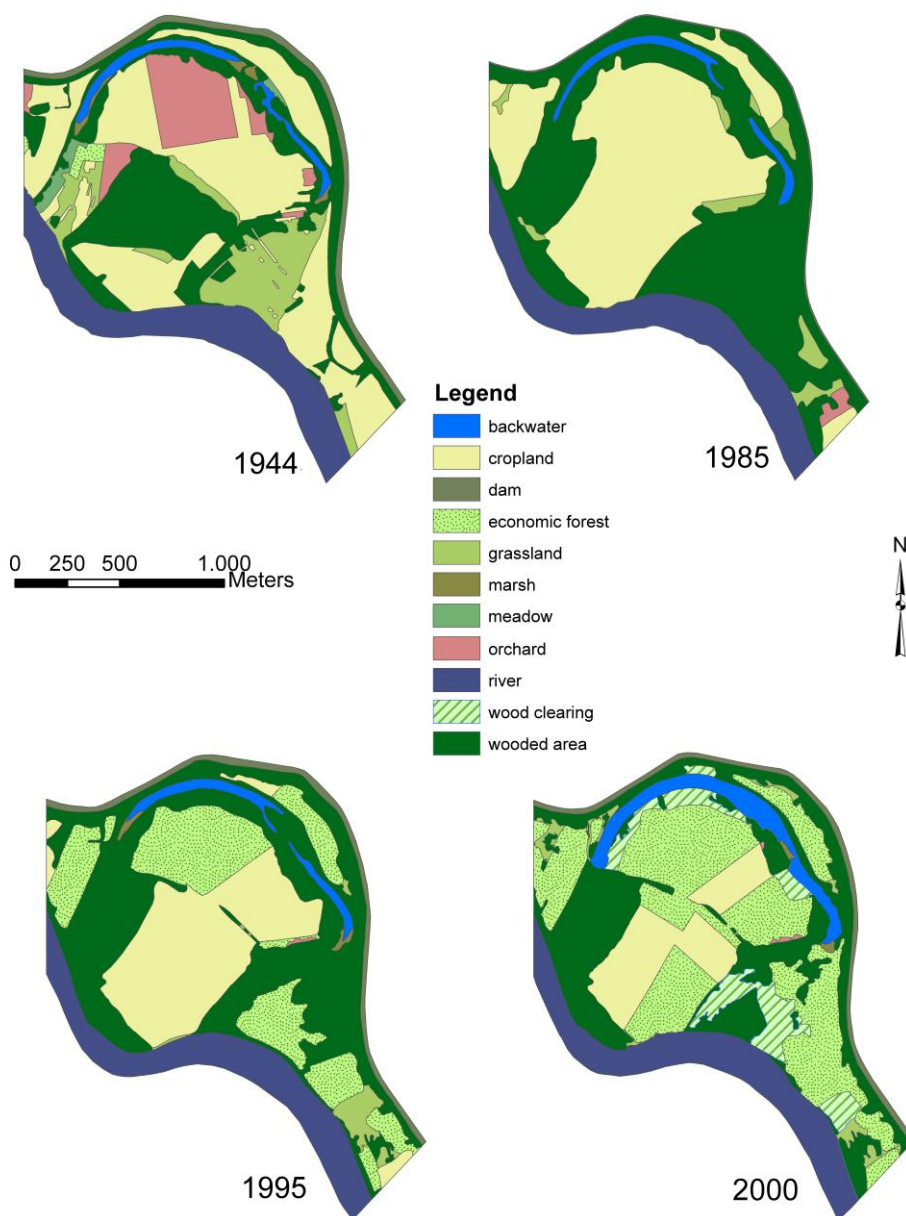


Fig. 4.2.2.2b. Land use changes of Foltos-kert from the first military map to 2005.

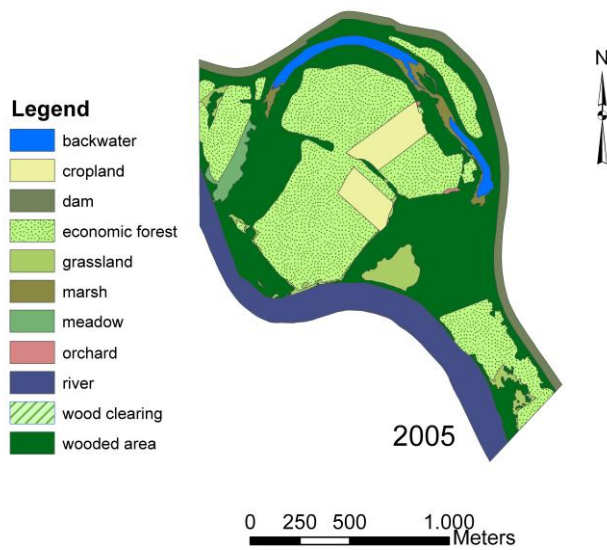


Fig. 4.2.2.2c. Land use changes of Foltos-kert from 2005.

Table 4.2.2.2a. Evolution of land cover categories (lccat) in area percent in Foltos-kert from the first military map to 2005.

Foltos-kert lccat	1784	1858	1884	1944	1985	1995	2000	2005
cropland				33.77	37.25	21.74	10.30	4.48
dam	8.55	2.92	8.73	3.81	0.88	3.40	3.08	5.43
economic plantation				0.68		20.47	32.68	34.54
grassland	9.07	46.06	48.23	9.63	3.15	1.91	1.57	2.79
marsh				0.53		0.33	0.20	1.30
meadow				0.92				1.19
orchard				8.07	0.56	0.09	0.13	0.07
backwater				2.28	2.15	2.22	4.83	2.38
river	22.92	25.84	21.21	14.05	13.28	12.81	13.26	12.37
wood clearing							6.94	
woodland	59.46	25.18	21.83	26.27	42.72	37.03	27.01	35.45

Table 4.2.2.2b. Evolution of land cover categories (lccat) in hectar (ha) in Foltos-kert from the first military map to 2005.

Foltos-kert lccat	1784	1858	1884	1944	1985	1995	2000	2005
cropland				80.5	86.7	51.2	24.2	10.5
dam	12.5	5.1	18.7	9.1	2.1	8.0	7.2	12.8
economic plantation				1.6		48.3	76.8	81.4
grassland	13.3	80.2	103.1	22.9	7.3	4.5	3.7	6.6
marsh				1.3		0.8	0.5	3.1
meadow				2.2				2.8
orchard				19.2	1.3	0.2	0.3	0.2
backwater				5.4	5.0	5.2	11.3	5.6
river	33.7	44.9	45.3	33.5	30.9	30.2	31.2	29.1
wood clearing							16.3	
woodland	87.4	43.8	46.7	62.6	99.5	87.3	63.5	83.5