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Land cover continuity as a tool for nature conservation

Landscape changes in Lake Fertő/Neusiedler See transboundary region during the past 200 years

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Land cover is the imprint of the man-nature interaction. It represents the combination of natural and cultural elements in a particular area and as such it is one of the most significant characteristics of the landscape and its transformations. This paper presents the land cover (LC) changes on a transboundary region which is both naturally and culturally diverse, the Fertő/Neusiedler See, where there have been divergent land cover change processes in Austria and in Hungary. The GIS assessment is based on historical maps from the 18th and 19th centuries and current land cover database (CLC2012). Changes were analysed by two approaches. Firstly the changes in the different landscape character types, identified by Konkoly-Gyuró et al. (2010b), were assessed on the two sides of the present state border. This approach enabled the comparison of the similarities and dissimilarities of the change processes in the two countries. Secondly the correlation between nature conservation status and continuity and stability of land cover was investigated. Stable, non-protected areas were identified, providing information for further nature conservation designation in order to preserve the majority of the valuable areas of the region.

Balázs P., Konkoly-Gyuró É. & Wrbka T., 2016: Kontinuität der Landbedeckung als Instrument für den Naturschutz. Landschaftswandel in der Fertő/Neusiedler See Region während der letzten 200 Jahre.
Landbedeckung ist ein Ausdruck der Mensch-Natur Wechselbeziehung. Sie stellt die Kombination von natürlichen und kulturellen Elementen in einem bestimmten Gebiet dar und als solche ist sie eine der wichtigsten Merkmale der Landschaft und ihren Veränderungen. In diesem Artikel werden die Landbedeckungsveränderungen einer natürlich und auch kulturell vielfältigen, grenzüberschreitenden Region Fertő/Neusiedler See dokumentiert und analysiert, wobei unterschiedliche Entwicklungstendenzen in Österreich und in Ungarn wahrgenommen werden können. Die Analyse basiert auf digitalisierten und georeferenzierten historischen Karten aus dem 18. und 19. Jahrhundert und der aktuellen Landbedeckungsdatenbank (CLC2012). Änderungen wurden durch zwei Ansätze analysiert. Zunächst werden die Änderungen in den verschiedenen Landschaftsräumen, sogenannten Landschaftscharaktertypen (Konkoly-Gyuró et al. 2010b) – auf den beiden Seiten der Staatsgrenze beurteilt. Dieser Ansatz ermöglichte den Vergleich der Ähnlichkeiten und Unterschiede der Veränderungsprozesse in beiden Ländern. Ferner wurde die Korrelation zwischen Naturschutz-Status und Kontinuität/Stabilität der Landbedeckung untersucht. Dabei konnten auch stabile, derzeit nicht geschützte Gebiete als Zielregionen für künftige Naturschutzaktivitäten identifiziert werden, um so das Naturerbe der Region zu bewahren.

Keywords: Lake Fertő/Neusiedler See, Hanság/Waasen, landscape change, historical land cover assessment.

Introduction

Landscape historical research has various focuses. One of them is the land cover transformation in order to provide useful information for landscape restoration and nature conservation. The aim of this paper is to present land cover changes of the last two centuries in the Fertő/Neusiedler See landscape and to find connections between land cover transformations and landscape character as well as present nature conservation of the area. Ac-

cording to our hypothesis, land cover transitions of the past allow us to identify the most stable surfaces, which should be the focal areas of habitat conservation today.

Recently several scientific research programs investigated landscapes, ecosystem services and green infrastructure in the Lake Fertő area (Prinz et al. 2010, Kuttner et al. 2013, Hermann et al. 2014, Harlov 2016). This paper is built on the results of these studies. Historical map processing of the Lake Fertő region was carried out within the frame of the TransEcoNet project (2008–2012) aiming to assess historical changes of transnational ecological networks in several Central European study areas (Konkoly-Gyuró et al. 2012). However, no detailed comparative land cover change assessment for both sides of the state border was done. This is what the current paper aims to present. Map analyses were implemented on actual landscape character types identified by an Austro-Hungarian common research project (Konkoly-Gyuró et al. 2010b).

Material and method

The transboundary research area is located in the transition zone of the pre-alpine mountains and the Pannonian Plain (Fig. 1). It extends from the Leitha and Sopron Mountains through hills and flatlands of the Fertő-Hanság basin towards the Danube floodplain Szigetköz. It covers around 2500 km^2 and includes 29 settlements in Austria and 41 settlements in Hungary. The various reliefs from the water level of Lake Fertő to the highest peak of the Sopron Mountain (182–623 m above Adriatic Sea Level) and geological settings resulted in a high diversity of landforms: deep lake basin on sediments, wetlands covered with peat, reclaimed marshland, low and elevated terraces, sandstone hills and crystalline low middle ranges.

The region is situated on the frontier of the Medio-European and continental climatic zone. Thus not only the diverse relief types but also the various climatic influences contribute to the significant diversity of habitat and species. Beside natural values, cultural heritage is also highly concentrated in this region. The traditions related to reed harvesting, fishing and viticulture are important characteristics of this area. Due to the bio-cultural richness of this landscape, large areas of the region are nationally and internationally protected, including the national parks in Austria and Hungary. Besides Ramsar sites, biosphere reserves and expanded areas within Nature 2000 status, the cross-border cultural landscape is classified as a UNESCO World Heritage site (Konkoly-Gyuró et al. 2010a).

Historical topographic maps are highly valuable sources for landscape historical assessment. To analyse changes of the last two hundred years, we used the Military Surveys from the Habsburg Empire and the Austro-Hungarian Monarchy (Arcanum 2006a, b, 2007), and current CORINE Land Cover maps, referred to as CLC2012 (EEA 2016). As the exact surveying years of each historical map sheet are different, we indicate a time interval for each time layer of the investigations. Details of maps are shown in Table 1. Due to the medium scale of historical maps, it was not possible to display all fine mosaic-structures, especially in open-water, wetland and grassland patches.

GIS processing of historical maps allows us to assess land cover changes far more detailed than traditional interpretations of the paper maps. The first step of map processing in GIS is geometric harmonisation, which includes georeferencing of non-projected maps and applying geometric corrections. It is followed by the interpretation of maps and identifica-

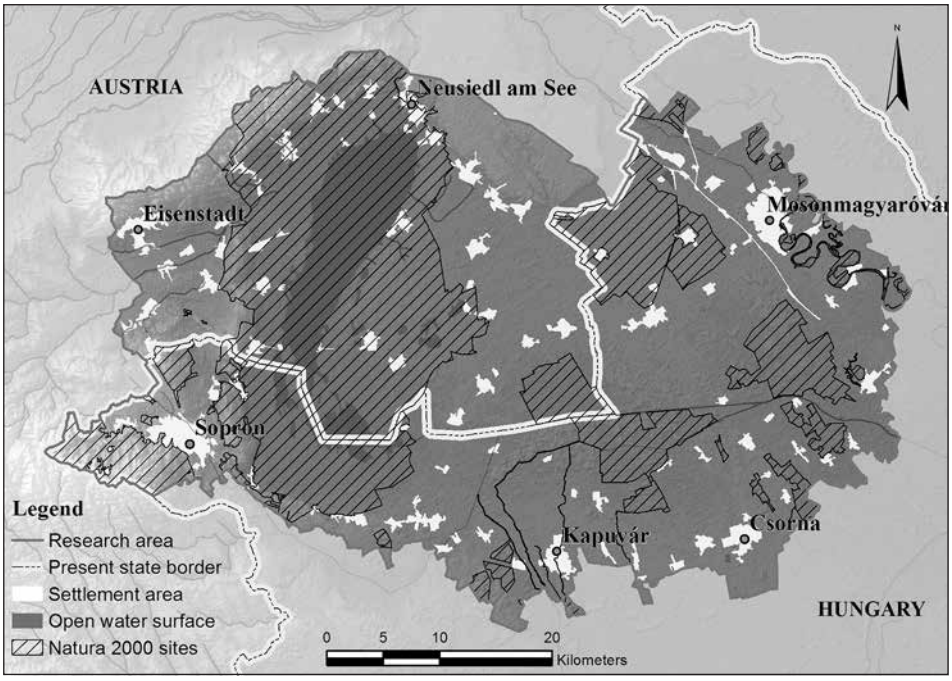


Fig. 1: Transboundary research area. – Abb. 1: Untersuchungsgebiet.

tion of the land cover according to a common category system. The final step is to generate a vector layer from the original raster image, which contains a network of polygons of identified land cover patches. More detailed information about map processing is available in Konkoly-Gyuró et al. (2010a), where the Hungarian part of the research was presented. In this paper we applied a land cover category system containing the following 9 main classes, which are essential in landscape related investigations: 1."Continuous urban fabric" including road and rail network; 2. "Discontinuous urban fabric" with green urban fabric; 3. "Arable land"; 4. "Orchard, vineyard" with gardens outside of settlements; 5."Forest", including wooded vegetation; 6. "Grassland", including transitional woodland shrub; 7. "Wetland"; 8. "Open-water surface" and 9. "Bare surface, other", which contains unidentifiable surfaces.

Tab. 1: Map sources. – Tab. 1: Kartenquellen.

Name of map	Scale	Mapping years of the research area	Time layers
The First Military Survey: Kingdom of Hungary	1:28800	1784–1785	End of 18th century
The Second Military Survey: Kingdom of Hungary	1:28800	1845–1846	Middle of 19th century
The Third Military Survey: Kingdom of Hungary	1:25000	1872–1880	Late 19th century
CORINE Land Cover 2012 v.18.4	1:100000	2011–2012	Present, beginning of 21th century

Beside traditional diagrams like column charts, we used transition matrices to represent changes between the two time periods. These tables, which are frequently applied in historical land cover assessments (Cousins 2001, Mouillot et al. 2005, Carmona and Nahuelhual 2012, Li et al. 2016), show each type of land cover transformation of a given area. It means that we can see not only the increase or decrease, but also the type of the transformation e.g. forest-grassland etc. To get the values recorded in transition matrices, we intersected two vector maps in ArcGIS software (ESRI 2016) and summarized their attributes with the pivot table tool in the MS Excel program. The present paper contains matrices, which show two percentage values for each land cover transformation process. The first value shows the transformation ratio referring to the entire investigation area; the second one shows the ratio referring to the sum of the given land cover category, from which the transformation has taken place (sum of each rows).

To facilitate the comprehension of the results, we used the following expressions in the text for each intersected map pair:

- 1st interval: first half of the 19th century (between the 1st and the 2nd military survey)
- 2nd interval: second half of the 19th century (between the 2nd and the 3rd military survey)
- 3rd interval: late 19th and the 20th centuries (between the 3rd military survey and the CLC 2012)

In most cases, the land cover change assessment performed on large investigation sites extended on various landscape types, relevant processes cannot be detected, as opposite transformations of different areas can counteract each other. E.g. the transformation of arable land to forest is rather typical on hills, but on the flatlands, mostly the opposite process took place. If we consider the sum of the changes we do not see significant transformations that in fact occurred. To eliminate these bias, we applied the present landscape character types as reference units. These landscape character types were identified by relief characteristics, human impact and dominant land cover in the frame of the former research (Konkoly-Gyuró et al. 2010b). We selected four pairs of main landscape character types, with pair-wise common relief settings, which represent the most characteristic change processes of the area (Fig. 2). Each pair contains a principally Austrian and a principally Hungarian type enabling us to analyse changes on both sides of the present state border.

Lake basin:	1a – Lake basin, with low intensity human use, dominated by reeds and grassland 1b – Lake basin, with various intensities of human use, dominated by open water
Deep lowland:	1d – Marshland with low intensity human use, dominated by a mosaic of forest, grasslands and water 2a – Reclaimed marshland and lake basin with low or medium intensity human use, arable and grassland dominance
Terraced lowland:	2b – Flatland with medium or high intensity human use and dominant homogeneous arable land cover 2c – Slightly undulating flatland with medium or high intensity human use and dominant vineyard cover

Hill range and foothills: 3a – Hill range and foothills with medium intensity human use and heterogeneous land cover
3b – Hill range and foothills with medium or intensive human use and vineyard dominance

Not selected landscape character types:
1c – Satellite lake basin, with low intensity human use, dominated by grassland and divers agriculture
2d – Slightly undulating flatland with medium or high intensity of human use and heterogeneous land cover
3c – Low mountains and foothills with low intensity human use, covered by closed forests
3d – Foothills and basins with historic towns and periurban areas
3e – Foothills and basins with low or medium intensity human use, mainly arable and grassland dominance

The second approach for studying land cover transformations focused on protected and non-protected areas. As conservation status we choose Natura 2000 sites to take into account, which occupy more than 40 % of the research area (Fig. 1). We analysed the changes based on their relevancy. By intersecting of all historical land cover maps we got polygons, identified by a four-digit number, representing a land cover class from each time layer (Skokanová 2009). The chrono-sequence of land cover is represented by this four-digit number, indicating stability or change.

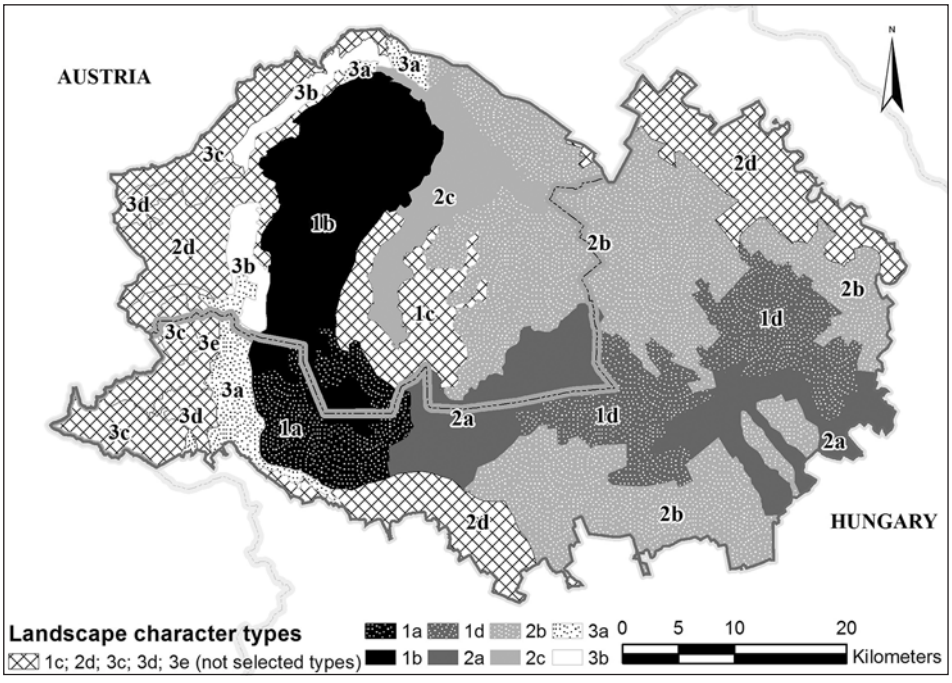


Fig. 2: Selected landscape character types of the research area. – Abb. 2: Ausgewählte Landschaftscharaktertypen des Untersuchungsgebiets.

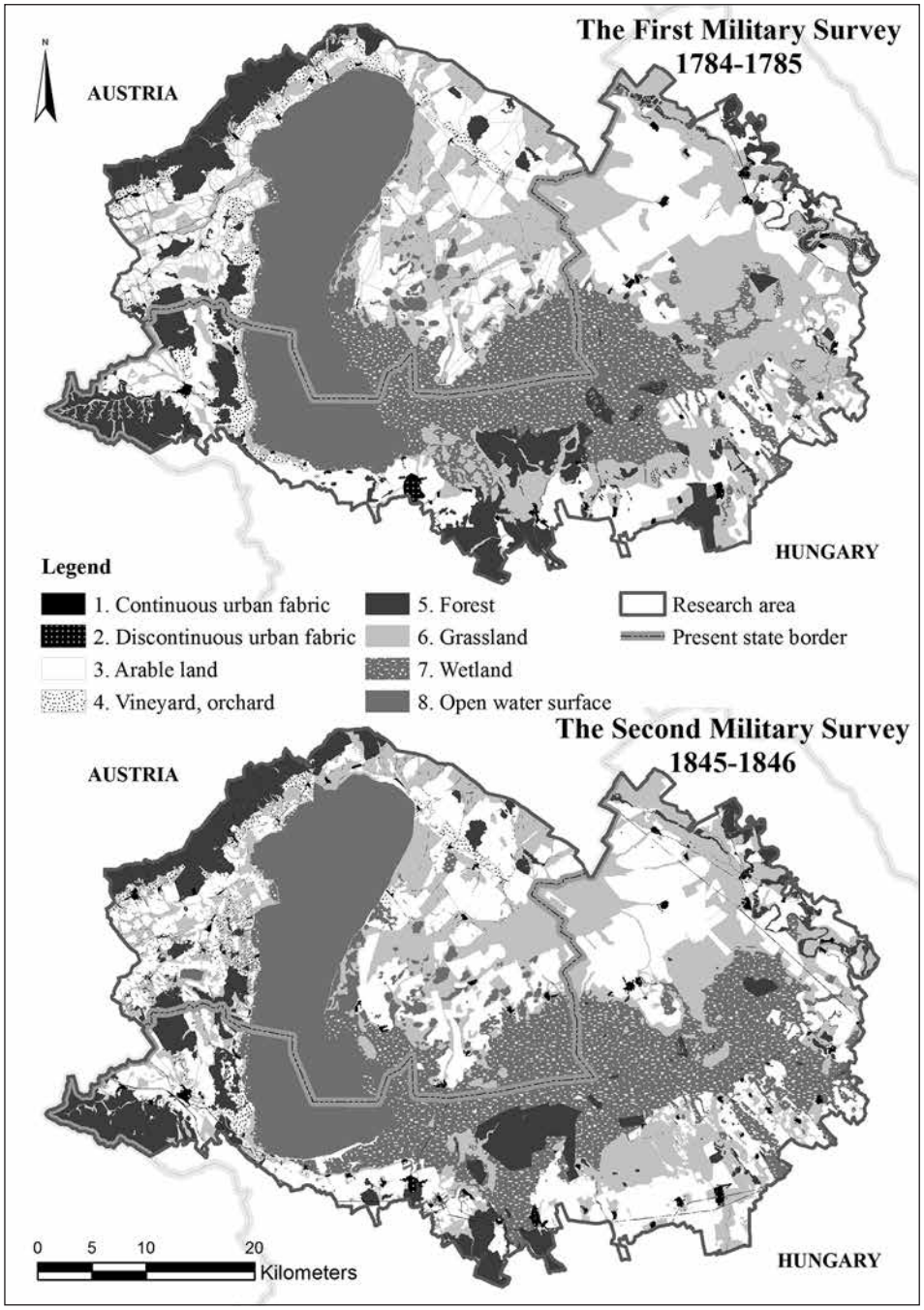


Fig. 3: Reconstructed land cover from the First and the Second Military Surveys. – Abb. 3: Rekonstruierte Landbedeckung basierend auf der Ersten und Zweiten Militärischen Landesaufnahme.

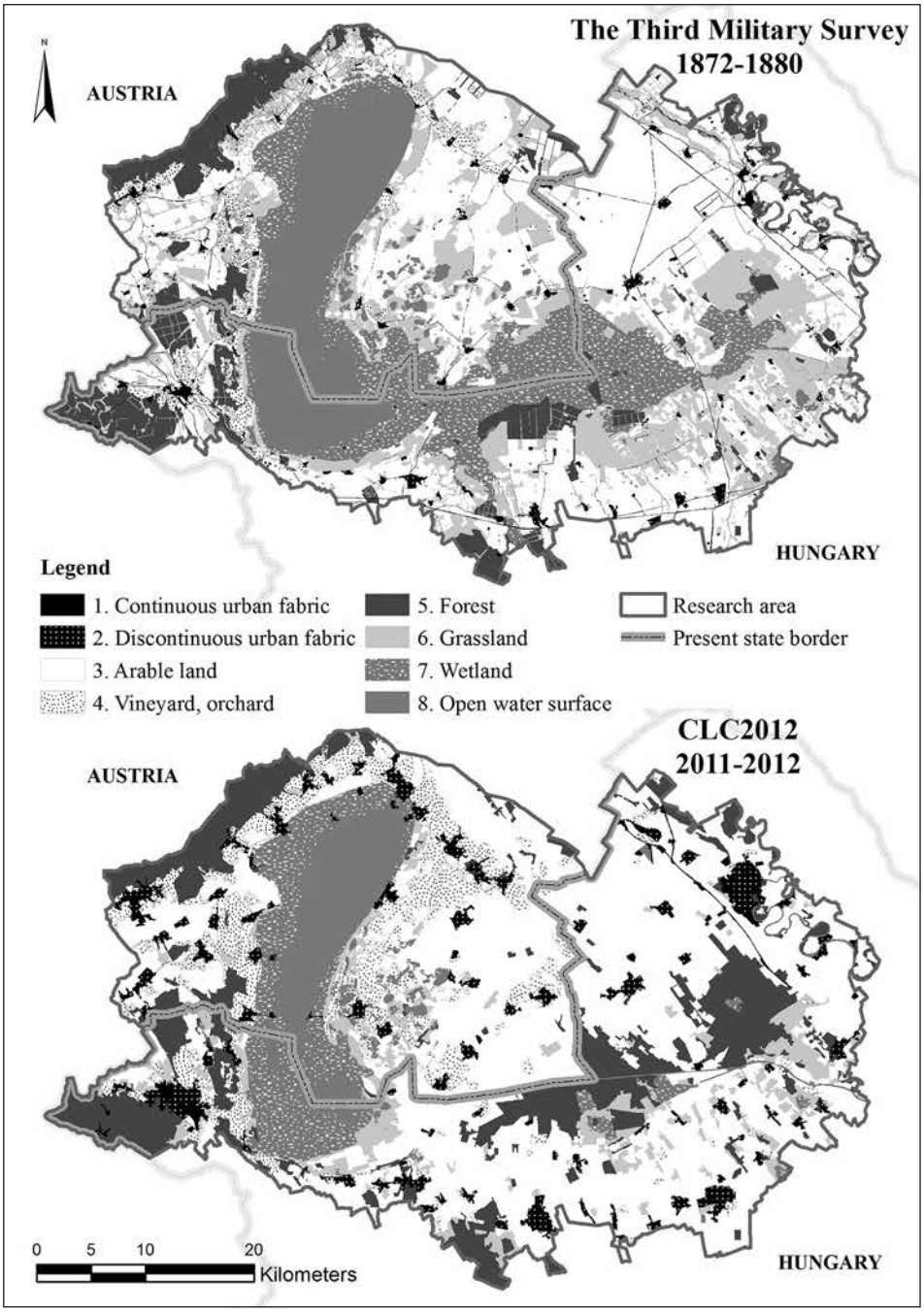
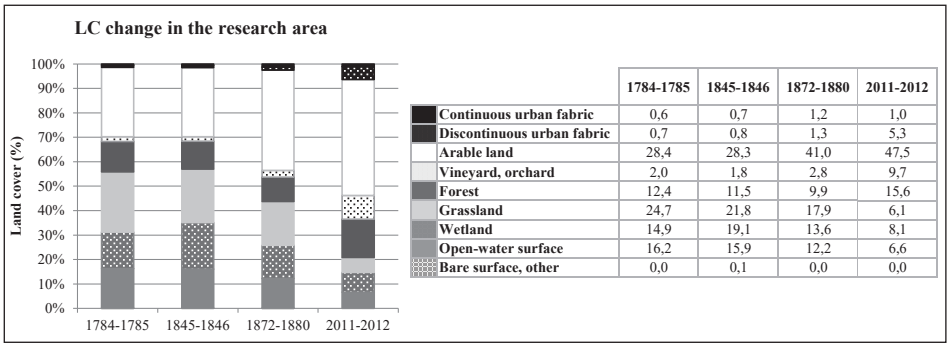


Fig. 4: Reconstructed land cover from the Third Military Survey and the present land cover of the research area based on the CORINE Land Cover 2012 database. – Abb. 4: Rekonstruierte Landbedeckung basierend auf der Dritten Militärische Landesaufnahme und die aktuelle Landbedeckung des Untersuchungsgebiets basierend auf der CORINE Land Cover 2012 Datenbank.

Results

The reconstructed digital land cover maps of the four time layers show the selected nine categories. The most eye catching change is the gradual disappearance of wetlands in the Hanság/Waasen as well as the shrinking of the grasslands (Fig. 3–4). Land cover statistics of the research area show that land cover proportions at the end of the 18th and in the middle of the 19th centuries are almost the same (Fig. 5). However, the map from the late 19th century already shows relevant changes, which coincide with the advancement of the water reclamation and regulation works of the region (Fig. 4–5). The most relevant change from that time till today was the enormous increase of arable land, parallel with the decrease of open-water surface, wetlands and grassland. These latter three categories made up more than half of the land cover of the area till the middle of the 19th century. Today these three classes cover only 20.8 % of the research area. Vineyards and orchards also show significant growth from the late 19th century, mainly on the Austrian side of the border (from 4.7 % to 18 %, while in Hungary the increase is only 2.1 %). Beside these processes, afforestation in Hanság also shows up in the charts, generating a relevant increase of forest cover ratio today (Tab. 2).



	1784-1785	1845-1846	1872-1880	2011-2012
Continuous urban fabric	0,6	0,7	1,2	1,0
Discontinuous urban fabric	0,7	0,8	1,3	5,3
Arable land	28,4	28,3	41,0	47,5
Vineyard, orchard	2,0	1,8	2,8	9,7
Forest	12,4	11,5	9,9	15,6
Grassland	24,7	21,8	17,9	6,1
Wetland	14,9	19,1	13,6	8,1
Open-water surface	16,2	15,9	12,2	6,6
Bare surface, other	0,0	0,1	0,0	0,0

Fig. 5 and Tab. 2: Sum of land cover changes of the research area. – Abb. 5 und Tab. 2: Summe der Landbedeckungsänderungen des Untersuchungsgebiets.

Land cover changes in landscape character types

This section demonstrates land cover changes of the selected landscape character type pairs. The location of each character type is presented in figure 2. The selected graphs and transition matrices below show the most relevant processes and within the matrices the changes of more than 2 % of the type's area are highlighted. In this chapter, we refer in most cases to the ratio of the transformation process to a given area (first values of each changes in matrices). Additional ratios are specially indicated.

Lake basin

The character type 1a (Lake basin, with low intensity human use, dominated by reeds and grassland) is situated mainly on the Hungarian part of Lake Fertő with its almost continuous reed cover (68.4 %). The open-water patches (3.6 %) are gradually disappearing (Fig. 6a).

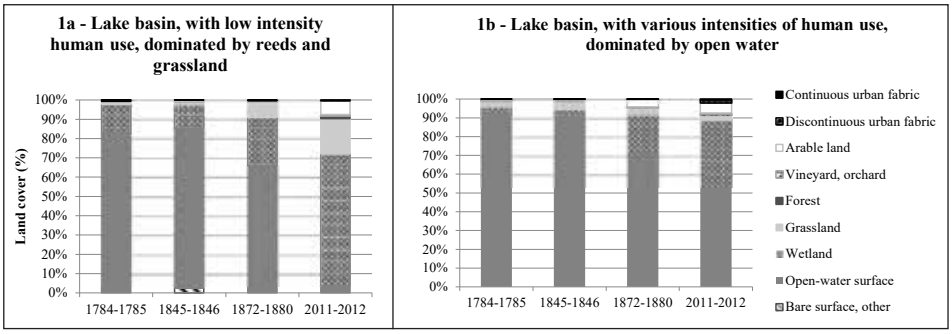


Fig. 6: Land cover changes of the lake basin: 1a (Fig. 6a) and 1b (Fig. 6b) character types. – Abb. 6: Landbedeckungsänderungen des Seebeckens: 1a (Abb. 6a) und 1b (Abb. 6b) Charaktertypen.

Tab. 3: Transition matrix of the 1a landscape character type in the 3rd interval. – Tab. 3: Übergangsmatrix des Landschaftscharaktertyps 1a in der dritten Zeitspanne.

3rd interval 1a character type	Continuous urban fabric		Discontinuous urban fabric		Arable land		Vineyard, orchard		Forest		Grassland		Wetland		Open-water surface		Bare surface, other	
Continuous urban fabric	0,0	0,0	0,0	10,2	0,1	70,2	0,0	4,5	0,0	0,0	0,0	6,5	0,0	8,6	0,0	0,0	0,0	0,0
Discontinuous urban fabric	0,0	0,0	0,0	37,6	0,0	0,0	0,0	38,0	0,0	0,0	0,0	18,0	0,0	6,4	0,0	0,0	0,0	0,0
Arable land	0,0	0,0	0,0	5,2	0,0	5,7	0,1	15,6	0,1	6,3	0,4	46,6	0,2	20,5	0,0	0,0	0,0	0,0
Vineyard, orchard	0,0	0,0	0,0	0,0	0,0	0,0	0,1	61,3	0,0	0,0	0,0	38,0	0,0	0,7	0,0	0,0	0,0	0,0
Forest	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Grassland	0,0	0,0	0,1	0,7	1,3	16,3	0,4	4,7	0,7	8,7	4,3	55,1	1,1	14,5	0,0	0,0	0,0	0,0
Wetland	0,0	0,0	0,3	1,2	**5,6**	22,1	0,4	1,4	0,5	2,1	**9,4**	37,4	8,8	35,1	0,2	0,7	0,0	0,0
Open-water surface	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**4,0**	6,1	**58,2**	88,6	3,4	5,2	0,0	0,0
Bare surface, other	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Tab. 4: Transition matrix of the 1b landscape character type in the 3rd interval. – Tab. 4: Übergangsmatrix des Landschaftscharaktertyps 1b in der dritten Zeitspanne.

3rd interval 1b character type	Continuous urban fabric		Discontinuous urban fabric		Arable land		Vineyard, orchard		Forest		Grassland		Wetland		Open-water surface		Bare surface, other	
Continuous urban fabric	0,0	22,1	0,0	29,2	0,0	33,1	0,0	2,0	0,0	0,0	0,0	13,0	0,0	0,6	0,0	0,0	0,0	0,0
Discontinuous urban fabric	0,1	66,0	0,0	31,1	0,0	0,0	0,0	2,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Arable land	0,0	0,4	0,3	6,7	2,5	61,8	0,4	9,6	0,2	4,2	0,4	10,7	0,3	6,7	0,0	0,0	0,0	0,0
Vineyard, orchard	0,0	0,4	0,2	40,7	0,1	14,9	0,2	39,9	0,0	0,0	0,0	3,9	0,0	0,2	0,0	0,0	0,0	0,0
Forest	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Grassland	0,0	0,7	0,3	6,7	1,4	37,1	0,1	3,3	0,1	2,8	1,6	40,0	0,4	9,4	0,0	0,0	0,0	0,0
Wetland	0,1	0,5	0,1	0,7	1,2	6,3	0,2	0,9	0,1	0,5	0,5	2,6	17,1	88,4	0,0	0,1	0,0	0,0
Open-water surface	0,3	0,4	0,8	1,1	0,0	0,1	0,0	0,0	0,0	0,0	0,1	0,1	**17,7**	24,5	53,4	73,9	0,0	0,0
Bare surface, other	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

According to the historical maps, the water surface was much more extensive in this part of the lake even in the late 19th century, when reed cover started to spread. Statistics show a drastic shrinkage of open-water from 82.3 % to 3.6 % during the investigated period. This can also be seen in the transition matrix of the 3rd interval (Tab. 3): altogether 83.2 % land cover of the character type has changed. Mainly conversions from open-water to wetland took place (58.2 %) but summarised transformations of other land cover categories to grassland is also significant (13.8 %).

The Austrian counterpart of the character type 1b (Lake basin, with various intensities of human use, dominated by open water) was also almost entirely covered by water surface (93.5 %) till the middle of the 19th century (Fig. 6b). Today much more open-water surface remained (53.4 %) and less reed cover can be seen compared to Hungary. It shows more stability than its Hungarian pair. Altogether only 25.3 % of its area changed in the 3rd interval, where the biggest changes happened (Tab. 4). Just as in Hungary, open-water to wetland conversions are significant.

Deep lowland

Character types 1d (Marshland with low intensity human use, dominated by a mosaic of forest, grasslands and water) and 2a (Reclaimed marshland and lake basin with low or medium intensity human use, arable and grassland dominance) represent the former marshland area of the region. Type 1d is situated only in Hungary; type 2a has areas both in Hungary and in Austria. Owing to the reclamation works, only small patches of the original dominant wetland and grassland cover remain. Wetland started to shrink in the late

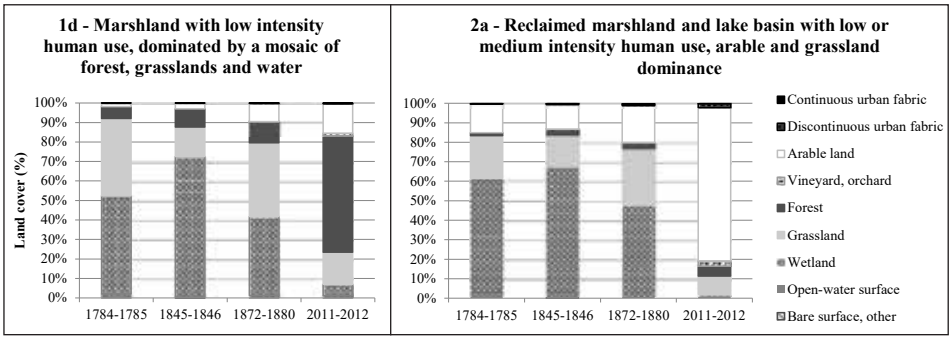


Fig. 7: Land cover changes of the deep lowlands: 1d (Fig. 7a) and 2a (Fig. 7b) character types. – Abb. 7: Landbedeckungsänderungen der Tiefebene: 1d (Abb. 7a) und 2a (Abb. 7b) Charaktertypen.

19th century in both types, replaced in 1d mainly by forest (poplar plantations), and in 2a mainly by arable land (Fig. 7).

The transition matrix of the 1d type shows that in the 3rd interval, not only wetland, but also grassland and arable land transformed into forest (Tab. 5). Here the source of arable land expansion was mainly the grassland category, while in the 2a type (aside from grassland) principally former wetland became arable land (Tab. 6).

Tab. 5: Transition matrix of the 1d landscape character type in the 3rd interval. – Tab. 5: Übergangsmatrix des Landschaftscharaktertyps 1d in der dritten Zeitspanne.

3rd interval 1d character type	Continuous urban fabric		Discontinuous urban fabric		Arable land		Vineyard, orchard		Forest		Grassland		Wetland		Open-water surface		Bare surface, other	
Continuous urban fabric	0,0	0,0	0,0	0,0	0,0	2,2	0,0	0,0	0,1	76,2	0,0	21,6	0,0	0,0	0,0	0,0	0,0	0,0
Discontinuous urban fabric	0,0	0,0	0,0	0,0	0,0	35,0	0,0	0,0	0,0	64,3	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0
Arable land	0,1	0,8	0,0	0,3	4,1	43,6	0,0	0,4	**3,0**	32,2	**2,1**	22,4	0,0	0,2	0,0	0,1	0,0	0,0
Vineyard, orchard	0,0	66,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	33,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Forest	0,0	0,0	0,0	0,0	0,6	5,1	0,0	0,3	10,1	91,9	0,2	1,4	0,1	0,8	0,1	0,5	0,0	0,0
Grassland	0,2	0,5	0,0	0,0	**9,1**	24,0	1,2	3,3	**15,4**	40,8	10,3	27,2	1,2	3,1	0,4	1,1	0,0	0,0
Wetland	0,0	0,0	0,0	0,0	1,4	3,4	0,0	0,0	**30,8**	76,2	**3,7**	9,2	4,0	9,9	0,5	1,2	0,0	0,0
Open-water surface	0,0	0,0	0,0	0,0	0,1	11,6	0,1	4,0	0,2	19,2	0,2	13,3	0,5	37,7	0,2	14,2	0,0	0,0
Bare surface, other	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Tab. 6: Transition matrix of the 2a landscape character type in the 3rd interval. – Tab 6: Übergangsmatrix des Landschaftscharaktertyps 2a in der dritten Zeitspanne.

3rd interval 2a character type	Continuous urban fabric		Discontinuous urban fabric		Arable land		Vineyard, orchard		Forest		Grassland		Wetland		Open-water surface		Bare surface, other	
Continuous urban fabric	0,0	0,2	0,1	10,9	0,5	81,7	0,0	0,1	0,0	0,0	0,0	6,0	0,0	0,7	0,0	0,3	0,0	0,0
Discontinuous urban fabric	0,0	0,0	0,4	76,3	0,0	8,7	0,0	3,2	0,1	9,6	0,0	2,2	0,0	0,0	0,0	0,0	0,0	0,0
Arable land	0,1	0,8	0,9	4,7	16,0	84,7	0,7	3,8	0,4	1,9	0,5	2,7	0,1	0,7	0,1	0,7	0,0	0,0
Vineyard, orchard	0,0	0,0	0,0	3,2	0,0	52,9	0,0	43,7	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0
Forest	0,0	0,0	0,0	0,5	0,7	28,6	0,0	1,9	1,5	64,4	0,1	4,2	0,0	0,0	0,0	0,3	0,0	0,0
Grassland	0,0	0,2	0,4	1,3	**21,0**	70,9	0,5	1,6	1,3	4,3	5,9	20,1	0,2	0,7	0,3	0,9	0,0	0,0
Wetland	0,0	0,0	0,2	0,5	**39,7**	85,0	1,4	3,0	1,7	3,7	**2,8**	5,9	0,1	0,2	0,8	1,8	0,0	0,0
Open-water surface	0,0	0,0	0,0	1,1	0,7	58,6	0,0	0,0	0,1	8,0	0,0	1,9	0,3	23,0	0,1	7,3	0,0	0,0
Bare surface, other	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Terraced lowland

Landscape character type 2b (Flatland with medium or high intensity human use and dominant homogeneous arable land cover) with its widespread arable fields, extends beyond the national border, while 2c (Slightly undulating flatland with medium or high intensity human use and dominant vineyard cover) dominated by vineyards is situated only on the Austrian side on the north-eastern shore of Lake Fertő. Till the middle of the 19th century, the land cover proportions do not show relevant changes (Fig. 8). Both areas were dominantly arable land and grassland with the difference that in 2b there was also considerable forest and wetland, while 2c had around 6–7 % vineyard coverage. In 2b large-scale extension of arable lands started in the late 19th century. Today it covers 86.8 % of this area, replacing almost all former grassland and forest. Changing processes in 2c were similar to 2b till the late 19th century but during the 20th century vineyards started to increase beside the extension of arable land. In the 3rd interval, the proportion of vineyards changed from 12.5 % to 60.6 %. Another significant phenomenon is the increase of the discontinuous urban fabric, especially in the Austrian 2c type (from 2.6 % to 11.9 %).

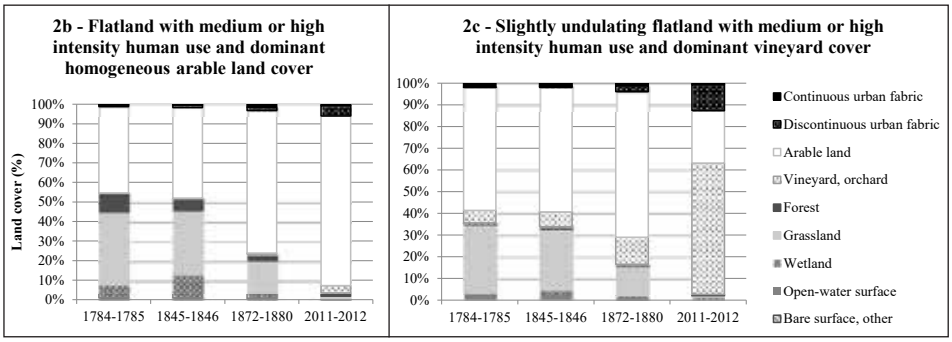


Fig. 8: Land cover changes of the terraced lowlands: 2b (Fig. 8a) and 2c (Fig. 8b) character types. – Abb. 8: Landbedeckungsänderungen der Schotterplatten: 2b (Abb. 8a) und 2c (Abb. 8b) Charaktertypen.

Tab. 7: Transition matrix of the 2c landscape character type in the 3rd interval. – Tab. 7: Übergangsmatrix des Landschaftscharaktertyps 2c in der dritten Zeitspanne.

3rd interval 2c character type	Continuous urban fabric		Discontinuous urban fabric		Arable land		Vineyard, orchard		Forest		Grassland		Wetland		Open-water surface		Bare surface, other	
Continuous urban fabric	0,0	0,7	0,5	39,4	0,2	15,9	0,5	42,4	0,0	0,3	0,0	0,1	0,0	1,1	0,0	0,0	0,0	0,0
Discontinuous urban fabric	0,3	9,6	2,4	88,9	0,0	0,0	0,0	0,8	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Arable land	0,3	0,5	**3,5**	5,1	18,3	27,2	**44,4**	66,1	0,5	0,8	0,0	0,0	0,2	0,3	0,0	0,0	0,0	0,0
Vineyard, orchard	0,1	0,4	**2,6**	21,0	0,2	1,8	9,5	76,4	0,0	0,2	0,0	0,1	0,0	0,1	0,0	0,0	0,0	0,0
Forest	0,0	0,0	0,0	8,8	0,0	0,0	0,4	91,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Grassland	0,0	0,1	**2,0**	14,6	**5,5**	39,5	**5,4**	39,3	0,0	0,0	0,3	2,2	0,6	4,2	0,0	0,0	0,0	0,0
Wetland	0,0	0,0	0,2	36,8	0,0	4,8	0,2	35,5	0,0	0,0	0,1	13,2	0,1	9,7	0,0	0,0	0,0	0,0
Open-water surface	0,0	0,0	0,7	45,7	0,1	4,7	0,0	1,3	0,0	0,0	0,0	1,8	0,7	46,5	0,0	0,0	0,0	0,0
Bare surface, other	0,0	15,6	0,0	41,6	0,0	0,0	0,0	42,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

The transition matrix of the 2c landscape character type shows that during the 3rd interval 69.5 % of the land cover has changed, due mainly to the expanding vineyards. Merely 9.5 % of the 2c area was continuous vineyard in the 3rd interval, which means only 15.7 % of the present vineyards.

Hill range and foothills

Landscape character type 3a (Hill range and foothills with medium intensity human use and heterogeneous land cover) and 3b (Hill range and foothills with medium or intensive human use and vineyard dominance) representing the hill range and foothills show nearly stable land cover till the late 19th century (Fig. 9). After that the expansion of vineyards and discontinuous urban areas began in both types, to the detriment of arable land and grassland. This process started earlier in the Austrian hill range and was more far-reaching until today where vineyards cover 77.7 % of the area (Fig. 9b).

As in the previous examples, the 3a and 3b column charts do not show relevant changes till the 3rd interval. Summarised values of changes (exclusive areas showing stability be-

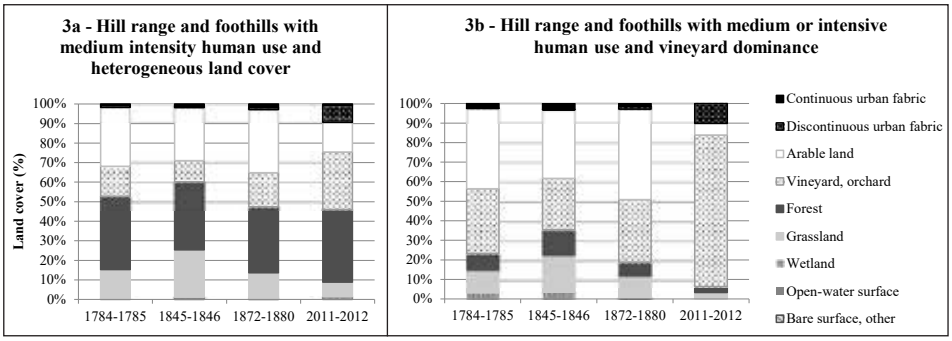


Fig. 9: Land cover changes of the hill range and foothills: 3a (Fig. 9a) and 3b (Fig. 9b) character types. – Abb. 9: Landbedeckungsänderungen der Hügelketten und Vorbergen: 3a (Abb. 9a) und 3b (Abb. 9b) Charaktertypen.

Tab. 8: Transition matrix of the 3a landscape character type in the 1st interval. – Tab. 8: Übergangsmatrix des Landschaftscharaktertyps 3a in der ersten Zeitspanne.

1st interval 3a character type	Continuous urban fabric		Discontinuous urban fabric		Arable land		Vineyard, orchard		Forest		Grassland		Wetland		Open-water surface		Bare surface, other	
Continuous urban fabric	0,1	9,6	0,0	0,0	0,2	33,8	0,0	0,0	0,1	19,2	0,3	37,3	0,0	0,0	0,0	0,0	0,0	0,0
Discontinuous urban fabric	0,0	0,4	0,5	53,7	0,1	11,7	0,2	15,4	0,0	1,3	0,1	11,2	0,0	3,5	0,0	2,7	0,0	0,1
Arable land	0,4	1,4	0,1	0,4	14,5	48,0	0,7	2,3	**3,4**	11,1	**11,1**	36,6	0,1	0,2	0,0	0,1	0,0	0,0
Vineyard, orchard	0,2	1,4	0,0	0,1	**3,3**	21,1	8,5	55,4	1,8	11,7	1,6	10,3	0,0	0,1	0,0	0,0	0,0	0,0
Forest	0,2	0,6	0,0	0,0	**4,7**	12,6	0,8	2,2	27,9	74,8	**3,6**	9,7	0,0	0,1	0,0	0,0	0,0	0,0
Grassland	0,1	0,7	0,1	0,7	**4,4**	28,8	0,6	4,3	1,6	10,5	7,5	49,7	0,6	4,0	0,1	0,7	0,1	0,5
Wetland	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	51,3	0,0	29,9	0,0	17,5	0,0	1,3
Open-water surface	0,0	2,5	0,0	0,0	0,0	3,6	0,0	0,0	0,0	3,1	0,1	48,7	0,0	0,0	0,0	34,5	0,0	7,6
Bare surface, other	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Tab. 9: Transition matrix of the 3b landscape character type in the 2nd interval. – Tab. 9: Übergangsmatrix des Landschaftscharaktertyps 3b in der zweiten Zeitspanne.

2nd interval 3b character type	Continuous urban fabric		Discontinuous urban fabric		Arable land		Vineyard, orchard		Forest		Grassland		Wetland		Open-water surface		Bare surface, other	
Continuous urban fabric	0,3	8,3	0,6	18,6	1,0	31,6	0,9	27,7	0,1	3,8	0,3	9,5	0,0	0,0	0,0	0,1	0,0	0,5
Discontinuous urban fabric	0,0	10,3	0,0	20,8	0,0	33,9	0,0	35,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Arable land	0,5	1,3	0,3	0,9	22,0	62,7	**10,5**	30,1	0,4	1,1	1,2	3,4	0,0	0,0	0,0	0,1	0,2	0,5
Vineyard, orchard	0,2	0,8	0,3	1,1	**7,2**	27,4	15,8	60,1	0,8	3,2	1,8	6,7	0,0	0,0	0,0	0,0	0,2	0,7
Forest	0,2	1,5	0,0	0,1	**4,4**	35,6	1,8	14,8	4,1	33,0	1,8	14,6	0,0	0,0	0,0	0,0	0,0	0,3
Grassland	0,4	1,9	0,1	0,7	**8,9**	45,4	**2,8**	14,4	0,9	4,6	6,3	32,4	0,0	0,0	0,0	0,1	0,1	0,5
Wetland	0,0	0,0	0,0	2,0	**2,1**	85,3	0,1	4,4	0,0	0,0	0,2	7,9	0,0	0,4	0,0	0,0	0,0	0,0
Open-water surface	0,0	0,4	0,0	1,0	0,6	68,3	0,1	6,5	0,0	1,1	0,1	11,1	0,1	10,9	0,0	0,1	0,0	0,5
Bare surface, other	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Tab. 10: Transition matrix of the 3b landscape character type in the 3rd interval. – Tab.10: Übergangsmatrix des Landschaftscharaktertyps 3b in der dritten Zeitspanne.

3rd interval 3b character type	Continuous urban fabric		Discontinuous urban fabric		Arable land		Vineyard, orchard		Forest		Grassland		Wetland		Open-water surface		Bare surface, other	
Continuous urban fabric	0,0	0,0	0,3	18,8	0,3	16,8	0,7	48,7	0,0	1,0	0,2	14,8	0,0	0,0	0,0	0,0	0,0	0,0
Discontinuous urban fabric	0,0	0,0	1,4	98,0	0,0	0,0	0,0	1,6	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Arable land	0,0	0,0	**3,8**	8,2	4,4	9,5	**37,2**	80,4	0,5	1,0	0,2	0,5	0,1	0,3	0,0	0,0	0,0	0,0
Vineyard, orchard	0,0	0,0	**3,2**	9,9	0,2	0,5	28,0	87,1	0,6	1,8	0,2	0,7	0,0	0,0	0,0	0,0	0,0	0,0
Forest	0,0	0,0	0,1	0,9	0,0	0,0	**4,7**	74,3	1,5	24,0	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0
Grassland	0,0	0,0	1,4	12,1	1,0	8,2	**6,6**	56,2	0,3	2,9	2,4	20,6	0,0	0,0	0,0	0,0	0,0	0,0
Wetland	0,0	0,0	0,0	21,2	0,0	0,0	0,0	36,0	0,0	0,0	0,0	0,0	0,0	42,8	0,0	0,0	0,0	0,0
Open-water surface	0,0	0,0	0,0	0,0	0,0	50,7	0,0	41,6	0,0	0,0	0,0	7,7	0,0	0,0	0,0	0,0	0,0	0,0
Bare surface, other	0,0	0,0	0,1	19,8	0,0	1,6	0,4	74,5	0,0	2,5	0,0	1,6	0,0	0,0	0,0	0,0	0,0	0,0

tween two investigated time layers) show that around 40 % of the 3a and 50 % of the 3b area were converted to other land cover classes in the 1st and the 2nd intervals (Tab. 8–9). Type 3b indicates one of the greatest changes in the 1st interval among all of the investigated landscape character types. In 3a mainly arable land - grassland transformations took place, while in 3b vineyard-arable land conversions were also significant in the 3rd interval.

Land cover transitions on protected and non-protected sites

The second approach of land cover change assessment was the comparison of the land cover continuity on the Natura 2000 sites and beyond. The intersection of maps helps us to detect those areas where land cover was presumably continuous or stable during the investigated time interval (Fig. 10–11). It means that the land cover in each time layer was the same. However, we cannot exclude the possibility that changes occurred meanwhile. Statistical analysis of intersected land cover maps shows that 81.6 % of the aggregated area of continuous grassland, wetland, open-water and forest's is located within Natura 2000 sites. Only the remaining 18.4 % of continuous areas fall outside. Almost all (99,9 %) of the continuous wetland (7777) and continuous open-water surface (8888) belong to Natura 2000 sites today. These two categories comprise the 31 % of the Natura 2000 areas. 67.4 % of stable grassland (6666) and 63.5 % of continuous forest (5555) are situated in Natura 2000 areas. 79.4 % of the present arable lands, which were cultivated in all investigated time layers (3333) are situated outside of Natura 2000 areas. 62.7 % of continuous vineyards (4444) is outside and 37.3 % is inside protected sites.

Transition analyses on Natura 2000 sites show the largest ratio (14.5 %) of continuity in open-water surfaces (8888) (Tab. 11a), forming the present Lake Fertő. The second largest value (10.9 %) is also linked to the water surfaces but in this case, areas were covered with water only till the end of 19th century; on the CLC2012 these areas are covered by reeds (8887). These wetlands are situated mainly in the southern, Hungarian part of Lake Fertő. Continuous forest and wooded vegetation (5555) of middle ranges accounts for 9.2 % and continuous arable land (3333) of plains and lowlands covers 7.1 % of the Natura 2000 sites. The next significant transition process (8877) extending over 4.9 % of the Natura 2000 sites is related to the expanding reed cover. These areas were open-water surfaces in the first and second time layer. After that they transformed into wetland (reeds). Parallel with

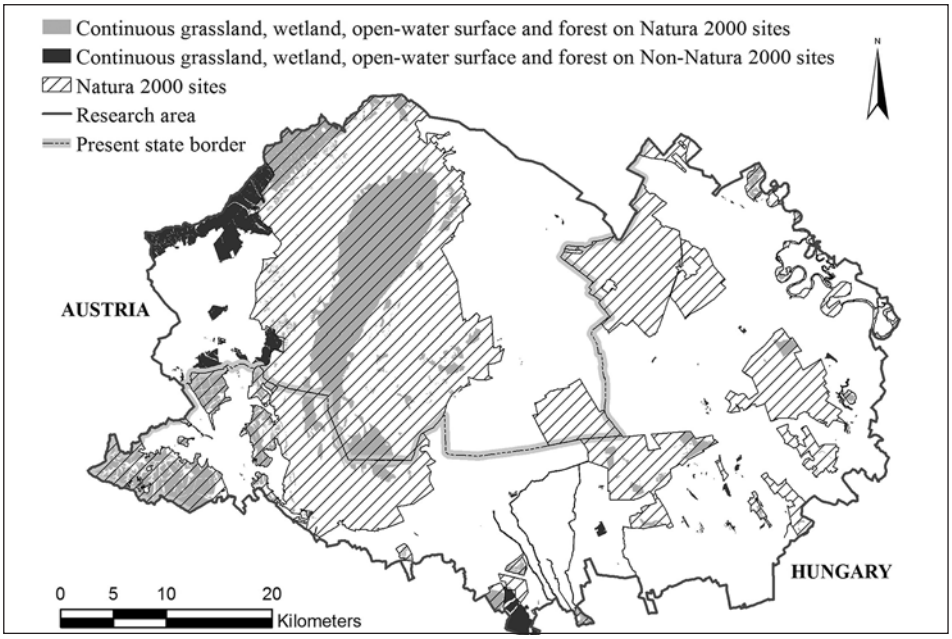


Fig. 10: Continuous natural and semi natural surfaces on Natura 2000 sites and beyond. – Abb. 10: Kontinuierliche naturnahe Landbedeckung inner- und außerhalb den Natura 2000 Gebieten.

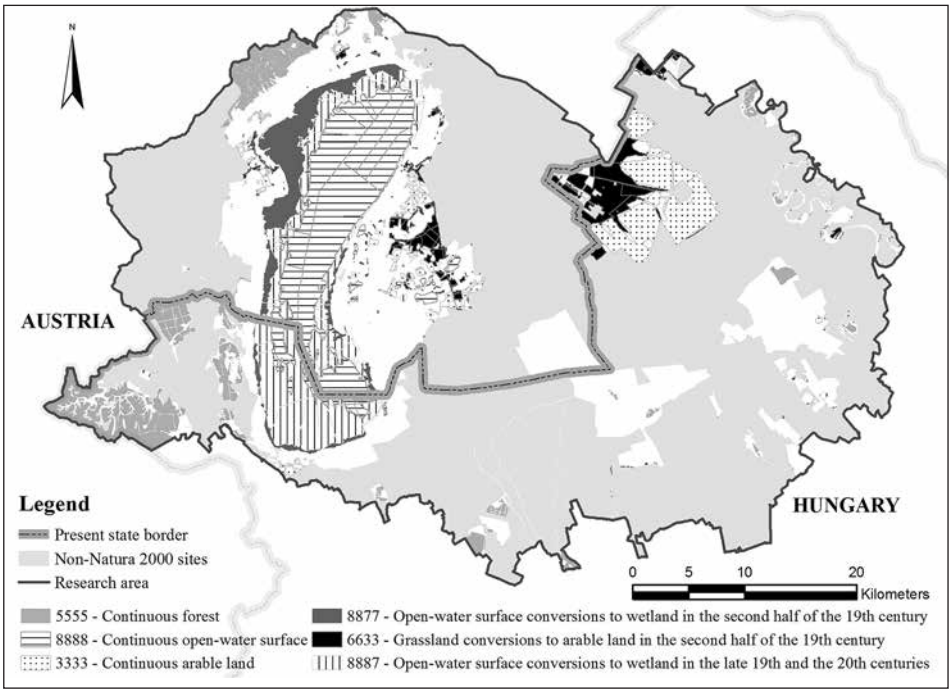


Fig. 11: Relevant land cover transitions (more than 3000 ha) on Natura 2000 sites. – Abb. 11: Relevante Landbedeckungskonversionen (über 3000 Hektar) in den Natura 2000 Gebieten.

Tab. 11: Land cover transformations on Natura 2000 sites (11a) and Non-Natura 2000 sites (11b). – Tab. 11: Landbedeckungstransformationen inner- (11a) und außerhalb (11b) den Natura 2000 Gebieten.

Chrono sequence of LC categories	Natura 2000 sites		Chrono sequence of LC categories	Non-Natura 2000 sites	
	Sum (m²)	Sum % ⬇		Sum (m²)	Sum % ⬇
8888	149369785,1	14,5 %	3333	281681579,0	19,3 %
8887	112421091,8	10,9 %	6633	112072750,1	7,7 %
5555	95117113,5	9,2 %	7773	69278065,3	4,8 %
3333	73158107,6	7,1 %	6663	61230512,5	4,2 %
8877	50546672,8	4,9 %	5555	54653952,4	3,7 %
6633	46709467,8	4,5 %	3334	49100811,4	3,4 %
7773	29919086,3	2,9 %	6333	48015905,2	3,3 %
3334	21358926,2	2,1 %	3633	39476351,4	2,7 %
7775	19016650,3	1,8 %	7775	35920675,8	2,5 %
7776	14711831,9	1,4 %	6763	28312638,2	1,9 %
6663	13842078,5	1,3 %	7763	25747748,9	1,8 %
6766	11416828,7	1,1 %	6733	22134257,9	1,5 %
6333	9687542,1	0,9 %	3332	20040342,0	1,4 %
6775	9253272,8	0,9 %	5333	15775926,0	1,1 %
7766	8752797,9	0,8 %	6765	15466335,2	1,1 %
3633	8400749,1	0,8 %	3663	14690286,8	1,0 %
7777	8023475,9	0,8 %	3363	14357678,3	1,0 %
6666	7760842,1	0,8 %	7663	14064309,3	1,0 %

this, 4.5 % of Natura 2000 sites were converted from grassland into arable land (6633) principally in the Hanság. Other land cover transformations on Natura 2000 sites of less than 3 % are shown in Table 11a.

On Non-Natura 2000 sites, continuous arable land (3333) has the highest ratio (19.3 %) among all of the land cover in the investigated time frame (Tab. 10b). It is followed by grasslands till the mid 19th century, then transformed to arable land (6633) (7.7 %). The next significant process happened during the 20th century when wetland and grassland were converted to arable land. They cover respectively 4.8 % (7773) and 4.2 % (6663) of the Non-Natura 2000 sites today. There is a relatively high proportion of continuous forest (5555) (3.7 %) and of the present vineyards and orchards (3.4 %) which replaced the continuous arable lands (3334) (3.4 %) of the Non-Natura 2000 sites in the 3rd interval.

Continuity analyses show that ratios of continuous forest and continuous grassland cover are nearly the same in Austria and Hungary. Both countries have nearly 50 % of these surfaces. The situation is totally different in wetland and open-water where 83.9 % of continuous wetland is situated in Hungary, while most of the continuous open-water surfaces (91.7 %) are in Austria.

Discussion and conclusion

Working with historical maps has always had some uncertainties. Generally, the older maps were that we worked with, the more geometric inaccuracy we got. That is what we have to take into account especially in more detailed investigations such as the level of

settlement. The interpretation of military surveys is also crucial from later analyses. Land cover is changing rapidly each year, especially in the conversion of grassland to arable land. The most significant land cover transformations are shown during the 20th century. However, it is also the longest investigated time interval (more than 100 years), while the 1st and 2nd intervals covered only around 60 and 30 years. Including an extra time layer from the 1950's into our analysis could significantly enhance the value of the results especially when comparing the two sides of the present border.

Till the middle of the 19th century, most of the research area does not show significant changes in land cover ratios. Changes accelerated principally from the late 19th century, parallel with the advancement of the reclamation of the Hanság along with the regulation of the Raab and its tributaries. Most of the deep lowlands transformed into cultivated areas. Only remnants of the former continuous wetland remain. Today arable land and large vineyards and much more intensive usage are characteristic in most parts of the former wide-spread wetland zone.

Detailed analyses of changes on selected landscape character type pairs show mainly similar processes before the First World War. After the Austro-Hungarian Compromise of 1867 customs union, capitalisation and economic development created a higher demand for cultivated areas. This period can be seen between the digitized maps of the Second and the Third Military Surveys, when arable land started to expand on lowlands and terraced flatlands of the region. After the designation of the present national border, change processes of the region show dissimilarities. In Austria intensive arable land and vineyards became dominant, because of the lack of other suitable cultivation areas in the alpine country. In contrast, in the neglected borderland and in its broader environment in Hungary, natural processes increased owing to the lack of development. After the Second World War, the damaged canals of the Hanság were reconstructed and new ones were built to stabilize the water level of Lake Fertő and gain new arable lands. However, the pressure for agricultural development was not as high as it was in Austria, which resulted in much less intensive usage of cultivated areas. At that time forests were planted in the Hanság area, hoping for a quick profit from poplar trees for use as pulpwood. Stabilizing and decreasing the water level of Lake Fertő resulted in mud sedimentation and siltation on the southern side of the lake, which resulted in an ongoing loss of open-water surface and the extension of reed cover. This is also perceptible in Austria, but in Hungary it is far more advanced. The extended reed belt represents the core area of the present nature conservation zone, but it is not stable as a result of recent landscape changes. Thus the question arises whether reed-belts (as a complex habitat structure) can be preserved without human management.

Hill ranges and foothills of the two countries show the same increase of vineyards. However, in Austria this process is more advanced, which together with the expansion of vineyards in lowlands presumably result from different agricultural subsidies of the two countries. A large proportion of extant "original" natural and semi-natural surfaces (showing land cover continuity) are situated on present protected areas. But not all of the continuous forest, wetland, grassland and water surfaces are under protection status. They are potential target areas for nature conservation and landscape restoration (e.g. reintroduction of free range grazing) (Korner et al. 2008). However, the quality or habitat value of these stable areas are not analysed in this paper. It requires future investigation to identify non-protected areas which deserve higher nature conservation status.

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