Abstract

Decreasing population density is a current trend in the European Union, and causes a lower environmental impact on the landscape. However, besides the desirable effect on the regeneration processes of semi-natural forest ecosystems, the lack of traditional management techniques can also lead to detrimental ecological processes. In this study we investigated the land use pattern changes in a micro-region (in North-Eastern Hungary) between 1952 and 2005, based on vectorized land use data from archive aerial photos. We also evaluated the methodology of comparisons using GIS methods, fuzzy sets and landscape metrics. We found that both GIS methods and statistical analysis of landscape metrics resulted in more or less the same findings. Differences were not as relevant as was expected considering the general tendencies of the last 60 years in Hungary. The change in the annual rate of forest recovery was 0.12%; settlements extended their area by an annual rate of 3.04%, while grasslands and arable lands had a net loss in their area within the studied period (0.60% and 0.89%, respectively). The Kappa index showed a smaller similarity (~60%) between these dates but the Fuzzy Kappa and the Aggregation Index, taking into account both spatial and thematic errors, gave a more reliable result (~70-80% similarity). Landscape metrics on patch and class level ensured the possibility of a detailed analysis. We arrived at a similar outcome but were able to verify all the calculations through statistical tests. With this approach we were able to reveal significant ($p<0.05$) changes; however, effect sizes did not show large magnitudes. Comparing the methods of revealing landscape change, the approach of landscape metrics was the most effective approach, as it was independent of spatial errors and ensuring a multiple way of interpretation.

Keywords: comparisons, fuzzy approach, landscape change, rural landscapes, forest recovery, Hungary

Introduction

According to the general trends in Europe, due to population decline and urbanization processes, numerous rural regions, especially in the Eastern countries, have experienced decreasing and aging populations since the middle of the 20th century (Antrop 2004a; Kozma 2006; Molnár and Pénzes 2008). Furthermore, as a consequence of reduced land use intensity the amount of arable lands has decreased since the area of forests has been constantly increasing over the last few decades (Rounsevell et al. 2005). This phenomenon is a general trend in Hungary and also in other Central European countries (Szabó 2003; Young et al. 2005). This study aims to investigate landscape changes induced by abandonment, which has altered the landscape pattern and can significantly influence the further survival of various valued native plant and animal species.

In this study we dealt with the identification of trends in LULC change and focused on landscape metrics on both patch and class levels. Traditional techniques of geoinformation science use the position of pixels (raster data model) or objects (vector data model) and provide proportional data about the difference between map pairs. However, maps always have geometric errors due to their orthorectification (i.e. when aerial photos are processed to eliminate distortions; Rocchini and Rita 2005). One can find several attempts to mitigate this effect (e.g. fuzzy sets) and these solutions can handle the errors of mispositioning but also influence the real linear elements of the landscape (Hagen-Zanker 2009). Landscape metrics are considered to be quantitative tools of landscape ecology which help to quantify visual observations with dozens of indices (Forman 1986, Uuemaa et al. 2013). The advantage of using them is the multiple perspectives we can apply: we are able not only to determine the spatial features on the historical land cover maps but also to investigate the area, edge and shape characteristics of patches, as well as their fragmentation and connectivity (Uuemaa et al. 2009). The goals of landscape preservation are to maintain or develop the natural elements of landscapes, and the functional connections among them. These indices can provide results to help such efforts. Although many spatial metrics are available, only a few of them (e.g. area, perimeter-area ratio, buffer zones) are used in the practice of landscape planning. On an international level there are good examples in the practice of spatial planning where the landscape connectivity was taken into account (e.g. usage of BEETLE model in afforestation with the aim of improving the connectivity of the existing forest patch network, Stone, 2007; or in the planning of the transportation system of California, Girvetz et al. 2008).

For the evaluation of habitat connections and the fragmentation of different species, landscape metric indices are commonly used (Caplat et al. 2006; Plieninger 2006; Ernoult et al. 2003). Landscapes have special features regarding the appearance of habitat patches and their patterns (Kerényi and Szabó 2007). The extent and quality of patches determine which species are able to use them as real habitats, corridors or stepping stones during migration (Kareiva and Wennergren 1995; Turner 1989). In addition to this, patterns, i.e. the absolute and relative status of patches, the distance from the next patch belonging to the same land cover class, and linkage density, also influence species distribution (Pimm 1984; Williams et al. 2002). Although there are several landscape metrics, they often correlate accounting for redundant information (Riitters et al. 1995), thus, their universality should also be considered (McGarigal et al. 2008, Szabó et al. 2014)

A map of land use or land cover (LULC) shows only the status of a given moment (depending on the date of the aerial photograph, satellite image or field survey). On the one hand, analyses of these maps provides valuable and indispensable information for nature conservation experts and landscape planners. On the other hand, knowing the directional trend of changes is an important element in understanding the landscape processes. Several studies have explored tendencies and identified changes, threats or processes in the landscape (e.g. Drummond et al. 2012; Frondoni et al 2011; Hill et al. 2008; Sallay et al. 2012; Šimanauskienė et al. 2007; Stellmes et al. 2013; Szilassi et al. 2006; Van Dessel et al. 2008). Time series LULC data can be used in spatially explicit land change models where the maps represent the input data and a future landscape is the target variable. These models are popular, although there is some uncertainty concerning validation. Although all models have errors and landscape change models are not exceptions (Martinez et al. 2011; Verburg et al. 2006), some authors found landscape models to be useful tools in planning (Ray et al. 2012).

In our study we investigated a study area where the type and intensity of human impacts has changed relevantly in the last few decades, with a decreasing extension of managed areas and changes in landscape cultivation. Former lands with extensive land use practices (moderate grazing, traditional forestry where the different activities were inter-related in several ways) are spatially dispersed. Activities have become separated, intensified (crop production, forestry) or have almost completely disappeared (moderate grazing). Meanwhile, new landscape functions have appeared (recreation, ecotourism, nature conservation), which require different methods of landscape management.

Our aim was to establish whether structural changes in land use practices and relevant socio-economic changes could also be identified in landscape patterns with landscape metrics. Besides this, we analyzed the possibilities of comparisons among the sets of land use maps and evaluated the efficiency of the methods applied. The main question was whether GIS methods, landscape metrics and statistical methods are the most appropriate tools to reveal the trend in changes in landscape structure and pattern.

Materials and Methods

Study area

The study area is a micro-region of Hungary, the Felső-Hegyköz with an area of 243 km^2 (Fig. 1). The dominant land cover type is deciduous forest, dominated by Beech (*Fagus sylvatica*), Hornbeam (*Carpinus betulus*) and Sessile Oak (*Quercus petraea*) with a considerable proportion of meadows and arable land. The whole area, except the settlements, belongs to the National Ecological Network (as both buffer and core areas) and the Natura2000 SPA sites. The Northern part of the area is a nature reserve (Zemplén Landscape Protection Area), declared a Protected Landscape in 1984, and belonging to the Aggtelek National Park Directorate. Since 2004 it has also been a Natura2000 SCI site.

#Fig. 1#

The study area contains 14 settlements with a total population of 5071 (2012) and a population density of 21 people/km^2; however, this figure was 31 people/km^2 in 1952. The area is considered a very thinly populated area even by Hungarian standards (the average population density of Hungary is 107 people/km^2 [HCSO, 2012]). The population of the study area is aging, and has decreased by more than 22% in just the last two decades (CSO, 2012).

The most valuable parts of the study area are the grasslands. Many protected (e.g. *Orchis*) species occur in these habitats and grazing or mowing would be desirable (Török et al. 2009; Valkó et al. 2012). Management was previously done by the inhabitants but given the age-structure of the surrounding villages, the inhabitants have given up animal husbandry. The traditional extensive cattle grazing (Petercsák, 1983) of the region was an important factor in forming and maintaining valuable ecological habitats and landscape structure. Therefore, to maintain these habitats and landscapes, management should be done by volunteers and national parks.

Given its natural value and scenic landscapes the territory has become a favourite location for ecotourism. Therefore, although human disturbance is decreasing in terms of the local inhabitants' landscape-cultivation activities, the landscape faces the phenomenon of an increasing number of tourists, which results in a different type of landscape use and cultivation, i.e. an increasing proportion of tourism infrastructure and disturbance. It was because of the importance of the area in sustaining biodiversity and protected species and habitats that we chose it to identify trends of land use changes, not only by summarizing the proportion of land cover categories but also by characterizing changes in their pattern.

Land use data

Aerial photos from 1952, 1971 and 1988 were provided to us by the Map Collection of the Museum of Military History. Aerial photos were scanned and orthorectified with DigiTerra Map 3 (DigiTerra Ltd.) using the SRTM digital surface model. The resolution was 10 m and RMSE values were kept under 3 pixels to ensure the exact overlapping of the polygons of habitat patches. Aerial photos of 2005 were orthophotos produced in the framework of the Hungarian Digital Orthophoto Program. Five LULC classes were distinguished (forests, grasslands, arable lands, orchards, and areas under strong anthropogenic activity) based on the overall interpretability of the aerial photos (coloured images from 2005 allowed more classes but older ones had their limits). Habitat patches were interpreted visually and vectorized in ArcGIS9 (ESRI, 2008). Minimum mapping unit was 0.01 ha.

The thematic accuracy of the LULC maps derived from archive aerial photos cannot be perfect (i.e. all maps contain uncertainties). It was also not obvious how to distinguish even these five categories. Orchards and forests can be similar, especially when their management has ceased as a consequence of abandonment: an orchard’s inner structure can fade without management. The thematic content was checked against field surveys (in the case of the 2005 images) and ancillary data in the case of older maps (3rd Military Survey Map, 1:25000 scale military maps of 1952, 1:10000 scale map of 1979 [EOTR10]).

Landscape metrics

Vector overlays were converted to raster format (with 10 m resolution) and were analysed with Fragstats 3.4 software (McGarigal and Marks, 1995). Neighbouring patches that belonged to the same LULC class were merged into one to ensure the correct number of patches (otherwise landscape metrics would provide false information). We chose the most relevant metrics to characterise the given state of the landscapes (Table 1). Selection was in accordance with these aims: to detect changes in patch and class level considering not only the area of the patches (AREA) but their shape and the level of fragmentation. Shape metrics (SHAPE, FRAC) were used to determine the complexity of the patch forms (applying the island biogeographical observations of McArthur [1964]: the more complex the patches, the fewer endemic or stenoecious species can live there because of the smaller undisturbed area). Distance between patches within a land cover type (ENN) and fragmentation metrics (DIVISION, MESH and IJI) revealed the landscape pattern and provided information about the connectedness of the patches.

#Table 1#

Map comparison

Spatial comparison of the maps was carried out with contingency tables (Chrisman 1987) and Fraction Correct (FC), Kappa (or Kappa Index of Agreement, KIA), Fuzzy Kappa and Aggregated Cell index (Cohen 1960; Hagen-Zanker 2009; Vliet et al. 2011). FC is the ratio of the number of pixels having the same values in both maps and the number of all pixels (Hagen-Zanker 2009); KIA is a simple measure of the association of two maps and its value expresses the magnitude of agreement compared to the case of agreement by chance (Rosenfield and Fitzpatril-Lins 1986). Both FC and KIA consider only the overlapping pixels while Fuzzy Kappa and Aggregated Cells can handle both the uncertainties of image rectification and the uncertain borders of habitat patches. In fuzzy analysis, we applied a 100 m transitional zone (with linear function) in order to be sure that errors of georeferencing and vectorisation could be ignored. Another possibility was the usage of the Aggregated Cells approach (Pontius, 2004): pixels were collapsed into one depending on an aggregation factor chosen by us. A value of 4 was applied, which meant 16 (4 x 4) pixels became one. Kappa, Fuzzy Kappa and Aggregated Cells ranged between 0 and 1. In this scheme 0 meant absolute independence between two images and 1 was perfect similarity. Indices were calculated using Map Comparison Kit (Visser and de Nijs, 2006).

Statistical analysis

Distribution of the patch level data was tested with the Shapiro-Wilk test and most of the variables did not have normal distribution; therefore, we applied nonparametric tests (Mann-Whitney, Kruskal-Wallis and Wilcoxon tests). Due to the specific characteristics of the data, we carried out the comparisons in two ways. The most important problem is that habitat patches are continually changing in space, thus it is not possible to trace them in a longitudinal way, in time, with unique IDs: there are patches which are forming or disappearing. Besides, links can connect formerly separated patches or links can be eliminated, resulting in new patches. Therefore, pairwise tests can be applied only on those patches where IDs are supervised by the user. We selected all the patches that can be identified in the different dates and tagged them with the same ID for the pairwise comparisons for each consecutive date-pair (1952-1971, 1971-1988, 1988-2005, and those which were identified in all dates; the number of cases was different in each pair: 102, 76, 110 and 33, respectively). Pairwise comparisons were conducted with the Wilcoxon test. We also carried out a comparison considering all data derived from the LULC maps with a non-pairwise method. Although in consecutive years we can probably work with a similar number of more or less changing patches, due to the large number of forming-disappearing and merging-separating patches, we omitted these from our analysis and only used the rest of the data (the proportion of patches having the same ID was 9.9% for 1952-1971; 9.1% for 1971-1988 and 12.0% for 1988-2005). The Kruskal-Wallis test was used in the case of four groups (i.e. 4 maps); for comparisons of the consecutive date-pairs the Mann-Whitney test was applied. We reported significance at $p<0.016$ as we did not perform a full factorial analysis and applied the Bonferroni correction: dividing the $p<0.05$ by the number of comparisons (i.e. 3: 1952-1971; 1971-1988; 1988-2005). Our null hypothesis (H_0) was that landscape metrics derived from LULC patches had the same mean rank, and the alternative hypothesis (H_1) was that the mean ranks of the metrics were different at the $p<0.05$ level. Only consecutive date-pairs were tested; thus, we were able to test their similarities or differences from several perspectives provided by landscape metrics.

We calculated effect sizes (r values) to quantify the magnitude of differences between groups in a standardized and comparable form (Cohen, 1992; Field, 2009). Statistical investigations were conducted with SPSS17 (SPSS Inc, Chicago IL) and PAST (Hammer et al. 2001) software. All statements on significance were interpreted at $p<0.05$.

Trends of landscape dynamics were revealed with Principal Component Analysis (PCA). We applied the Varimax rotation to extract principal components (PCs) and the number of PCs was determined using the Kaiser’s rule. Accuracy of sampling adequacy was controlled with the Kaiser-Meyer-Olkin (KMO) measure (Zar, 2010). We involved the class level data in the analysis with the following variables: AREA, SHAPE (as a shape metric), ENN (as a distance metric) and IJI (as the measure of interspersion of the given class with other classes).

Results

Changes in LULC

Patch areas ranged from 200 m^2 to 174 km^2 and the upper quartile was 0.04, 0.09, 0.14 and 0.07 km^2 respectively in order of time (1952, 1971, 1988, 2005), including a high percentage of outliers (>1.5 times interquartile range) and extreme data (>3 times interquartile range).

Forest was the most dominant land cover type at all examined dates between 1952-2005 in the study area with about 70% coverage (Table 2, Fig. 2). The proportion of orchards was small (0.2%) and their presence decreased to 0.002% during the examined period. Although arable lands occupied a larger area (19.4%), this decreased to almost half the previous value (10.2%). The area of grassland varied over time (from 8.5% to 13.7%); after a brief period of increase, the area decreased again (11.2%).

#Table 2#

#Fig. 2#

Comparison with GIS methods

Firstly, we compared the maps pairwise in chronological order (Table 3). Each three comparison algorithms showed that changes were the smallest between 1952 and 1971 and relevant changes occurred from 1971 to 1988. Changes after 1988 became smaller again. Fuzzy Kappa and Aggregated Cells had larger values as these algorithms diminished the spatial errors and indicated a higher level of similarity between the given dates (e.g. in 1952-1971 the similarity was 69%, whilst Aggregated Cells showed almost 86%).

#Table 3#

These overall values did not reflect those changes in the LULC classes for which reasons could be established. Consequently, it did not inform us about the causes of the change; thus, we demonstrate the possibilities of comparisons with contingency tables for the years 1952 and 1971 (Table 4). Although these numbers are biased by the error of orthorectification, we can observe the main characteristics of the changes: similarities in settlements, forests and arable land were above 50%, and orchards showed the greatest change. Transitions of land cover units were also considered relevant information. For example, areas under anthropogenic influence in 1952 turned into forests (4892/30786; 16%), arable lands (3426/30786; 11%) and grasslands (1462/30786; 4.7%), and areas under anthropogenic influence in 1971 were mainly forests (6547/41131; 16%) and arable lands (8441/41131; 20%).

#Table 4#

KIA as a general indicator of association was 0.69, indicating moderate agreement between 1952 and 1971, while KIA values calculated per category showed a greater variance. Arable land showed the largest, and orchards the smallest, agreement. The Fuzzy Kappa values calculated per category were similar to the Kappa values, but reflected greater agreement between 1952 and 1971 (Table 5).

#Table 5#

The area of the transitional zone, where the fuzzy category membership was not equal to 0 or 1 (indicating a change in, or permanence of, the land cover), was 26.11 km^2. We reduced the fuzzy values to 0.3-0.7, presuming that values close to 0 or 1 can be regarded as being inside the error limit and considering this area as containing elements which cannot be unambiguously classified. The extent of this area was 11.9 km^2, representing 4.6% of the study area. We demonstrate the consequences of the fuzzy approach in Fig. 3 (No. 1-4 areas). Area No. 1 was a real grassland strip, but lengths were different in 1952 and 1971. The uncertain fuzzy membership for the whole extent of the strip is the result of the uncertainty of the orthorectification, where the two existing grassland strips did not cover each other exactly. We can observe the same situation in area No. 2. Area No. 3 was a former grassland, whose area was reduced by the intensive invasion of the surrounding forest. Area No. 4 highlighted another aspect of the error of orthorectification: although the grassland habitat existed in both dates to almost the same extent, we observed an increase in the area on the Western side, while there was a reduction in the Eastern and Southern part.

Fig. 3#

Comparison of patch level landscape metrics with a pairwise statistical approach

We found significant differences only in the case of shape metrics (SHAPE, FRAC) in the period from 1952-1971, PERIM from 1971-1988 and FRAC from 1988-2005 (Table 6). Effect sizes (r) were usually above 0.15 even in the case of non-significant differences indicating a slight magnitude between the analysed pairs.

#Table 6#

Comparison of patch level landscape metrics

As a subsequent step we compared the rest of the data by landscape metrics with non-pairwise methods. Patch areas changed significantly between 1952 and 1971 and 1988 and 2005, but the magnitude of the change was slight (Table 7). Fractal dimension (FRAC) indicated significant changes for patch shapes in each date pair but the magnitude was large only for the 1988-2005 period. The largest changes were identified in this latest period, as well; except for PERIM, all landscape metrics showed a significant difference, especially for shape metrics and ENN.

#Table 7#

Changes in fragmentation

Nearest neighbour distances (ENN) of forests increased slightly between 1952 and 2005, from 50 m to 68 m (Table 8). Distances between grasslands varied but stayed under 200 m, which was important from the point of view of connectedness. However, distances between forested areas decreased using the increased 100 m radius PROX values (i.e. the available parts of neighbouring patches of the same LULC class became larger). In terms of subdivision metrics (MESH and DIVISION) grasslands and orchards were completely fragmented and isolated. Forests represented a large proportion of the total area in each map (i.e. for each date), and there was a large patch which occupied 69% (16,900 ha) of the whole study area; however, the rest of the forest area was fragmented into small patches. This was the reason for the relatively high value of DIVISION for forests. The interspersion (IJI) of LULC classes was different and orchards had the most diverse environment. Because grasslands bordered mainly on forests, they had low values (below 30%).

#Table 8#

Trends of the changes

PCA of four of the class-level landscape metrics explained 87% of the total variance (KMO=0.69); PC1 accounted for 56%, correlating with AREA, SHAPE and ENN; PC2 explained 31%, correlating with IJI. The scatterplot of the PC-scores reflected the trajectories of the changes according to LULC classes (Fig. 4). We observed definite trends in the case of arable lands, forests and orchards, while change trajectories of grasslands and areas biased by the anthropogenic influence varied.

#Fig. 4 approximately here

General tendencies in total land cover and land use pattern were most obvious in the extension of forested areas (Fig. 2a): besides a slight increase in area, the complexity of the shapes of forest patches also increased, but the nearest distances between neighbouring patches (ENN) decreased, indicating the natural afforestation processes. Accordingly, there was also an increase in interspersion. Furthermore, arable lands retreated (Fig. 2b), their area and shape complexity decreased and ENN increased. Their interspersion with other LULC classes also decreased. Orchard patch sizes decreased, as did the number of patches (Table 5) and shape complexity, but the main tendency was increasing interspersion. A conspicuous spatial reorganization took place in grassland pattern patches (Fig. 2c). While PC1 indicated the maintenance of the average patch size and shape, the pattern changed: the interspersion decreased (Fig. 4). Changes in anthropogenic areas did not follow a trend.

Discussion

Methodological evaluation

Pairwise spatial comparisons have several problems, with mistakes that cannot be handled objectively, especially with aerial photos taken in the middle of 20th century which cannot be georeferenced without errors, due to a lack of available (and currently identifiable) ground control points. This leads to the misplacing of the habitat patches and so overlays from different periods will not exactly cover each other. Thus, even if we use a fuzzy approach to mitigate the differences arising from misplacements, results will be more reliable but still loaded with errors: e.g. small real differences will disappear when the search radius is wider (i.e. linear landscape elements and ecological corridors can be omitted from the analysis). However, distance-based weighting techniques have been considered a promising solution in comparisons (Rose et al. 2009). In our study Fuzzy Kappa values were higher, indicating correspondence between the maps, according to the transitional zone. Rose et al. (2009) found that Aggregated Cells was insensitive to search radius and it gave a higher level of similarity in our examinations as well.

According to Raines (2002), spatial metrics are appropriate tools to compare maps. Since in these investigations spatial characteristics are taken into account regardless of absolute location (exact overlapping is not required), patches are identified with unique identifiers (an identical ID for the same patch in different dates). Therefore, errors generated from georeferencing can be ignored when using landscape metrics. A common issue with this approach is the question of patches being traceable longitudinally; thus, the number of objects in the analysis can be the same as the original number, but can be very low according to the landscape dynamics.

From a methodological point of view, all comparison methods showed a weak change; however, it was only the landscape metric approach which was able to answer whether changes were significant ($p<0.05$). In addition, we were also able to judge the magnitude of the changes with effect sizes. A significant difference can only be interpreted as a “large change” but it can be a small difference with narrow confidence intervals (Field, 2009). Although most of the changes were significant, effect sizes (r) indicated that in our case the changes did not have high magnitudes.

As a summary of the comparisons, we can conclude that there is no method that can cope with all the possible issues relating to geometric accuracy and statistical preconditions without trade-offs. We have summarized the advantages and shortcomings of the different techniques (Table 9) and our suggestion is to apply them in a combined way. Contingency tables with the Kappa Index report the similarity in an incorrected way, while Fuzzy Kappa can eliminate the problems of mismatching the pixels. If we determine the area of pixels which have transitional membership (between two LULC classes), and quantify the area of this zone, results can be interpreted with a better understanding of possible spatial and thematic errors. Longitudinal analysis of landscape metrics can be biased by the issue of the independency of the consecutive dates, but can be handled by separating the patches with the same IDs and the rest of the data. A narrative description of class level data is an efficient method to demonstrate the landscape dynamics and can be supported by PCA biplot diagrams to reveal trends over time. Landscape metrics can be correlated but not always redundant: the provided information can be interpreted in different ways depending on the aims of the investigations (Uuemaa et al. 2011; Szabó et al. 2014).

#Table 9#

Landscape change of the study area

Concerning the area of the habitat patches, reforestation is a serious problem for nature conservation: without management the valuable small grasslands will disappear. If the area and, as a consequence, inter-patch distances, change, the possibilities of species migration relating to grasslands can decline (Szabó et al. 2012). Grasslands are the most endangered habitats in the study area. Forests are dominant elements of the landscape and form large patches. Just as Sitzia et al. (2010) found in numerous case studies, we could also establish a constantly increasing mean patch size in the study area. Smaller changes do not influence their characteristics significantly; they are persistent and less sensitive to anthropogenic disturbance. Naturally, this statement is true to a limited degree, considering only forests in general. Individual patches can be invaluable habitats and associations (Simon 2006).

Comparisons of different periods by LULC classes revealed the specific details; we were able to follow the changes from several perspectives, considering both area and shape. Our findings reflected that there were changes in the study area, but that the magnitude was not large. There are several areas in Hungary where the landscape is dominated by agriculture and has experienced two structural transformation periods (in the 1950s when the agricultural cooperatives were formed and after 1990, when cooperatives were divided up again). However, our study area was not affected by this process, except for the merging of small parcels; the extent of ploughed land did not change to a relevant degree. The relief and the inherited structure determined the agricultural possibilities. This was strengthened by the fact that the area of ploughed land patches only changed to a non-significant extent. Beside forests, grasslands are the most valuable habitats in the area but they will disappear without human maintenance (mowing and grazing). Agricultural abandonment is not exceptionally intense in the area, but due to the decline of traditional cattle holding, traditional hay-meadows are shrinking, which endangers species richness (Török et al. 2009). The most important task for conservation planning is to encourage grazing and mowing on grasslands to sustain biodiversity. The area of grasslands in 2005 was about half what it was in 1977, but shapes were ecologically vulnerable; shape metrics indicated complex geometry (i.e. patches had concave shape which reduces the valuable core area; Forman, 1986) at all examined dates. Beside the small increase in the proportion of the occupied area, mean patch size decreased; accordingly distances to the nearest neighbouring grasslands also decreased. Thus, the availability of these patches improved; however, the habitat quality was not uniformly good (Valkó et al. 2012). The real risk is that smaller patches can become distinct more easily than large ones; consequently, biodiversity will also be reduced.

Conclusions

Comparisons were successful in indicating the changes but the level of efficiency was the function of the limitations of the methods. In general, GIS related methods can provide acceptable solutions but if we need detailed information, usage of landscape metrics can be suggested.

Overlapping (cross tabulation and Kappa Index) a series of maps performs well when there are no errors of georectification; however, we often have to count with the consequences of the non-matching pixels. Therefore, the comparison is not completely accurate, but its measure is the function of the geometric accuracy.

Fuzzy approach (Fuzzy Kappa and Aggregated Cells) can mitigate both the geometric and thematic errors but also diminish real changes within the transitional zones defined by the user. Thus, especially the elongated patches can disappear. The extent of the transitional zone was 4% of our study area and real ecological corridors were considered as geometric errors. Fraction Correct indicated larger similarity (79-85%) than Kappa and Fuzzy Kappa. Kappa was the most rigorous index of association (KIA values were between 0.54-0.69) but biased by the georectification, while Fuzzy Kappa indicated better agreement (values were 0.08-0.12 larger than KIA).

Landscape metrics have the potential to reveal several important characteristics of the changes from ecological aspects beside the extent of the patches. Patch shape, fragmentation and isolation also can be determined. In addition, this object oriented approach is based on the patches and not the location (i.e. all patches are identified and can be traced in different maps). These investigations should be combined with statistical analysis. Hypothesis testing is an efficient tool to determine the difference between the dates. We pointed out that the statistical significance itself is not enough to judge the magnitude of the changes; effect size (r) was the appropriate tool for this task.

Principal Component Analysis can overcome the issue of independency of the dataset of the consecutive dates and was useful in revealing the trend of the changes regarding the time series by LULC types.

Acknowledgement

This work was supported by the University of Debrecen (RH/751/2015) and the SROP-4.2.2.B-15/1/KONV-2015-0001 project. The project has been supported by the European Union, co-financed by the European Social Fund.

References

Antrop M (2004) Landscape research in Europe. Belgeo 2-3: 199–207

Aspinall R (2004) Modelling land use change with generalized linear models – a multi-model analysis of change between 1860 and 2000 in Gallatin Valley. Montana. J Environ Manage 72: 91–103

Caplat P, Lepart J, Marty (2006): Landscape patterns and agriculture: modelling the long-term effects of human practices on *Pinus sylvestris* spatial dynamics (Causse Mejean, France). Landscape Ecol 21:657–670

Cohen J (1992) Statistical power analysis. Curr Dir Psychol Sci 1:98–101

Cushman SA, McGarigal K, Neel MC (2008) Parsimony in landscape metrics: Strength, universality, and consistency. Ecol Indic 8:691-703

Drummond MA, Auch RF, Karstensen KA, Sayler KL, Taylor JL, Loveland TR (2012) Land change variability and human environment dynamics in the United States Great Plains. Land Use Policy 29:710–723

Ernoult A, Bureau F, Poudevigne I (2003) Patterns of organisation in changing landscapes: implications for the management of biodiversity. Landscape Ecol 18:239–251

ESRI (2008) ArcGIS – A Complete Integrated System. Environmental Systems Research Institute, Inc., Redlands, California. www.esri.com/software/arcgis (accessed September 2013)

Forman RTT (1986) Land Mosaics: The Ecology of Landscapes and Regions, Cambridge University Press, Cambridge-New York

Frondoni R, Mollo B, Capotorti G (2011) A landscape analysis of land cover change in the Municipality of Rome (Italy): Spatio-temporal characteristics and ecological implications of land cover transitions from 1954 to 2001 Landscape Urban Plan 100:117–128

Girvetz EH, Thorne JH, Berry AM, Jaeger J (2008) Integration of landscape fragmentation analysis into regional planning: A statewide multi-scale case study from California, USA. Landscape Urban Plan 86:205–218

Hagen-Zanker A (2009) An improved Fuzzy Kappa statistic that accounts for spatial autocorrelation. Int J Geogr Inf Sci 23:61–73

Hammer Ř, Harper DAT, Ryan PD (2001) PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontol Electron 4:1–9 http://palaeo-electronica.org/2001_1/past/issue1_01.htm

HCSO (2012) Hungarian Central Statistical Office, www.ksh.hu (Accessed at 2015)

Hill J, Stellmes, A, Udelhoven Th, Röder A, Sommer S (2008) Mediterranean desertification and land degradation mapping related land use change syndromes based on satellite observations. Global Planet Change 64:146-157

Kareiva P, Wennergren U (1995) Connecting landscape patterns to ecosystem and population processes. Nature 373:299–302

Kerényi A, Szabó G (2007) Human impact on topography and landscape pattern in the Upper Tisza region, NE Hungary. Geogr Fis Din Quat 30:193–196

Kozma G (2006) Place marketing, Debrecen University Press, Debrecen

Martínez J-MÁ, Suárez-Seoane S, Calabuig EL (2011) Modelling the risk of land cover change from environmental and socio-economic drivers in heterogeneous and changing landscapes: The role of uncertainty. Landscape Urban Plan 101:108–119

McGarigal K, Marks BJ (1995) FRAGSTATS: Spatial Pattern Analysis Program for quantifying landscape structure. Gen. Tech. Rep. PNW-GTR-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station

Mezősi G, Fejes C (2008) Landscape metrics. Eds: Dövényi Z, Schweitzer F: Landscape and Environment, GRI HAS, Budapest, pp 229–242

Molnár E, Pénzes J (2008) The role of migration in the population issues of Hungary after the 2nd World War. Debreceni Disputa 1:47–54

Petercsák T (1983) Traditional cattle grazing in Zemplén Hegyköz. Miskolci Herman Ottó Múzeum, Miskolc, 161.pp. (in Hungarian) ISBN 963 01 29590

Pimm SL (1984) The complexity and stability of ecosystems. Nature 307:321–326

Plieninger T (2006) Habitat loss, fragmentation, and alteration – Quantifying the impact of land-use changes on a Spanish dehesa landscape by use of aerial photography and GIS. Landscape Ecol 21:91–105

Pontius RG, Huffaker D, Denman K (2004) Useful techniques of validation for spatially explicit land-change models. Ecol Model 179: 445–461

Raines GL (2002) Description and comparison of geologic maps with FRAGSTATS – a spatial statistics program. Comput Geosci 28:169–177

Ray DK, Pijanowski CJ, Kendall AD, Hyndman DW (2012) Coupling land use and groundwater models to map land use legacies: Assessment of model uncertainties relevant to land use planning. Appl Geogr 34:356–370

Rocchini D, Rita A (2005) Relief effects on aerial photos geometric correction. Appl Geogr 25:159-168

Riitters KH, O'Neill RV, Hunsaker, CV, Wickham JD, Yankee DH, Timmins SP, Jones KB, Jackson BL (1995) A factor analysis of landscape pattern and structure matrics. Lansdcape Ecol 10:23–40

Rounsevell MDA, Ewert F, Reginster I, Leemans R, Carter TR (2005) Future scenarios of European agricultural land use: II. Projecting changes in cropland and grassland. Agric Ecosyst Environ 107:101–116

Sallay Á, Jombach S, Filepné-Kovács K (2012) Landscape changes and function lost landscape values. Appl Ecol Env Res 10:157–172.

Šimanauskienė R, Linkevičienė R, Taminskas J (2008) Spatial analysis of forest fragmentation (the case study of Lithuania, In: Martin Boltižiar (ed.) Proceedings of the 14th International Symposium on Problems of Landscape Ecology Research, Stara Lesna, Slovakia, pp. 427-433

Simon T (2006) Botanical values of the Zemplén Mountains (In Hungarian). Folia Historico Naturalia Musei Matraensis 30:407–414

Sitzia T, Semenzato P, Trentanovi G (2010) Natural reforestation is changing spatial patterns of rural mountain and hill landscapes: A global overview. Forest Ecol Manag 259:1354–1362

SPSS Inc. (2007) SPSS Statistics Base 8.0 for Windows User's Guide. SPSS Inc., Chicago IL.

Stellmes M, Röder A, Udelhoven T, Hill J (2013) Mapping syndromes of land change in Spain with remote sensing time series, demographic and climatic data. Land Use Policy 30:685–702

Szabó G (2003) Agro-environmental protection and prospects of the Hungarian agriculture on the threshold of the EU-accession. In: Csorba P. (Ed) Landscapes under the European Transformation, Debrecen, pp 103–116

Szabó S, Novák T, Elek Z (2012) Distance models in ecological network management: A case study of patch connectivity in a grassland network. J Nat Conserv 20(5): 293–300.

Szabó S, Túri Z, Márton S (2014) Factors biasing the correlation structure of patch level landscape metrics. Ecol Indic 36:1-10

Szilassi P, Jordan G, Van Rompaey A, Csillag, G. (2006) Impacts of historical land use changes on erosion and agricultural soil properties in the Kali Basin at Lake Balaton, Hungary. Catena 68:96–108

Török P, Arany I, Prommer M, Valkó O, Balogh A, Vida E, Tóthmérész B, Matus G (2009) Vegetation, phytomass and seed bank of strictly protected hay-making Molinion meadows in Zemplén Mountains (Hungary) after restored management. Thaiszia J Bot 19:67–78

Turner MG (1989) Landscape ecology: The effect on process. Annu Rev Ecol Evol S 20:171–197

Uuemaa E, Antrop M, Roosaare J, Marja R, Mander Ü (2009) Landscape Metrics and Indices: An Overview of Their Use in Landscape Research. Liv Rev Landscape Res 3: http://www.livingreviews.org/lrlr-2009-1

Uuemaa E, Roosaare J, Oja T, Mander Ü (2011) Analysing the spatial structure of the Estonian landscapes: which landscape metrics are the most suitable for comparing different landscapes? Estonian J Ecol 60:70-80.

Uuemaa E, Mander U, Marja R (2013) Trends in the use of landscape spatial metrics as landscape indicators: A review. Ecol Indic 28:100–106

Valkó O, Török P, Matus G, Tóthmérész B (2012) Is regular mowing the most appropriate and cost-effective management maintaining diversity and biomass of target forbs in mountain hay meadows? Flora 207:303–309

Van Dessel W, Van Rompay A, Poelmans L, Szilassi P, Jordan G, Csillag G (2008) Predicting land cover changes and their impact on the sediment influx in the Lake Balaton catchment. Landscape Ecol 23:645–656

Verburg PH, Schulp CJE, Witte N, Veldkamp A (2006) Downscaling of land use change scenarios to assess the dynamics of European landscapes. Agr Ecosyst Environ 114:39‒56

Visser H, De Nijs, T (2006) The map comparison kit. Environ Modell Softw 21:346‒358

Vliet J, Bregt AK, Hagen-Zanker A (2011) Revisiting Kappa to account for change in the accuracy assessment of land-use change models. Ecol Model 222:1367–1375

Williams RJ, Berlow EL, Dunne JA, Barabasi AL, Martinez ND (2002) Two degrees of separation in complex food webs. P Natl Acad Sci 99:12913–12916

Young, J., Watt A, Nowicki P, Alard D, Clitherow J, Henle K, Johnson R, Lacko E, McCracken D, Matouch S, Niemela J, Richards C (2005) Towards sustainable land use: identifying and managing the conflicts between human activities and biodiversity conservation in Europe. Biodivers Conserv 14:1641‒1661

Zar, J.H. (2010). Biostatistical Analysis. Prentice Hall, 5th Edition, New Jersey, 944 p.

Figure captions

Fig. 1. Location of study area

Fig. 2. General changes in landscape pattern: extent of forests (a), ploughlands (b) and grasslands (c) in the study area between 1952 and 2005

Fig 3. Result of fuzzy based comparison of 1952 and 1972 LULC maps with 100 m transition zone

Fig 4. Scatterplot of PCA-scores considering class level data of AREA, PERIM, ENN and IJI (F: Forest, G: Grassland, A: Anthropogenic influence, P: Ploughland, O: orchard; ●: 1952; ◊: 1971; □: 1988; ■: 2005)

Table 1. Landscape metrics used in the investigations (P: patch level; C: class level; after McGarigal and Marks, 1995; Jaeger, 2000)

Landscape metric (abbreviation)	Level	Description
Area (AREA)	P, C	Area of a patch or a LULC class (ha)
Perimeter (PERIM)	P, C	Edge of a patch or a LULC class (m)
Shape Index (SHAPE)	P, C	A standardised measure of patch complexity: perimeter is divided by a perimeter of a compact shape with the same area (FRAGSTATS calculates with a square; range: 1≤)
Fractal Dimension Index (FRAC)	P, C	A standardised measure of patch complexity: the index is the ratio of the logarithm of perimeter and logarithm of area (range: 1-2)
Euclidean Nearest Neighbour (ENN)	P, C	Euclidean distance of the nearest patch of the same LULC class (m)
Number of Patches (NP)	C	Total number of patches of a LULC class
Landscape Division Index (DIVISION)	C	Indices are measures of fragmentation and redundant but can be interpreted in a different way. DIVISION is a probability that two randomly placed points will be in the same patch. MESH is the expected size of a patch considering the probability of connectedness.
Effective Mesh Size (MESH)	C	
Interspersion and Juxtaposition Index (IJI)	C	Measure of interspersion that takes into account the adjacency of patches. Length of patch borders are calculated by LULC classes (range: 0-100).

Table 2. Area of LULC classes by dates (ha)

LULC class	1952	1971	1988	2005
forest	17138.6	17032.5	17200.0	18270.9
grassland	2064.6	2491.4	3342	2721.9
orchard	67.1	76.6	38.6	4.9
arable land	4723.0	4301.1	2949.4	2486.5
anthropogenic	319.7	411.4	783.0	828.8

Table 3. Pairwise comparisons of LULC maps

Map pairs	Fraction Correct	Kappa	Fuzzy Kappa	Aggregated Cells
1952-1971	85%	0.691	0.773	0.858
1971-1988	79%	0.546	0.662	0.789
1988-2005	79%	0.627	0.703	0.836

Table 4. Contigency table of LULC classes for the changes of 1952-1971

		1971						
	LULC class	Anthropogenic	Forest	Grassland	Orchard	Arable land	Total	Unchanged
1952	Anthropogenic	20887	4892	1462	0	3426	*30786*	***0.68***
	Forest	6547	1567695	89427	4	27654	*1691393*	***0.93***
	Grassland	4310	81809	111756	327	27149	*225370*	***0.50***
	Orchard	946	5756	2566	4914	5045	*19242*	***0.26***
	Arable land	8441	34883	52420	2404	366830	*465003*	***0.79***
	Total	*41131*	*1695035*	*257631*	*7649*	*430104*	*2431550*	
	Unchanged	***0.51***	***0.92***	***0.43***	***0.64***	***0.85***		FC:0.85

Table 5. Changes by LULC categories reflected by Kappa and Fuzzy Kappa

LULC class	1952-1971		1971-1988		1988-2005	
	Kappa	Fuzzy Kappa	Kappa	Fuzzy Kappa	Kappa	Fuzzy Kappa
Anthropogenic	0.502	0.645	0.549	0.668	0.946	0.967
Forest	0.804	0.939	0.727	0.744	0.740	0.766
Grassland	0.639	0.691	0.292	0.350	0.370	0.400
Orchard	0.383	0.430	0.309	0.360	0.144	0.153
Arable land	0.823	0.951	0.609	0.678	0.784	0.808

Table 6. Differences of landscape metrics in a time series calculated with the pairwise Wilcoxon test (results were calculated based on the paired data of the habitat patches of the consecutive dates; r: effect size; **$p<0.05$**)

	1952-1971		1971-1988		1988-2005	
	z	r	z	r	z	r
AREA	1.26	0.12	1.69	0.19	1.88	0.18
PERIM	1.02	0.10	2.63	**0.30**	1.05	0.10
SHAPE	2.50	**0.25**	0.53	0.06	1.84	0.18
FRAC	2.66	**0.26**	0.10	0.01	3.25	**0.31**
ENN	1.87	0.18	1.54	0.18	1.58	0.15

Table 7. Differences of landscape metrics in a time series calculated with the Mann-Whitney test (results were calculated omitting the objects having identical pair in the consecutive date; r: effect size; **p<0.05**)

	1952-1971		1971-1988		1988-2005	
	z	r	z	r	z	r
AREA	3.48	**0.13**	1.89	0.08	3.45	**0.13**
PERIM	2.44	**0.09**	0.95	0.04	1.89	0.07
SHAPE	1.21	0.05	1.29	0.06	21.27	**0.83**
FRAC	4.73	**0.18**	4.23	**0.18**	21.51	**0.84**
ENN	0.76	0.03	1.04	0.05	6.72	**0.26**

Table 8. Landscape metrics on a class level

Date	LULC TYPE	AREA*	SHAPE	CIRCLE	ENN	PROX	DIVISION	MESH	IJI
1952	forest	106.8	2.42	0.79	50	46266	0.69	8639	70.4
	grassland	13.9	2.14	0.7	177	242	1	5	41.3
	orchard	4.5	1.48	0.59	470	1	1	0	71.4
	arable land	92.6	2.09	0.63	157	12863	0.98	463	52.7
	anthropogenic activity	12.3	2.34	0.72	1074	14	1	0	70.3
1971	forest	146.1	2.41	0.74	81	26703	0.69	8633	66.3
	grassland	17.8	2.16	0.7	218	333	1	7	31.5
	orchard	5.5	1.45	0.48	2088	0	1	0	69.5
	arable land	95.6	2.07	0.62	176	5108	0.99	373	55.6
	anthropogenic activity	12.9	2.11	0.68	633	50	1	0	57.9
1988	forest	440.4	2.37	0.7	67	31449	0.71	8126	53.5
	grassland	13.7	1.9	0.66	144	140	1	8	31.3
	orchard	4.8	1.51	0.61	1787	0	1	0	83.9
	arable land	77.6	1.96	0.63	243	1437	1	68	64.3
	anthropogenic activity	39.1	2.53	0.7	973	0	1	2	69.1
2005	forest	443.5	2.37	0.69	68	104584	0.6	11094	55.3
	grassland	8.5	2	0.68	128	124	1	5	28.5
	orchard	2.4	1.6	0.62	4121	0	1	0	81.9
	arable	57.8	1.83	0.61	279	1300	1	40	64.1

	land								
	anthropogenic activity	33.2	2.35	0.68	772	61	1	2	62.7

*: mean patch size

Table 9. Evaluation of the applied comparison methods (+: yes; -: no; +/-: possible with limitations)

	Contingency table	Kappa	Fuzzy Kappa	Landscape metrics
Geometric accuracy is important	+	+	+	-
Thematic accuracy is important	+	+	-	+
Can be determined in class level	+	+	+	+
Areas influenced by the changes can be determined (by pixels/objects in different dates)	+	-	-	+
Trend of change can be determined	+	-	-	+
Pairwise (pixel to pixel/object to object)	+	+	+	+/-*
Magnitude of changes can be determined	-	-	-	+
Considers further information beside the territorial/proportional data (e.g. shape, nearest neighbour, pattern etc)	-	-	-	+
Can be associated with probability	-	-	-	+
Can identify landscape ecological processes	-	-	-	+

*: changes can be determined with the IDs but only in cases when objects exist in each dates