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LONG-TERM CHANGES OF LAND USE/LAND COVER PATTERN IN HUMAN TRANSFORMED MICROREGIONS – CASE STUDIES FROM BORSOD-ABAUJ-ZEMPLÉN COUNTY, NORTH HUNGARY

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Abstract: Using historical geographic and landscape ecological methods three North Hungarian landscape units that underwent different types of anthropic impact were studied. Viticulture in the Nagy Hill of Tokaj was founded more than eight centuries ago, however, due to economic crises and the phylloxera epidemic extension of the vineyards has fallen to less than one-half during 250 years; wetlands and grassland of the Taktaköz were changed by arable lands after river regulation and flood prevention performed in the second half of the 19th century; and traditional land use/land cover pattern of the East Borsod Coal Basin has been transformed by coal mining and industrialization from the end of the 19th century. On the basis of study on transformation of land use/land cover patterns, consequences concerning landscape planning of the studied areas can be drawn. (1) Vineyards of the Nagy Hill of Tokaj have represented a traditional land use category in the area for many centuries; therefore, re-plantation of the abandoned vineyards would be the reasonable purpose. (2) In the Taktaköz arable lands have become dominant land use elements. Although the recent land use pattern can be regarded as traditional, the ancient wetlands and grasslands could be, at least partly, restored by significant landscaping work. (3) In the East Borsod Coal Basin the extension of forest has spontaneously increased after the closure of coal mines, therefore, the pre-mining landscape pattern could be more-or-less restored without considerable landscape transforming action.

Keywords: land use/land cover change, human impact, disturbance, hemeroby, landscape planning

1. INTRODUCTION

Study on long-term changes in land use/land cover (LULC) is quite important from several points of view. Studying the long-term development of LULC we can understand dynamics and transition of the landscape and the land systems, consequently, these researches can be directly used in landscape planning and natural conservation. Moreover, social, economic and environmental problems can also be detected not only on local but even on global scale (see, for example Kates et al., 1990; Turner II et al., 1994; Vitousek et al., 1997).

Although humans have transformed the land cover for centuries, and during the last half-century rate of alteration of the natural and/or traditional landscape was much higher than ever (Ramankutty & Foley, 1999; Foley et al., 2005; Goldewijk, 2001). Furthermore, human geomorphological impact may have exceeded that of the natural geomorphological factors (Nir, 1983; Hooke, 2000; Rózsa, 2007; Szabó, 2010). In the formerly socialist countries fundamental changes have occurred in LULC pattern after the collapse of the political regime.

Transition of the LULC and its different environmental and social impacts have been studied in detail in the post-socialist countries, such as in the Czech Republic (Popelková & Mulková, 2011; Skokanová et al., 2012; Havlíček & Chrudina, 2013; Bičík et al., 2015; Kupková & Bičík, 2016), in Poland (e.g. Latocha, 2009; Harvey et al., 2014; Ciupa et al., 2016), in Romania (e.g. Müller et al., 2009; Petrişor, 2012; Prăvălie et al., 2013; Gavrilidis et al., 2015), in Slovakia (e.g. Cebecauer & Hoflerka, 2008; Olah et al., 2009; Kanianska et al., 2014), in Serbia (e.g. Ristić et al., 2013), and in Ukraine (Dezső et al., 2005). Moreover, bilateral and multilateral cross-border studies have also been performed (Feranec et al., 2000; Munteanu et al., 2014; Skokanová et al., 2016).

Similarly, in Hungary several studies have been completed concerning consequences of changes in LULC pattern; thus, for example, papers dealing with impact of historical land use changes on aquatic environment (Nagy & Jung, 2005), sediment fluxes (Jordan et al., 2005), soil properties and erosion (Szilassi et al., 2006, 2010), topography of urbanised areas (Lóczy & Gyenizse, 2010), landscape values (Sallay et al., 2012), floodplain area (Varga et al., 2013), viticulture and vineyard reconstruction (Dobos et al., 2014), and land-stability (Demény et al., 2016), etc. have been published.

In this paper, comparative study of three areas of different dominant landscape types is presented. These areas are located in Borsod-Abaúj-Zemplén County, NE Hungary, and they have undergone different human disturbances: on the Nagy Hill at Tokaj town viticulture has been the dominant land use for centuries; in the Taktaköz tillage has represented the main land use type for more than one century; and in the East Borsod Coal Basin (EBCB) coal mining was the main landscape forming factor during the 20th century (Fig. 1).

Although ecological, physical geographical and geological conditions of these areas have intensively been studied, however, only a few studies have been published concerning their LULC: Csorba & Szabó (2009) estimated hemeroby levels for Taktaköz and Nagy Hill; Dobány (2010; 2014) introduced historical geographical conditions of Sajó-Bódva interfluve and Taktaköz, respectively; Nyizsalovszky & Fórián (2007) investigated human impact of the Tokaj Foothill Region; and Novák et al., (2013a, 2013b) studied relationship of land use and anthropic transformation in Nagy Hill at Tokaj; Demeter (2006) revealed connection between land use change and social-economic needs in the southern part of the EBCB; and Sütő (2013) studied the impact of coal mining on land use pattern for the EBCB.

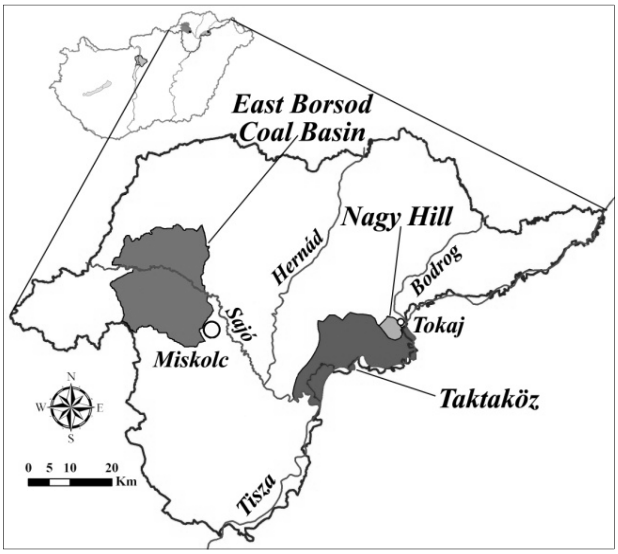

Figure 1. Location of the study areas

Aim of our recent study was to compare different types of human interventions on the LULC during the last 250 years. Accordingly, we intended

(1) to identify and determine the changes in LULC in the study areas in the last 250 years;

(2) to trace driving forces of the changes in LULC.

(3) to suggest landscape-planning implications of long-term changes in LULC pattern.

2. STUDY AREAS

Nagy Hill (514 m a.s.l.) is located at the southern end of the Tokaj Mountains. Its areal extension is approximately 2.1 km^2, and it can be delimited by the 100 meter elevation contour line. Nagy Hill is an eroded Late Miocene stratovolcano built up from pyroxene dacite lava flows and pyroxene dacite tuff; in the northern margin some rhyolite and perlite can also be found (Zelenka et al., 2012). Significant part of the remnant volcano is covered by 1-10 m thick loess deposited in the late Pleistocene. The annual mean temperature is 8.5-10 ºC, lower at the top, and higher at the base; the precipitation varies between 550-600 mm with a maximum in summer. The natural vegetation is deciduous forest dominated by pedunculate and sessile oak (Quercus robur and Quercus petraea, respectively) as well as hornbeam (Carpinus betulus). On the exposed slopes forest-steppe mosaics (Quercus pubescens, Stipa and Festuca spp.) could be native (Dövényi, 2010). The steep slopes as well as geological-pedological conditions of the hill are favourable for viticulture which was founded as early as the 13-14th century immediately after the Tartar invasion (1241–42), and it has been the dominant human activity on the hill, excepting slopes situated higher than 400 m a.s.l. where forest can be found.

The Taktaköz microregion is located south and southwest of the Nagy Hill between the Tisza River and the Takta Brook. The extension of this alluvial floodplain is cca. 209 km^2, its elevation varies from 93 to 115 m a.s.l. The known basement of the area is built up from Miocene rhyolitic-dacitic formations. During the Pleistocene water flows coming from the Tokaj Mountains built their 30-120 m thick fans containing sandy and silty sediments, and some loessy cover deposited on the surface. Finally, in the Early Holocene the area became the floodplain of the Tisza River which eroded more than 90% of the sandy and loessy surface, and deposited floodplain silt. The annual mean temperature of the microregion is 9.5-10°C the annual precipitation is 540-580 mm. The potential vegetation was hard-wood floodplain forest of ash and elm (Ulmo–Fraxinetum), tall graminoid meadow marsh (Phragmiti–Magnocaricetea), as well as here and there small oak forests (Aceri tatarico–Quercetum) (Dövényi, 2010). Settling was determined by channel network and flood of Tisza River and their affluents: levées and wind-blown sand "islands" (approximately one third of the total area) served as scenes for human settlements (Dobány, 2014). The recent landscape dominated by arable lands was formed after the river regulation of the 19th century.

The approximately 500 km^2 intra-montane hilly area of the EBCB is rather an economic geographical-geological than a physical geographical region. From physical geographical point of view, EBCB is the area of the hills on both sides of Sajó River that belong to catchments of small affluents of the river. Its central part is the Sajó Valley Basin microregion which divides it into two parts: the southern one is actually formed by the northern part of Tardona Hills and Uppony Mountains, and the northern one is formed by southern part of Putnok Hills microregions, respectively. These microregions can be regarded as foothill areas dissected by watercourses. The Palaeozoic-Mesozoic basement is covered by mass movement susceptible Miocene fluviatile aleurite-sand-clay with intercalation of 5 mineable (and more than 50 adjacent) seams (Salgótarján Lignite Formation). On the hilly areas potential vegetation are forest with oak and turkey oak (Quercaetum petraeae–cerris), along the brook-valleys soft-wood floodplain forest with sallow and alder can be found; along the Sajó River potential vegetation are floodplain forests and marshy meadows. Along the brooks and the Sajó River hydromorphic earth, on the hilly areas brown earth was formed. The annual mean temperature is 8.8-9.3°C, the annual precipitation is 550-600 mm (Dövényi, 2010). Settling progressed from the river valley towards the hilly areas, however, because of low productivity soils, as well as erosion and mass movement susceptibility on the slopes only small villages occurred until the mid-19th century. This pattern was fundamentally transformed by coal mining providing energy basis for heavy industry founded in the region. Consequently, population and extension of the settlements as well as extension of tillage showed quick growth (Sütő, 2013).

3. METHODS

Comparison of the model areas was made by using censuses (such as the *Investigatio* compiled for the Maria-Theresa's *Urbarium* in second half of the 18th century) and mining records and maps (BSzT, 1957a–d, 1960, Bertalanfy et al., 1986). The relevant sheets of the military surveys were also used, i.e., the First Military Survey (1783–1784) mapped on a scale of 1:28000; the Second Military Survey (1857–58) mapped on a scale of 1:28000; and the Third Military Survey (1883) mapped on a scale of 1:25000; and explanatories of military survey maps (Takács, 1987; Pesty, 1988; Tóth, 1991; Pók, 1993). Applying the sheets of these surveys for study on historical LULC is widely used in the countries of the former Habsburg Empire (Mackovčin, 2009; Olah, 2009; Olah et al., 2009; Skaloš et al., 2011; Skokanová et al., 2012; Varga et al., 2013; Dobos et al., 2014; Kanianska et al., 2014; Ciupa et al., 2016; Demény et al., 2016). To study the recent LULC pattern the Corine Land Cover 2000 on the scale of 1:50000 (CLC2000) digital map of Hungary was used. Maps of different projections and topics were converted into common projection system (EOV) with Quantum GIS 2.12. To trace the changes, land use data of the maps were uniformized by categories (settlement, mining, industrial area, vineyard, arable land, grassland, forest, wetland, water course or lake) and vectorized with ArcGIS 10 software.

Table 1. Multiplying factors for the hemeroby levels

oligohemeroby	1
mesohemeroby	2
β-euhemeroby	4
α-euhemeroby	8
polyhemeroby	10
metahemeroby	15

To estimate human transformation of landscapes in a given period LULC categories were classified into 6 (oligo-, meso-, α-eu-, β-eu-, poly-, metahemerobe) levels, and ratio of the LULC categories were weighted by multiplying factors suggested by Csorba and Szabó (2009). These factors are listed in Table 1. (For classification of categories of LULC into hemeroby levels see Table 1 in the cited paper.)

To estimate montanogenic relief disturbance a new method was developed (Sütő, 2013). Values of vertical relief changes were calculated for each montanogenic field objects, and then their absolute values were summed, that is:

(1) $B_d=\ln(|M_t|+|M_h|+|M_{\mathrm{bt}}|+|M_{\mathrm{bv}}|+|M_e|)$,

where B_d: mining disturbance;
- M_t: thickness of the extracted bed;
- M_h: elevation of waste dump;
- M_{bt}: mining plant (used average: 1 m);
- M_{bv}: mining railways (used average: 1 m);
- M_e: elevation or deepness of other mining objects summarised on given surface (in meter).

4. RESULTS

By using digitalized historic maps and records mentioned in chapter 2 as well CLC 2000 extension of different LULC categories was calculated for 4 periods (late 18th century, mid-19th century, late 19th century, and turn of the Millennium. Ratios of LULC categories for the sites in the different periods are listed in Table 2.

Land use indicated by the First Military Survey, was regarded as the ancient traditional land use (Fig. 2A&B). Due to the different natural and environmental conditions LULC patterns of the studied areas differed from each other even then. In the late 18th century almost 85% of the area of Nagy Hill was used as vineyard; approximately 50% of the Taktaköz was grassland, however, wetlands also represented considerable land use; the EBCB was dominated by forests (more than 40%), but extension of arable land was also significant (almost 30%).

The Second Military Survey indicates only moderate changes in LULC for the EBCB, however, remarkable transformations can be noticed for the Nagy Hill and the Taktaköz. In the case of Nagy Hill significant decrease in vineyards (almost 25%), and increase in extension of arable land and grassland (almost 10% per each) can be observed. In the Taktaköz wetland area seriously reduced (from 22.7 to 7.1%), while extension of grassland increased by more than 10%.

By the time of the Third Military Survey, significant changes in LULC pattern had occurred for Nagy Hill: vineyard area reduced by another 10%, and ratio of arable land reached more than 20%; extension of grasslands, however, shows no change. In the Taktaköz more significant transformations occurred. Ratio of arable lands increased by two and a half times, and it became the dominant land use in the microregion. At the same time, extension of grassland almost halved. In the ECBC area former tendencies in LULC, i.e. moderate increase of arable lands and decrease of forests, continued. As a result, ratios of arable land and forest were equalized.

CLC2000 indicates that some further remarkable changes happened to LULC pattern of the study areas from the late 19th century to the turn of the Millenium (Fig. 2 C, D). In the Nagy Hill extension of vineyards reduced to as low as one third of the total area of the microregion. Viticulture tended to concentrate on the lower part of the slopes (Boros, 1982). Ratio of arable lands considerably decreased, it practically halved. At the same time, ratio of forest shows six-fold increase (from 4.9 to 29.4%). In the Taktaköz area arable lands further increased, their ratio exceeded 60%. Although grassland remained the second largest land use type, however, its extension more than halved.

Table 2. Pattern of LULC of the study areas in the investigated period

LULC	Nagy Hill				Taktaköz				EBCB			
	1	2	3	4	1	2	3	4	1	2	3	4
	%	%	%	%	%	%	%	%	%	%	%	%
Artificial surface*	3.8	6.2	8.1	8.1	1.3	2.2	2.4	3.9	1.1	1.1	2.0	9.5
Arable land	2.8	12.8	20.5	11.0	16.4	17.8	45.8	61.6	28.8	28.9	33.4	22.8
Forest	6.5	3.5	4.9	29.4	6.0	5.0	4.8	7.9	41.5	38.7	34.2	39.7
Grassland	2.7	12.0	12.7	13.9	49.1	61.2	39.4	15.4	17.6	20.1	19.3	22.3
Vineyard	84.2	60.7	50.8	35.4	0.0	0.0	0.0	0.2	8.0	6.6	6.7	<0.1
Waterflow, still water	0.0	0.0	0.0	0.1	4.5	6.7	5.8	4.9	0.6	0.6	0.6	0.5
Wetland	0.0	0.0	0.0	0.0	22.7	7.1	1.8	4.3	0.8	1.3	1.4	0.1
Other**	0.0	4.8	3.0	2.1	0.0	0.0	0.0	1.8	1.6	2.7	2.4	5.1

1.First Military Survey; 2. Second Military Survey; 3. Third Military Survey; 4: CLC2000
*including settlements, industrial areas, quarries, mining claims
**orchards, gullies, complex cultivation, etc.

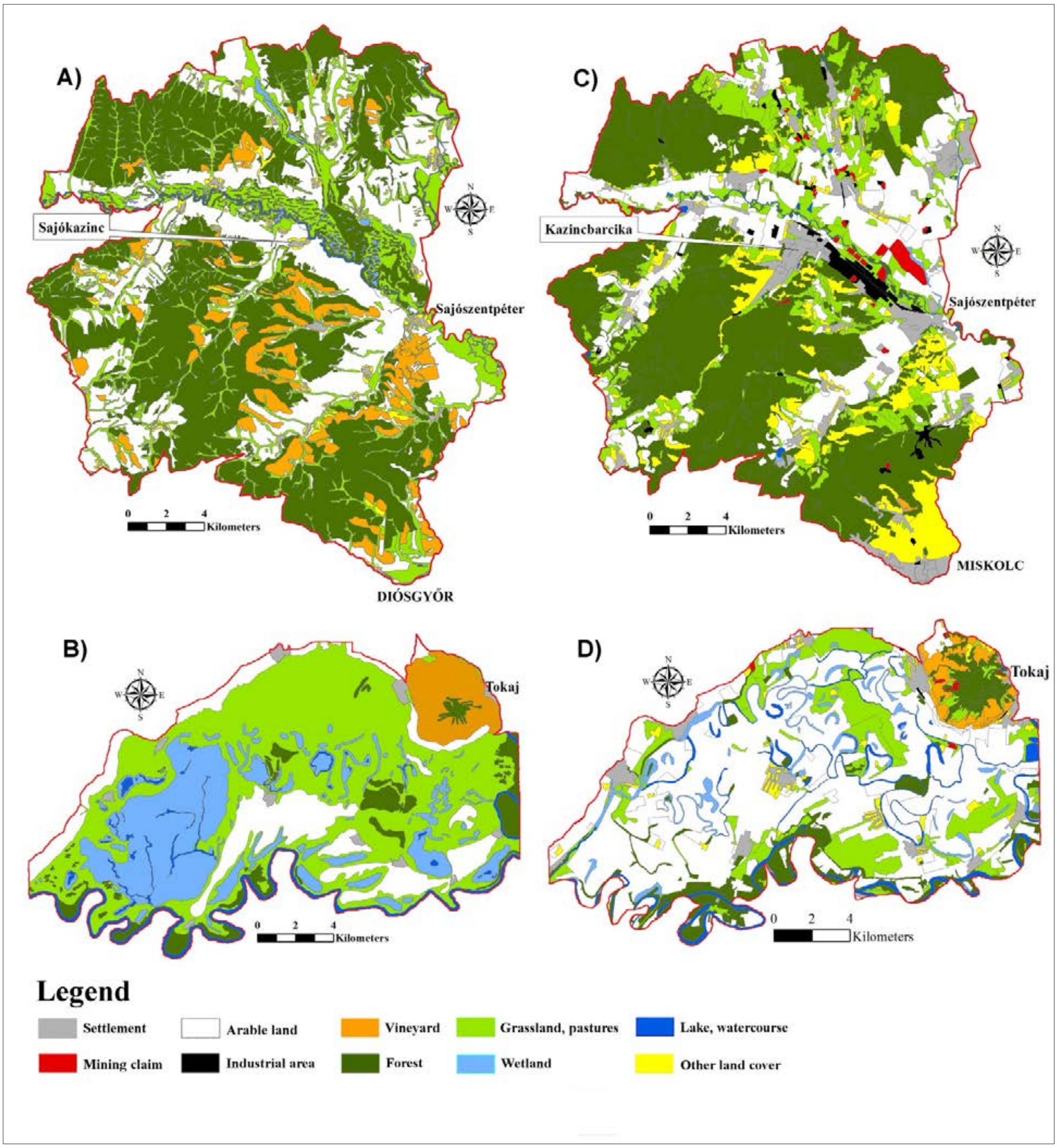

Figure 2. A) LULC pattern in the EBCB at the time of the First Military Survey
B) LULC pattern in the Taktaköz and in the Nagy Hill at Tokaj at the time of the First Military Survey
C) LULC pattern in the EBCB according to the CLC2000 digital map
D) LULC in the Taktaköz and in the Nagy Hill at Tokaj according to the CLC2000 digital map

In the EBCB forests represent the largest land cover type, their ratio almost reaches 40%. Moreover, area of artificial surface dramatically increased; increase in its ratio was almost fivefold. At the same time, extension of arable lands significantly decreased, and it reduced to two-third of its former value.

5. DISCUSSION

Although all the three study areas can be regarded as rural country of peripheral geographical situation, due to their different natural conditions and socio-economic background their LULC differed from each other as early as the 18th century. Later, during the last two and a half centuries different human impacts affected these territories. Degree of human influence on natural environment is usually characterized by using hemeroby scale. Aggregate hemeroby values for the study areas in the different investigated periods are listed in Table 3. The values were calculated by the weighting method suggested by Csorba & Szabó (2009) (see Chapter 3 for details).

Table 3. Changes of hemeroby values for the study areas

year	Nagy Hill	Taktaköz	EBCB
1783-84	754	217	280
1856-60	677	245	277
1883-84	652	310	301
1999	514	361	340

In the case of Nagy Hill at Tokaj between the First and the Second Military Surveys degree of hemeroby decreased (Fig. 3) due to the significant increase of arable land and grassland area against vineyards. By the end of the 19th century hemeroby values moderately decreased due to further loss of vineyard area and growth of the extent of arable lands. In the late 1880s and early 1890s devastating phylloxera epidemic swept over the Hungarian vineyards. As a consequence, famers tended to give up cultivating the vinery. Moreover, the rapidly developing industry offered possibility of employment for the agricultural labour surplus. After the phylloxera epidemic, however, human disturbance gradually decreased because of forestation and an increase of shrubby-bushy areas. Simultaneously, extension of both vineyards and arable lands considerably decreased. Accordingly, hemeroby value for the microregion considerable decreased mainly due to remarkable increase in forest.

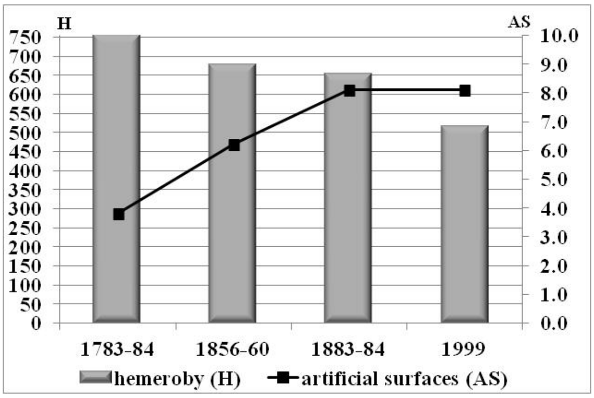

Figure 3. Changes in values of hemeroby and ratio of artificial surfaces for the Tokaj Hill

Peculiarly, hemeroby values and ratio of artificial surface has changed oppositely. This suggests that direct and intentional human impact concentrated in the relatively small area of two settlements (Tarcal and Tokaj) located in the foothill area, and changes in hemeroby values was basically controlled by changes in the extent of vineyards, arable lands, grasslands and forests.

In the second half of the 18th century almost one-fourth of the Taktaköz plain was wetland flooded by Tisza River and Takta Brook year by year; arable land represented less than one-sixth of the area. Moreover, ratio of artificial surfaces (settlement, roads, etc.) hardly exceeded 1%. Consequently, the calculated hemeroby value for the area is as low as 217 (Table 2 and Fig. 4).

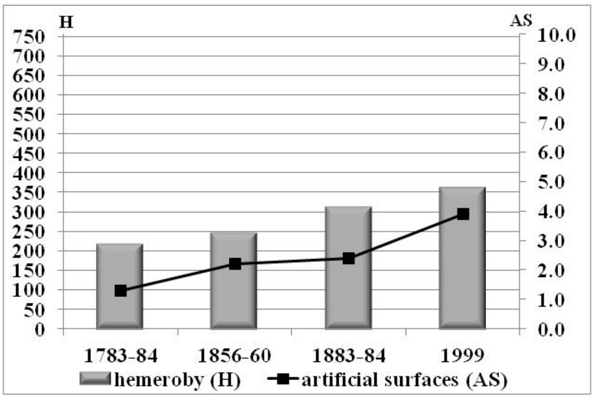

Figure 4. Changes in values of hemeroby and artificial surfaces for the Taktaköz

Although some decrease in wetland area and increase in grassland can be observed, the semi-natural character was retained until completion of river regulation and inland water protection works in the second half of the 19th century. Since the area has become practically to be prevented from floods, the ancient landscape and the traditional LULC had to be changed: floodplain management and pasturing was replaced by arable farming; this tendency continued during the 20th century, and a relatively homogeneous agricultural landscape has been formed (Fig. 2 B, D). Hemerobic conditions declined parallel to gradual extension of arable lands. Because of increase in maintenance capability of the area coming from river regulation population of Taktaköz doubled within some decades (Dobány, 2014). Since then, however, increase of population and that of artificial surface became slow (Fig. 4).

From the late 18th to the end of the 19th century LULC pattern in the area of the EBCB moderately but progressively changed: area of forest decreased from 41.5 to 34.2% while that of arable lands increased from 28.8 to 33.4%; although ratio of artificial surfaces doubled, its value was as low as 2% (Table 2). Consequently, hemeroby level for the EBCB hardly increased during that period (Table 3; Fig. 5).

Initially, coal mining did not represent significant impact on the surface and on LULC in the EBCB. The mining activity operated under the surface, and increase in built-up area of the settlements was quite moderate. From the late 19th century, however, a fivefold increase in artificial surface can be observed due to foundation of the dominantly coal mining based heavy industry, however, this industrialization process basically concentrated in the southern part of the Sajó Valley microregion. Moreover, mainly spontaneous reforestation in the hilly area can also be observed: ratio of forests has approximated the value in the late 18th century (Table 2). This kind of reforestation of the abandoned agricultural areas is quite general in the post-socialist countries (Munteanu et al., 2014; Varga et al., 2015). As a consequence, considerable increase in artificial surface was followed by quite moderate increase of hemeroby level (Fig. 5).

However, mining considerably transformed the landscape in some areas of the EBCB. According to the disturbance map, in the region the largest rate of transformed surfaces is found in the Pereces and Lyukó catchment area. According to disturbance index calculated by using Equation (1), 68-70% of its area underwent mining disturbance due to long-term exploitation of four coal seams (Fig. 6).

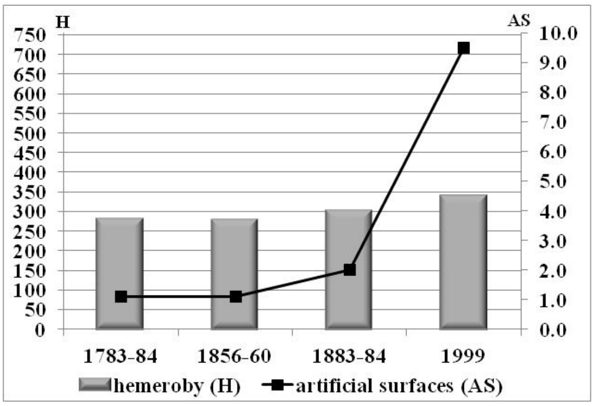

Figure 5. Changes in values of hemeroby and artificial surfaces for the EBCB

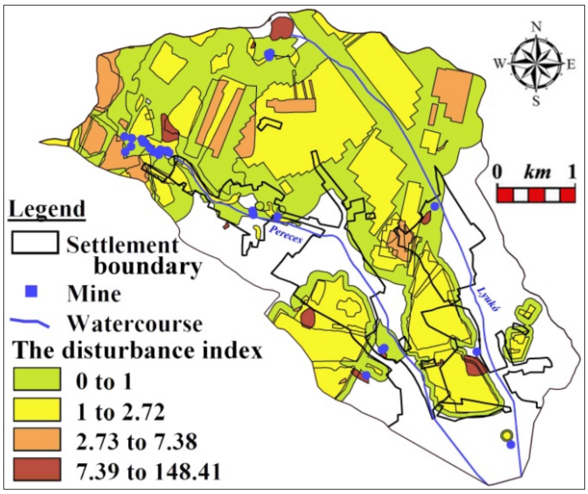

Figure 6. Disturbance map of the Pereces and Lyukó catchment area

6. CONCLUSIONS

Study on the three investigated areas revealed similarities as well as differences in their long-term transformation of LULC pattern.

At the end of the 18th century more than four-fifth of the area of Nagy Hill was used as vineyard. During the next half a century, however, ratio of vineyards significantly decreased (although remained dominant) as that of arable land and grassland increased. This crisis of viticulture in the Tokaj Region was the consequence of partition of Poland and the subsequent imposition of duties (Nyizsalovszky & Fórián, 2007). In the next 30-40 years restriction of viticulture continued. In 1885 the phylloxera epidemic reached Tokaj and destroyed vast majority of the grape plantations. Although reconstruction of the vineyard started in the 1900s, the process was not completed because Tokaj wine lost considerable part of its domestic market due to collapse and disintegration of the Austro-Hungarian Empire. During the second reconstruction the new plantation were formed mainly in the lower part of the slopes, and vineyards in the higher and steeper slopes were abandoned and partly afforested (Nyizsalovszky & Fórián, 2007).

In the late 18th century human impact was limited to quite small area in the Taktaköz, and until the last third of the 19th century there were no significant changes in LULC pattern for the area. Due to river regulation and flood control work of Tisza River performed in the second half of the 19th century, LULC pattern was radically transformed: ratio of grassland characteristic for the area decreased considerably and the microregion has become a cropland dominated terrain. During the last one hundred years dominance of arable land continuously increased.

From the end of the 18th century to the middle of the 19th traditional LULC pattern dominated by forests and, subordinately, arable lands and grasslands hardly changed in the EBCB. In the last quarter of the 19th century, however, Hungary underwent a rapid and powerful social and economic development basically due to the Austro-Hungarian Compromise concluded in 1867. Energy need of the developing heavy industry and railway system induced the exploitation of coal resources of the country including the coal fields in Borsod County. After World War II coal production was continued to increase for satisfying energy requirements of enforced industrialization. Coal mining and heavy industry as dominant human activities transformed LULC pattern of the area: ratio of arable lands has decreased, while that of artificial surfaces has increased fivefold.

Study on transformation of LULC may also have landscape planning implications, since prevention or reconstruction of historical landscape must be supported by anthropo-geomorphological and landscape metric analyses based on historical geographical studies. Land use planning, however, should meet not only the current but future social and ecological expectations (Brown & Raymond, 2014).

In the case of the Nagy Hill at Tokaj, viticulture as the dominant human impact of the landscape have history of several centuries, and the name of 'Tokay wine' became a world-famous brand. Therefore, increase of human viticultural activity would be required and replantation of the once famous abandoned vineyards would be the most reasonable and advantageous purpose.

Arable land dominated LULC pattern has been characteristic for the landscape of Taktaköz for more than a century, and it may represent cultural heritage and landscape structure elements (Altieri, 2004); consequently, one possible landscape planning aim would be to prevent and sustain tilling of arable land. Due to topographic and hydrographic conditions, however, some elements of floodplain management could be resumed in fallow lands and arable lowlands of poor quality meadow soil.

Economic prosperity of hilly terrains of the EBCB was supported by coal mining, and mining closure was followed by rapid economic decline leading to a kind of autarchy, again. Although there are some projects intending to re-open some closed coal mines, landscape history of the area suggests that coal mining itself does not improve long-term sustainable economic development of the area. Because non-visible consequences of subsurface coal mining represent restraining factors in land use development, re-vitalisation of traditional hilly farming and forestry may play important additional role in the low populated inner hilly areas (Sütő, 2013). Spontaneous reforestation should be followed by planned afforestation focusing on both timber industrial and ecological aspects would be required.

It is well-known that land use conflicts are frequent, particularly, in the peri-urban area (von der Dunk et al., 2015; Gavrilidis et al., 2015). In our study areas conflicts between the economic operators and the natural preservation organizations may emerge. Far-seeing landscape planning, however, is able to take nature and extent of human disturbance into consideration, and focusing on anticipation and negotiation (Dobos et al., 2014; Hersperger et al., 2015) disagreements may be eliminated or, at least, reduced.

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