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Analysis of land stability and land-use change processes in the 19–20th centuries: a case study in Gödöllő Hillside, Hungary

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Abstract: The manuscript presents land-use change processes based on former military map analyses. Military maps were derived from the 1770s until the 1890s and later from the CORINE Land Cover map. I observed the transition direction of areal distribution of various land uses. Digitalized maps showed 19–20th century land-use conditions; besides them, we created a grouping system which is based on the intensity of land use. We distinguished six land-use types, ranking them according to the anthropogenic influence (1. built-up areas; 2. arable fields; 3. orchards and vineyards; 4. meadows and pastures; 5. forests; 6. wetlands).

Keywords: historical maps, land stability, land use

1. Introduction

In the past few decades, several studies have been written about the research on landscape change [1, 2, 3, 4, 5], which help to understand the rapid changes in the spatial structure of the landscape. They are also trying to provide a starting point for landscape planning by means of using different approaches and aspects.

Not only the structure of the landscape has changed rapidly but also the methods used for the description of such changes. Besides simple, descriptive studies – and often complementing them –, there have been studies using landscape metrics [6, 7, 8, 9, 10, 11, 12], which help to understand social, economic, and environmental issues. Among other things, they are useful in assessing the naturalness and anthropogenic alteration of landscapes [13], thus revealing the fragmentation of the landscape. The primary causes for the fragmentation of the landscape is increasing land usage [14, 15], but the development of transport infrastructure (roads, railways) and the expansion of human settlements also contribute largely to the break-up of habitats, causing severe fragmentation [9, 16, 17, 18, 19, 20].

Besides studies using landscape metrics, the primary analysis of research findings concerning the presentation of changes in the landscape and in land cover is based on the examination of historical maps [21, 22, 23, 24, 25, 26, 27, 28], aerial photography [29, 30, 31, 32], as well as (GIS-based) satellite images [33, 34, 35, 36]. The advantage of such approaches is that they make it possible to understand current events and to explore future possibilities. They can provide a basis for exploring the differences and similarities or the stability and changes between two or more points in time, even in terms of land-use categories. They may also help to resolve disputed land ownership issues.

This study applies the latter direction, i.e. out of the different approaches we have chosen the method that utilizes historical maps. We will present the locations and intensity of land use during the past 200 years.

2. Materials and methods

The region we explored is the area of Gödöllő Hillside, which is situated to the east of the capital (Budapest); it is rich both in nature and landscape values. It belongs to the Northern Mountain Ranges according to the micro-region classification. The area of Gödöllő Hillside is 550 km^2 and it consists of 16 settlements. The landscape varies between 130 and 344 m.a.s.l., which reduces towards the south-east [37]. The highest point of the hillside is Margita (344 m), which is situated near the village of Szada, located in a suburban region, and the lowest point is near Gyömrő (130 m). It is a diverse micro-region with twofold natural characteristics. Due to its landscape characteristics, the micro-region is a transitory area between a plain terrain and medium-height mountain ranges from the aspect of geological, climatic, botanical, and soil features. Besides the natural conditions, the land use in the micro-region is determined by its role in the country's economy, good accessibility, and ecological conditions. The change in land use happened in parallel with the transformations in the population number [38].

In this study, we have analysed only the area delineated by the four central towns (Veresegyház, Szada, Gödöllő, and Isaszeg) of the 16 settlements belonging to Gödöllő Hillside (*Figure 1*). The administrative boundaries of 12 settlements extend beyond the border of the hillside; therefore, we narrowed down the area to the settlements the outer boundaries of which are entirely within the hillside. Our previous observations [39, 40] have also confirmed that this is the area where the scope of changes requires further analyses.

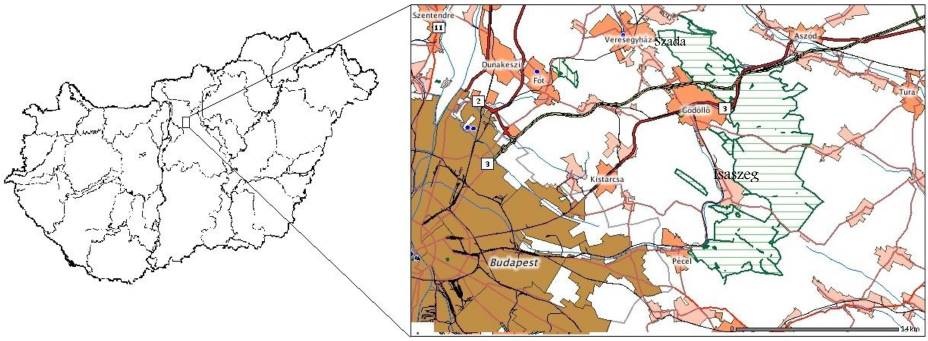

Figure 1. Location of surveyed areas [41]

The changes in land use have been studied by the aid of the 1st and 3rd military maps, as well as the CORINE Land Cover (CLC 50) maps. Our aim, besides presenting the 19–20th century conditions, was creating a category system which is based on the intensity of land use, i.e. on changes in the “natural environment” caused by anthropogenic influence. We digitized available maps, carried out a comparative study between adjacent time periods, and then we displayed the results on a map.

We distinguished six different land-use methods: built-up areas, orchards and vineyards, meadows and pastures, forests, wetlands, and arable fields. The various land-use categories have been ranked according to anthropogenic influence, primarily from the nature conservation point of view, as follows: 1. built-up areas; 2. arable fields; 3. orchards and vineyards; 4. meadows and pastures; 5. forests; 6. wetlands.

Next, maps from earlier periods have been projected on later maps (the First and Second Military Survey as well as the Third Military Survey and the CLC 50 survey), which resulted in a change map. The polygons have been recoded, and then ranked according to the above aspects, after which the direction of the change (positive, negative, no change) was identified.

As a result, we received an 11-member scale: from (-5) to (+5), where the section between -5 and -1 denotes a negative change, the section between 5 and 1 shows positive change, while 0 means that the area of the given polygon was stable and free of change (*Table 1*).

Table 1. Evaluation of different land-use types based on historical maps

	After	Built-up area	Arable land	Orchard, vineyard	Meadow, pasture	Forest	Wetland
Before	Code	1.	2.	3.	4.	5.	6.
Built-up area	1.	**0**	+1	+2	+3	+4	+5
Arable land	2.	-1	**0**	+1	+2	+3	+4
Orchard, vineyard	3.	-2	-1	**0**	+1	+2	+3
Meadow, pasture	4.	-3	-2	-1	**0**	+1	+2
Forest	5.	-4	-3	-2	-1	**0**	+1
Wetland	6.	-5	-4	-3	-2	-1	**0**

After this, the categorization was refined according to negative changes, since our aim was to determine anthropogenic alterations,
where: -0 = stable area,

– (-1) – (-2) = denote minor alterations. We agreed on labelling a change which is one or two value points a minor change (in any category). Any change greater than this indicates a higher intervention, therefore larger figures, i.e.:

– (-3)-(4)-(-5) = denote major alterations for the purposes of our study.

We prepared the area of land cover maps using the following sources:

1. 1st (1763–1787) Military Survey Map (Scale = 1:28,800) (Arcanum Ltd),
2. 2nd (1806–1869) Military Survey Map (Scale = 1:28,800) (Arcanum Ltd),
3. 3rd (1869–1885) Military Survey Map (Scale = 1:25,000) (Arcanum Ltd),
4. CORINE Land Cover maps (2003) (Scale 1:50,000).

ESRI ArcView 3.2 was used for digitizing the maps, to prepare spatial statistics and layouts for presentation.

3. Results and discussions

The structure of the land has changed significantly in the past 200 years. Due to intensive land use (farming of lands, building up of areas, developing roads), the average size of habitats has diminished, the previously homogeneous land-use methods have become greatly fragmented. The huge increase of patches indicates the same tendency.

The towns we have chosen (Veresegyház, Szada, Gödöllő, and Isaszeg) belong to the core of Gödöllő Hillside, covering 1/3 of the area. In the late 1700s, after the end of the Ottoman rule, their population was insignificant, but by the end of the 1900s and the beginning of the 2000s population had boosted significantly, which greatly increased the proportion of developed environments (23.7%) and the intensity in land use (*Table 2*).

Table 2. Land-use changes between 1763 and 2003 (%)

Land-use type	1st Military Survey Map	2nd Military Survey Map	3rd Military Survey Map	CLC 50
Built-up area	0.74	1.09	1.27	23.72
Forest	33.30	33.66	27.09	46.76
Wetland	7.77	5.26	4.86	1.46
Pasture, meadow	48.23	41.94	25.31	5.18
Arable land	4.59	12.23	34.13	22.28
Orchard	0.90	1.22	1.26	0.59*
Vineyard	4.47	4.60	6.09	

*orchard + vineyard

3.1. The 1st and 2nd military maps

Comparative analysis based on the 1st and 2nd military maps revealed that during the 19th century the area of 65.79% stayed unchanged, which indicates a large stability in land use. Negative changes, however, are more dominant than positive ones: they affected 22.35% of the land.

No major restructuring occurred during the 1st (1763–1787) and the 2nd (1806–1869) military survey; the two dominating land-use methods were meadow/pasture management and forestry. Larger contiguous forests can be found in the middle and eastern parts of the hillside (around Gödöllő and Isaszeg), which retained their original functions. It should be noted that viticulture had a great significance relative to the size of the inhabited area, providing a major way of living in the region for about 100 years (*Table 2*).

Based on the ranking of sensitivity, forests proved to be stable land-use methods (*Table 3*), while wetlands were the most affected by changes. Wetlands were primarily transformed into meadows and pastures or became used as arable fields. Disregarding wetlands, stability distribution is above 60%.

Table 3. Ranking of sensitivity according to the land-use methods between the 1st and 2nd military maps (%)

Land use /code	**Built-up area (1.)**	**Arable land (2.)**	**Orchard/ Vineyard (3.)**	**Meadow/ pasture (4.)**	**Forest (5.)**	**Wetland (6.)**
-5	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.55
-4	*0.00*	*0,00*	*0.00*	*0.00*	0.22	16.34
-3	*0.00*	*0.00*	*0.00*	0.50	1.03	3.63
-2	*0.00*	*0.00*	5.01	14.74	2.07	39.08
-1	*0.00*	0.00	2.48	2.88	19.31	13.37
0	**62.92**	**73.48**	**61.79**	**64.04**	**77.03**	**27.04**
+1	0.24	0.02	19.81	13.08	0.34	*0.00*
+2	19.35	11.25	9.72	4.76	*0.00*	*0.00*
+3	1.25	1.03	1.19	*0.00*	*0.00*	*0.00*
+4	12.46	14.22	*0.00*	*0.00*	*0.00*	*0.00*
+5	3.77	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

Typical transformations: built-up area → orchard/vineyard; arable field → wetland; orchard, vineyard → built-up area; meadow, pasture → arable field; forest → meadow, pasture; wetland → meadow, pasture. The area is characterized by minor transformations (*Figure 2*) although changes affected wetlands the most, which are the most sensitive areas in terms of nature conservation.

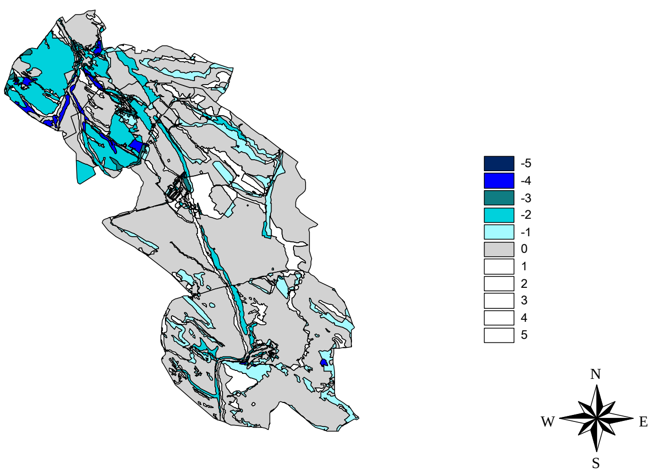

Figure 2. Degree of transformation between 1st and 2nd Military Map

3.2. 3rd Military Maps and CLC50 Maps

By the end of the 1800s, in the period of the 3rd Military Survey (1872–1885), the main land-use methods were arable field (34.13%) and forestry (27.09%). The proportion of meadows, pastures, and forests further decreased by ploughing up grasslands, and thus resulting in more arable fields (*Table 2*).

The abovementioned two farming methods remained dominant at the end of the 1900s and the beginning of the 2000s, but in a different order. The proportion of forests is exceptionally high, forestry being, as seen below, one of the most stable land-use methods. The role of forestry was greatly influenced by the fact that the area was first a royal pasture and then a hunting ground.

40.44% of the studied area remained stable, while nearly one third (32.34%) was transformed negatively. Negative changes affected primarily orchards, vineyards; meadows/pastures and wetlands; in all three cases, they were predominantly transformed into built-up areas (*Table 4*).

Two land-use methods are especially notable: built-up areas and forests. Following the rapid population growth of the 20th century and the suburbanization after the political changes in 1989, the area of built-up areas increased significantly. A large number of home gardens and much of the wetlands was also built up or filled in and became used as arable land.

Table 4. Ranking of sensitivity according to the land-use methods as to the 3rd Military Map and the CLC 50 Map (%)

Land use/code	**Built-up area**	**Arable land**	**Orchard/ vineyard**	**Meadow/ pasture**	**Forest**	**Wetland**
	(1.)	**(2.)**	**(3.)**	**(4.)**	**(5.)**	**(6.)**
-5	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	26.78
-4	*0.00*	*0.00*	*0.00*	*0.00*	7.94	25.16
-3	*0.00*	*0.00*	*0.00*	27.54	6.93	0.03
-2	*0.00*	*0.00*	65.68	14.06	0.06	15.28
-1	*0.00*	21.50	11.06	0.00	1.20	18.24
0	**85.02**	**41.92**	**0.00**	**4.71**	**83.61**	**14.51**
+1	10.26	1.70	0.03	52.66	0.25	*0.00*
+2	0.00	6.95	23.22	1.02	*0.00*	*0.00*
+3	0.58	26.57	0.00	*0.00*	*0.00*	*0.00*
+4	2.41	1.36	*0.00*	*0.00*	*0.00*	*0.00*
+5	1.73	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

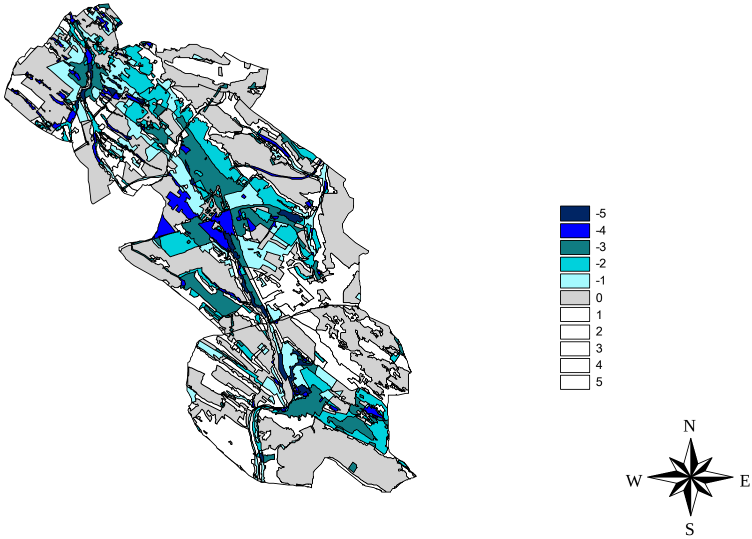

Figure 3. Degree of transformation between 3rd Military Map and CLC 50 Map

Typical transformations: built-up area → arable fields; arable fields → forest; orchard, vineyard → built-up area; meadow/pasture → forest; forest → built-up area; wetland → built-up area (*Figure 3*).

4. Conclusion

The methodology is capable of revealing numerous and obvious changes in land use. Areas with no changes between two snapshots of the land use (two mapping periods) provide good information about land stability that can be further analysed again as we approach the next mapping period.

The first period we investigated shows high landscape stability (65.79%), which is not characteristic of the second period (40.44%). The study focused mainly on changes in nature conservation areas, and we can also conclude that the introduced categorization was useful and indicated a decrease in landscape stability. These changes are caused by the fragmentation of previously contiguous areas (increasing number of polygons) and the increasing role of anthropogenic alteration (primarily, e.g. the areal changes due to the effects of suburbanization).

It is clear that negative effects predominate over positive changes in both time periods. Although we showed minor transformations in both cases, stability indicators varied on a wider scale in the second time period. According to our calculations, the stability percentages vary between 0 and 85.05%.

We have clearly proved that transformations in the first period had multiple causes, such as demographic changes or changes in the structure of agriculture. Transformations during the second period were primarily caused by population growth, which resulted in more built-up areas in the region. For the most part, this can be explained by the proximity of Budapest. Changes in the 19th century affected more of the northern, more densely populated part of the region, which may have been caused by the construction of the Veresegyház railway line. By the 20th century, these changes spread equally to the southern parts as well, which may be explained by the building of the suburban railway line.

Analysis of landscape stability based on historical maps can greatly contribute to predicting the future changes in the landscape structure of Gödöllő Hillside. The tendencies we have observed are probably valid in the medium term, as well. The current analysis may be further complemented, e.g. by a sensitivity ranking with economic considerations. Such a study would offer a more precise and broader set of criteria to be used in the assessment of the tendencies in landscape stability.

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