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THE TEMPORAL VARIETY AND VARIABILITY OF LAND COVER FROM THE SECOND HALF OF THE 19TH CENTURY IN THE REGION OF KECSKEMÉT

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Summary: In order to understand the relationship between society and its natural environment it is crucial to research historical land use and land cover. As a result, both past and current land cover changes are more and more closely looked at – in accordance with international trends – within Hungarian geography. Through our research using a Geographical Information System, we examined the variety (diversity) and variability (land use stability) of land cover on 25x25 km urban, rural and transitional regions in the Duna-Tisza Interfluve from the second half of the 19^{th} century to the present days, through five different time horizons. For this research we used the database previously compiled for our past landscape history and land use analysis. In this recent paper our main aim was to answer the following questions: 1. What kind of spatial characteristics can be recognized in land use stability? 2. How did the ratio of stable and transformed land cover areas, as well as the annual mean size of change affected areas vary over time? 3. What kind of conclusions can we draw from the results in terms of the driving factors and from the angle of landscape protection? By answering these questions, we would like to emphasize the driving force of the agroecological potential, while also pointing out a relationship between natural conditions and the change in land cover, as well as land use stability.

Key words: historical land use and land cover change (LULCC), land use stability, driving forces, landscape protection

1. INTRODUCTION

The GIS analysis of land use stability can also play an important role in uncovering the causes of landscape changes. From the viewpoint of understanding the landscape function it is interesting to determine when, where and why there might be significant changes in land use (Csorba 2006). Comparing the stability map that shows the spatial differences of land use stability with maps that represent other landscape characteristics can highlight that a particular landscape characteristic can play a significant role in landscape changes. This landscape characteristic can be regarded as the driver, as well as the prohibitive factor to landscape changes.

Stability maps can also be used for landscape protectional purposes, which can further increase the significance of the GIS analysis in land use stability. With regard to landscape protection and nature conservation, long-lasting and originally also natural forests, grasslands, swamps and lakes make up the most valuable parts of all landscapes, the so-called natural areas.

According to our presumptions the locations of areas with a stable or relatively stable land cover indicate areas with higher agroecological potential and with more favourable conditions from the agricultural point of view. Research shows that natural areas were best able to maintain, and abandoned areas could best regenerate in landscape parts where natural conditions were especially unfavourable from the angle of agriculture. The best natural conditions are characteristic to areas with stable land cover, which have been utilized for a long time only as arable land and where other ways of land use have not become real alternative to arable farming.

Agricultural land use is not only determined by natural conditions, but also by economical, as well as technological-infrastructural factors; therefore, the geographical position of a town can be essential to land cover change trends.

Logically, land use stability and the level of human impact, i. e. hemeroby are closely related to each other, since stable land cover means that no considerable land forming has taken place in the given area in a long period of time; therefore leaving its naturalness also unaffected as well.

When examining land cover change chronologically, we can discuss the variety and variability of the land cover or land use types. Variety means how many types of the land cover can be noticed on a given area, while variability expresses how many times the land cover has changed there. The dynamics or stability of anthropogenic activities in the environment are closer associated with the variability of the land cover. However, if we want to find out how fit a given area was to satisfy the different land use demands, we have to examine the temporal variety of the land cover.

In this study, we attempted to evaluate the land cover variety and variability (land use stability) in Kecskemét and its surroundings from the second half of the 19^{th} century to the present days, with a retrospective approach and applying GIS methods.

2. STUDY AREA AND METHODS

Our study area – in the surroundings of Kecskemét – covered a 25x25 km area in the middle part of the Duna-Tisza Interfluve, Hungary (Fig. 1).

Its present land use is rather heterogeneous: it includes Kecskemét and other closed built-up areas (e.g. Kerekegyháza, Helvécia), more opened built-ups and garden-plots with mixed utilization, rural areas, homesteads, large agricultural fields, forest plantations, as well as meadows and pastures. Its physical geographical conditions are also diverse: characterized by loess surfaces, sand-sheets, sand dunes, swamps and intermittently flooded areas. The study area can be divided into highly protected (national parks, landscape protected areas, nature reserves), protected – and from the point of view of landscape protection – into less significant landscape details (garden-plots, built-up areas).

Vector land use and land cover data were collected from archive topographic maps, current orthophotos and digital land registry database within the following seven time horizon by visual interpretations and decodings (HIM 1783 1860-1864 1883 1940-1944 1958-59, FÖMI 1989-1996 2005 2008). We converted the vector layers of the land cover mosaics into 50, 100 and 200 meter pixel size raster files.

1. The second half of the 18th century (1783)
2. Mid 19th century (1860-1864)
3. The second half of the 19th century (1883)
4. 1940-1944
5. 1958-1959

6. 1989-1996
7. 2005-2008

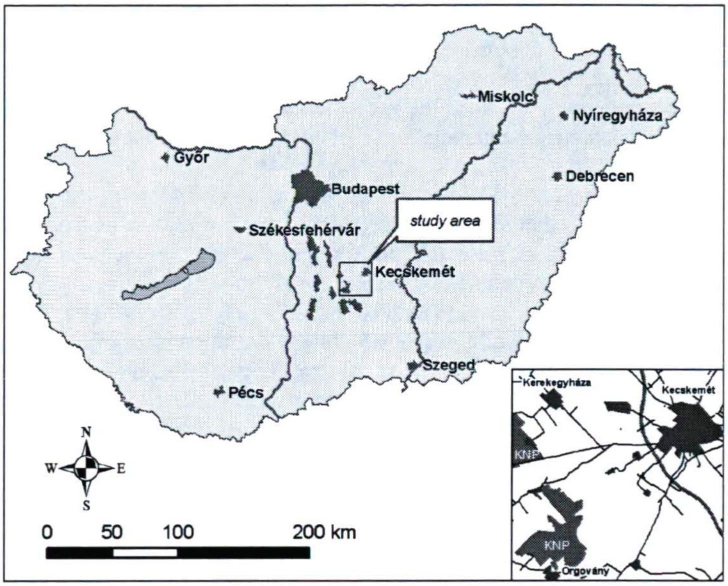

Fig. 1 The location of the study area

In our previous paper landscape historical changes were evaluated applying historical sources and scientific papers (Dóka et al. 2010). This study was also carried out with the help of the ArcGIS 9.3 software, but due to the quality limits of the raw map data in the first and second time horizons only for the period between 1883 and today (3^{rd}-7^{th} time period). With the help of GIS applications our standardized land cover classification system used in the previous landscape history research, as well as our database have been refined, and as a result we applied the following land cover types (classes):

1. Regularly and permanently water-covered areas, natural still waters, swamps
2. Grasslands, scrublands, as well as grasslands with scattered trees and scrubs
3. Closed forests, woodlands, forest plantations
4. Arable lands
5. Vineyards, orchards, gardens
6. Areas with high sparse settlement density
7. Build-ups, closed settlements
8. Artificial still water bodies

Based on our experience a standard database cannot be established in the Duna-Tisza Interfluve with the automatic application of the key codes from the 2^{nd} and 3^{rd} Military Surveys. Since military archive maps are only considered an indirect data source (Nagy 2004), it is possible that the interpretations based on the key codes provide improper information.

When evaluating the maps from the 2^{nd} Military Survey, it can be misleading that the „forests" displayed on it can represent forest plantations (from anthropogenic sources), natural closed forests, as well as spontaneous scrublands (Biró 2008). It is also true about the maps from the 3rd Military Survey. Since on later maps we categorized grasslands, scrublands, as well as grasslands with scattered trees and scrubs to be part of the land cover class 2, we had to re-categorize the areas from the 3rd Military Surveys that were marked „forest" by the key code, with consideration to the origins of their patches.

We applied landscape metrics to determine the origins of a particular area. To support our GIS application we used the base theory that natural or anthropogenic origins are present in the geometrical characteristics of the landscape structural features (Mezősi and Fejes 2004).

Since neither the analysis of the fractal dimension (FRAC) nor the investigation of the shape index (SHAPE) that display the regularity and complexity of the patches yielded acceptable results, we developed a patch index, which made natural and artificial forest and scrubland patches easier to separate. For the index we used the Patterson „Shape Geometry Extension", which supplies the inside angles of polygons (Patterson 2004).

In view of the number and the size of angles [so the number of angles close to 90° and 270° (±15°)] we can numerically define the angularity of the features. It is important to add that the result of the analysis is rather sensitive to the rules and preciseness of digitalization.

We calculated first our patch index for the „forest patches" of the 2nd Military Survey. After determining the natural or artificial origin of „forest patches" with the help of a known „reference patch", we had to separate the real forests and spontaneous scrublands. Our aid was the 1st Military Survey, which shows scrublands as part of grasslands. The forests that are identified on the 1st Military Survey and also shown on the 2nd, were categorized in land cover class 3, while the scrublands were made part of land cover class 2.

We divided the „forests" that are displayed on the map of the 3rd Military Survey into two groups, one of which consists of completely new areas, while the other includes „forests" that are present on the map of the 2nd Military Survey already. The members of the former group became part of class 3, while in case of the latter we originated the land cover type from the map of the 2nd Military Survey by applying the identity GIS function and calculating the shape indices of the „sliver" and „parent polygons". Using the ratio of the „sliver polygons" and „parent polygons" shape index we constituted three classes with the help of The Jenks Natural Breaks Classification and merged the „sliver" polygons that had a value close to 1. The remnant polygons, as well as the completely new polygons became part of land cover type 3.

In our work we separated sparsely populated areas with agricultural and forestry usage (land cover classes 2-5) from the areas with high sparse settlement density. We defined these using the raster density files from the point-database of the sparse settlements, applying mean sparse settlement density data for garden-plots from 2005 (FÖMI 2005). We used a 100 meter search radius for the calculations according to the following.

Due to the increasing level of spatial „flattening" and generalization resulting from the interpolation, only lower values can be used, which causes the higher sparse settlement density areas to better fit to the vector patch edges, and are also closer to the point-like nature of the base data used. Therefore, the search radius (r=564.3) of a circle with a 1 km^2 area is not appropriate for the calculations. Applying a search radius, which is significantly shorter than 100 meters (e.g. r=50) makes the high sparse settlement density areas much too scattered and as a result the advantage of the method (the possibility to form spatially continuous data from discrete point data) also diminishes significantly. Furthermore, we would like to add that in every such application, the spatial base data must originate from an area that is larger at least by the search radius than the analyzed reference area.

Using this method with 50, 100 and 200 meter cell size the sparse settlement density for the garden-plots yields 139 sparse settlement/km^2 after rounding the result. This value mostly represents the former garden-plots, but high sparse settlement density is possible in other regions as well. Areas with high sparse settlement density mean those where the values exceed 139 sparse settlement/km^2 in the raster files

All the methods illustrated above improve the comparability of land cover types from different time periods. Due to the different scale of the source maps, it was inevitable to generalize larger scale maps to the smallest scale (1:50 000). For these generalizations we used Töpfer's radical law.

We compared the maps with different scale and content using combination and reclassification, following the generalization, and the conversion of the vector content to 50, 100 and 200 meter pixel size raster files, then took the average of the results and analyzed it statistically.

Land cover variety was measured using the variety tool of the cell statistics tools with the help of GIS software, while variability (land use stability) was analyzed per the combined data in Microsoft Access. We filtered the variety and variability database with the use of low type „filter" functions to make the display of the results more assessable visually.

3. RESULTS AND DISCUSSION

Land cover variety and variability – according to our results – are both in close relation with the agroecological potential. The „soil quality score" expresses the natural fertility of different soils in the percentage of the fertility of the most fertile soil (Várallyay et al. 1985). Based on the soil quality score attribute of the digital agrotopographical map of Hungary (MTA TAKI 1996) we can create soil quality score categories (class 1: 0-10, class 2: 11-80 soil quality scores) using the criteria of representing roughly equal area sizes. We can generate maps that show areas with the same category based on their soil quality scores as well. If we compare the maps generated on the basis of the soil quality score to the stability and variety maps, we will see that large stability and small variety is typical for areas with high and medium soil quality scores (class 2), while on areas with low soil quality scores (class 1) there are generally more land cover changes and more land cover types occurring (Figs. 2 and 3). This spatial concurrence can be recognized even with changed cell sizes.

This can be explained with the following. The wind-blown sand which makes up within the study area – beside solonchak, solonchak-solonetz and more humic sands – the majority of the areas with low soil quality scores is barely appropriate for arable farming, as opposed to the more fertile meadow soils and chernozems with medium and high soil quality score. This region was typically agricultural-determined over more than 100 years, therefore the scale of the agroecological potential has impacted both land use stability and land cover variety. The close relation with the agroecological potential is more obvious on the variety map (Fig. 2).

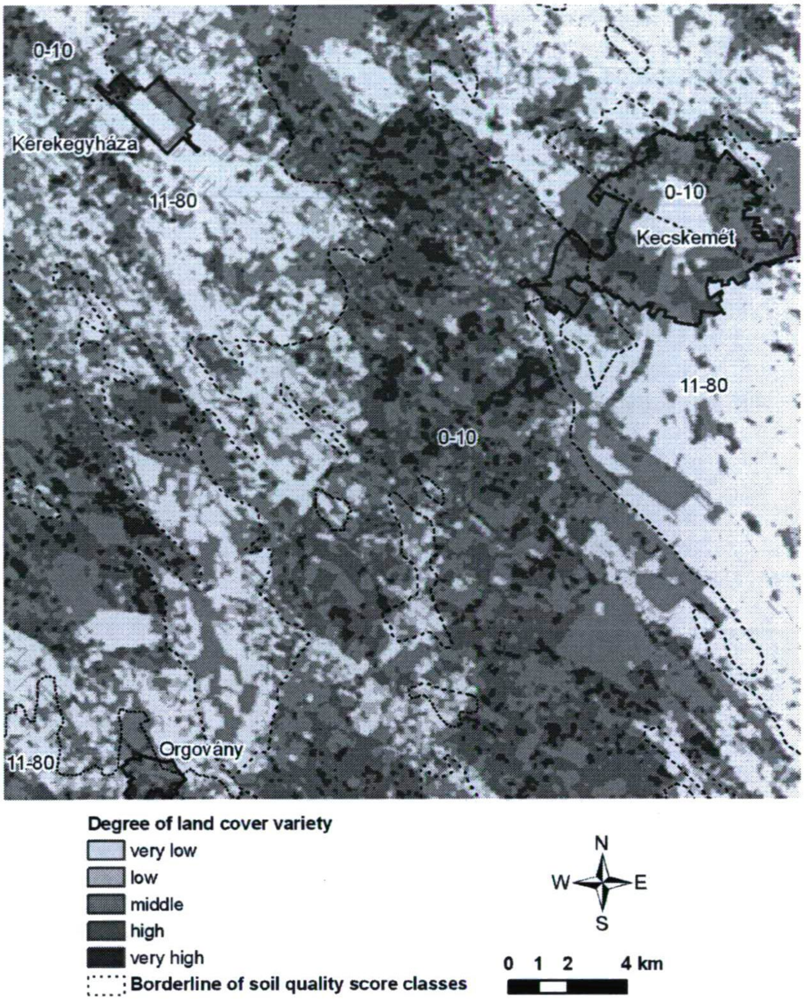

Fig. 2 Degree of land cover variety from the second half of the 19th century to the present days (50 m cell size, low type filter)

The most diverse and variable land cover areas can mostly be found with high density in the „Central Sand Region". This „Central Sand Region" as mentioned by Lettrich (1968) is situated to the east-southeast of Kecskemét, and according to its landscape history and natural conditions is a well-distinguishable part of the region in the surroundings of Kecskemét. Its typical land cover range is e.g. grassland – arable land – vineyard – grassland – forest plantation, or grassland – vineyard – area with large sparse settlement density – built-ups. It seems that some of the sandy areas, where previously agricultural production was the main form of land use, have lost their agricultural character as the conditions changed due to urbanization. Characteristically the cultivation of the land has been replaced by another land use form which is less related to the land.

From the results we can conclude that the agroecological potential in this region has operated as driving force over the past 130 years. Recent research concerning a Hungarian study area has also found that soil quality has a relevant role in the transformation of the rural landscape in Hungary (Szilassi et al. 2010).

Besides this close relation to the agroecological potential, another geographical regularity can be seen on the variability map, namely that in the zone surrounding the 19th century Kecskemét, where mostly built up areas are present nowadays, the result map displays a diverse land cover. The reason behind this is that the exterior parts of historical cities were utilized in the past in many different ways in accordance with the different urban and agricultural demands, like in the case of Kecskemét.

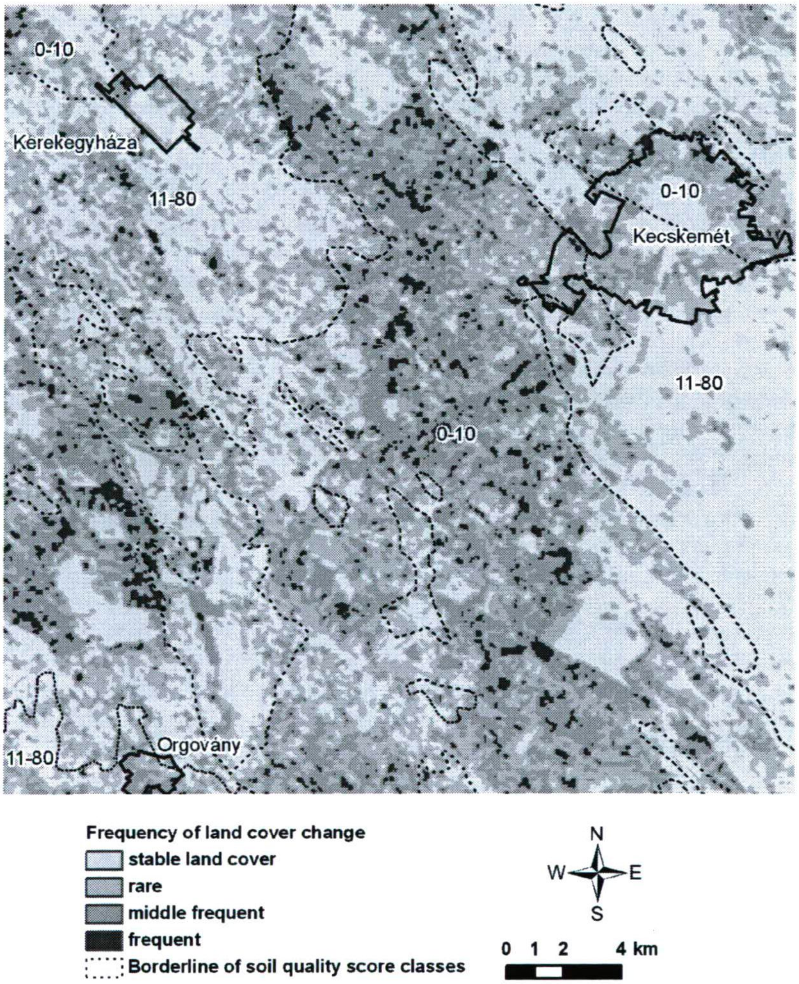

Fig. 3 Frequency of land cover change from the second half of the 19th century to the present days (50 m cell size, low type filter)

Our numerical results can only be considered estimates, as precise evaluation is impossible for several reasons. Results can be slightly affected by the preciseness of georeferencing and digitalization, the algorithms used in the origination of the data, as well as by the quality of the source maps. For example, natural still water bodies and swamps were mapped with a different extent at different times, partially for objective (drier climate period), partially for subjective (the determination of the borderlines of surface waters, the time of the mapping) reasons. In our statistical evaluation the alterations of 1) and 2) land cover types between two different time horizons were not considered an anthropogenic change.

According to our data, in the study area 44-45% of the land cover changed during the six decades following 1883, while this ratio was 28-29% from the first half of the 1940s to the end of the '50s. If we calculate the annual mean size of the transformed land area, we get a value 2.5 times larger than in the earlier period, which can be explained by the sweeping changes in socio-economical conditions that took place following World War 2.

From 1958-59 to the early years of post-communist transformation 44-45% of the study area was affected by land cover change. The annual mean size of the transformed land area is slightly more than half of the same value from the previous period, indicating a decrease in the extent of changed land cover.

During the time period between the early years of post-communist transformation and our present day 27-28% of the land cover has been changed. The annual mean size of the transformed land area doubled compared to the previous period, which refers to a much more intense land use change after the early years of post-communist transformation related to the altered socio-economic conditions.

The significant variation in the annual mean size of the transformed land area shows that the rate of land cover transformation and the intensity of land evolution are both rather irregular. According to our experience, land cover and land use change substantially after significant socio-economical changes compared to more stable socio-economical periods, in our study area as well.

It is remarkable from the viewpoint of landscape protection that since the early years of post-communist transformation stable grasslands, scrublands, still waters and swamps, which are valuable from the standpoint of nature conservation, were considerably affected by land cover change. 5% of the total area of these land cover types has been transformed, which represents 1.5-2% of the total transformed land cover area. Stable forests and woodlands haven't changed recently.

The most significant transformations were the alterations of grasslands and scrublands caused by new ploughings (around 53%), afforestations and self-reforestations (around 34%). In addition building up (6-7%) and transformation into vineyard or orchard (4%) or into reservoir (2%) also occurred in the case of them. Change of natural still waters and swamps by ploughings and the creation of reservoirs also occurred, though obviously not as frequently and extensively as in the case of grasslands.

Negative changes have lately been characteristic to every part of the study area, but as a matter of course they rather occurred in places where the wetlands, grasslands and scrublands had pre-condemned a greater area. Unfortunately these transformations didn't entirely avoid the protected areas either.

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