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Landscape continuity versus landscape transformation: a case study in the Wiar River catchment, Polish Carpathians (1780 - 2000)

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Abstract. All landscapes change over time. The rate and magnitude of changes determine, whether the identity of the landscape survives. In this paper the distinction between continuity and transformation of landscape is discussed.
A case study in the hilly rural area of the Upper Wiar River catchment is conducted to exemplify the issue. The study area experienced wide range of possible landscape changes, from gradual evolution in the XIX century to rapid transformation in the middle of the XX century (forced depopulation), causing irreversible loss of landscape character. Two major characteristics of landscape composition (forest cover and settlement area) are analyzed by means of hierarchical and k-means clustering. Contemporary and historic maps dating back to XVIII century are used to reveal the dynamics of the region covering 233 km2. Methodological limitations and possible misinterpretations are also discussed.

Key words: landscape change, forced depopulation, historic maps, GIS, the Carpathians

Introduction

All landscapes are subject to change over time. Structure and spatial elements of landscape are evolving in different directions and at different speeds creating variety of patterns of change. The rate and magnitude of change determine, whether or not the landscape retains its character. Swanwick (2002) defines landscape character as distinct, recognizable and consistent pattern of elements in the landscape. Character is what makes landscapes unique and creates a particular sense of place in a locality (Swanwick 2004). It is an expression of the holistic nature
of the landscape (Antrop 2003). This approach is derived directly from the classical theory of perception called Gestalt, whose basic assumption is that the whole is more than the sum of its composing parts (Antrop 1998).
Nowadays one of the core question concerning landscape is: When does the landscape character change in an irreversible manner (Van Eetvelde, Antrop 2009)? The next question resulting from the above is: How much change have to take place to make the landscape lose its identity? Antrop (1998) compared changing of a landscape to the ageing of a person. In most cases, he writes, even though the person and its appearance changes drastically during his lifetime, he will be recognized still as the same person. However, situations may occur in a person's life that disrupt his personality, so that he really becomes someone else. So it is in the case of a landscape. Basing on this analogy the distinction between landscape continuity and landscape transformation is introduced.
Landscape transformation is defined as a set of changes in landscape characteristics that leads to loss of its identity and change in the character, making the perception of the landscape different from that prior to the change. Landscape continuity is defined as a set of changes in landscape characteristics that retains the

character of a landscape.
According to Swanwick (2002) landscape characteristics are elements, or combinations of elements, which make a particular contribution to the uniqueness of a given landscape. Elements are individual components which make up the landscape, such as trees and hedges.
The aim of this study is to find out, whether the theoretical distinction between landscape continuity and landscape transformation can be verified practically by means of quantitative methods. In another words, can we group several patterns of change into two significantly different clusters representing continuity and transformation? Exploring the diversity of patterns of change over time and space in the chosen study area is the secondary goal.

Materials and Methods

To conduct an exploratory analysis and group patterns of change a specific study area is needed with accessible materials concerning state of landscape in several sections of time.
The study area was chosen so as to:
- enclose different patterns of change,
- obtain an isolated area in terms of physiographic whole,
- the temporal variability of the analyzed characteristics in the last 220 years was as high as possible,
- the physiographic boundaries of the area were close to administrative boundaries.

The Wiar River catchment up to the fringe of the Carpathians meets these criteria. The selected area is located in the Sanok-Turka Mountains (Poland) about 20 km south of Przemyśl close to the Ukrainian border. It is a rural hilly region in the East Carpathians covering about 230 km2. It was a highly populated Polish-Ukrainian borderland up to the Second World War. In the late 40s Ukrainian peasants were forcibly displaced in the name of mono-national policy due to the political decisions conducted by the Polish communist government inspired by the Soviet Union regime (Motyka 1999, Pisuliński 2009). In the catchment area there are 26 smallest administrative units (25 villages and The Turnica Forest). In the analysis the boundaries of the study area were adjusted to the village administrative boundaries of 1852 (fig. 1).
It was decided to use cartographic methods due to the fact that maps are the only source of continuous spatial data with the time horizon exceeding 200 years. Seven series of military topographic maps in the middle scale

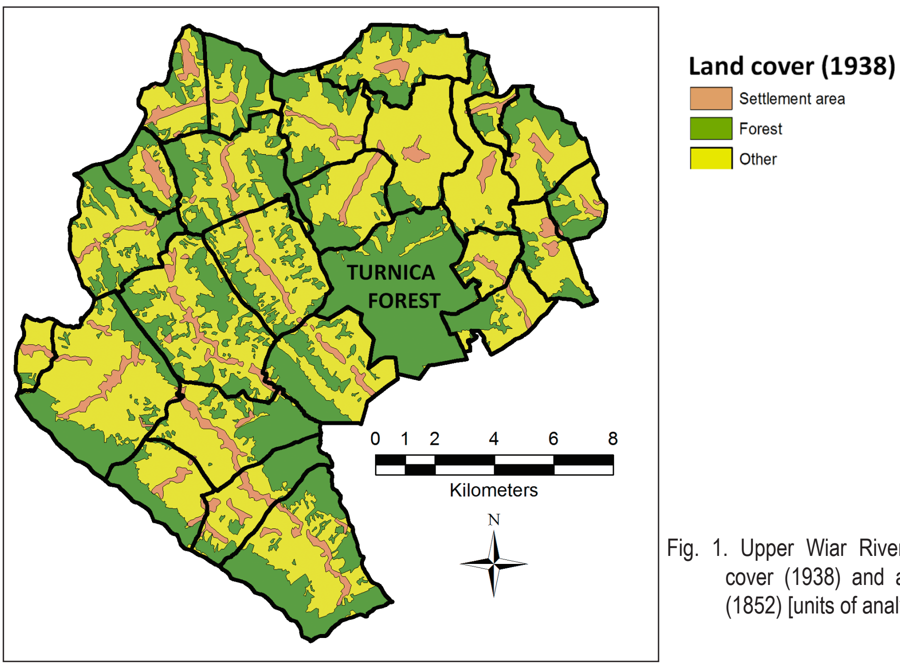

Fig. 1. Upper Wiar River catchment. Land cover (1938) and administrative units (1852) [units of analysis]

dating from 1780 to 2000 was gathered (table 1). The smallest scale map (Tactical Map of Poland) is known for its precision and accuracy (Krassowski 1973) and does not differ greatly in details of terrain representation from the older topographic maps in larger scales.

Table 1. Details of used map series

Map series	Date of content acquisition	Scale	Coordinate system	Datum	Spheroid	Projection
First Military Survey of the Habsburg Monarchy	1780	1:28 800	none	none	none	nonmetric
Second Military Survey of the Habsburg Empire	1852	1:28 800	custom	Lwów	custom	modified Cassini
Third Military Survey of the Habsburg Empire	1897	1:75 000	MGI (Ferro)	Her-mannskogel	Bessel	Double Stereographic
Tactical Map of Poland	1936	1:100 000	Borowa Góra	Borowa Góra	Bessel	Double Stereographic
Military Topographic Map	1958	1:25 000	PUWG 42	Pulkovo	Krasovski	Transverse Mercator
Military Topographic Map	1981	1:25 000	PUWG 65	Pulkovo	Krasovski	Double Stereographic
M 853	2000	1:25 000	UTM	ETRS_1989	GRS_1980	Transverse Mercator

All the maps were scanned and georeferenced in GIS environment using ESRI software (ArcMap 10) according to the procedure described in details elsewhere (Affek 2011). Raster digital maps were brought to a common projected coordinate system PUWG92 (EPSG: 2180). Two main characteristics of landscape composition were included to the analysis: forest cover and settlement area. Having been easy to determine they are also considered to be contributing most to organize the structure and function of rural landscape. Other types of land use were omitted due to the difficulty in unifying the map legend covering period of time of that length. Other parameters of geographical environment, such as relief or habitat type were not included to the analysis of changes assuming that these parameters remain more a less constant.

Despite the large variation of maps in terms of legend used and the date of creation it was concluded, that the definitions of the forest on military maps are comparable due to the common military purpose of creation of the map. According to the legend, young trees and shrublands were not treated as forest. Settlement areas are a composition of built up areas, gardens and orchards. They were marked when a group of at least three residential buildings was recognized on the map.

To study similarities between patterns of change one of the most popular statistical exploratory method was applied: a cluster analysis. Both hierarchical cluster analysis and k-means cluster analysis were performed using STATISTICA 10 software. The first method was implemented to explore hierarchical structure and relative distances between patterns of change, the other one to check the adequacy of two cluster solution.

Analytical model built to explore the similarities of patterns of change included 22 variables reflecting the degree of change (table 2).

Twelve of them refer to increase and reduction of settlement area, the other eight refer to increase and reduction of forest cover. Forest cover has not been calculated for the first time section due to low accuracy of maps of the First Military Survey. Open spaces have been mapped much better, therefore settlement area could be included in the analysis. The spatial unit, which pattern of change refers to, is the smallest administrative unit in Poland with the borders adopted from the cadastre map of 1852. The unit of measurement is the percent of the village administrative area, that has changed. In the model, to emphasize the importance of settlement areas for the landscape, the percent of the changed settlement areas has been weighted by two.

Table 2. Variables included in the analysis

Variables	Description
SA_1+, SA_2+, SA_3+, SA_4+, SA_5+, SA_6+,	settlement area increase in a given interval
SA_1-, SA_2-, SA_3-, SA_4-, SA_5-, SA_6-,	settlement area reduction in a given interval
FC_2+, FC_3+, FC_4+, FC_5+, FC_6+,	forest cover increase in a given interval
FC_2-, FC_3-, FC_4-, FC_5-, FC_6-,	forest cover reduction in a given interval

On the basis of theoretical assumptions of cluster analysis (Statsoft 2006) and experimental modeling using various databases three possible solutions were assumed in the situation, when variables in the database are of one dimension arranged on the axis from lowest to highest value.
Cluster analysis - possible solutions (fig. 2):
a) if all the villages experience continuous changes, cluster total means (means of total changes for each cluster) will not differ significantly (t test) and variables will have comparable magnitude of change over time,
b) if all the villages experience transformation, cluster total means will not differ significantly (t test) and variables will have incomparable magnitude of change over time,
c) if some villages experience continuous changes and others experience transformation, cluster total means will differ significantly (t test), and variables will have incomparable magnitude of change over time.

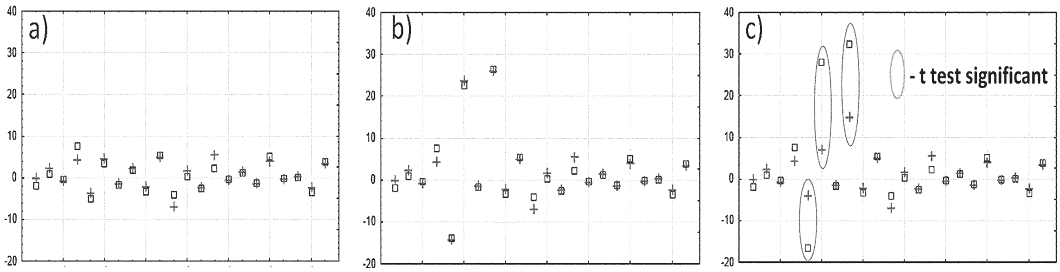

Fig. 2. Examples of possible solutions of k-means cluster analysis in terms of landscape change. Plot of means for each cluster [two clusters solution implemented a priori]: a) general continuity, b) general transformation, c) distinction between continuity and transformation. X axis – variables, Y axis – magnitude of change, "+" - cluster 1, "□" - cluster 2.

Results

The analysis of forest cover change revealed a dramatic increase of total forest cover in the period between 1936 and 1958 and in the following period (1958-1981) (fig. 3). In the remaining intervals forest cover was generally constant.
Similar but opposite general pattern of change was obtained for settlement area (fig. 4). In the period between 1938 and 1958 settlement area decreased more than three times. Despite those general trends at the landscape scale, pronounced differences were detected at the village scale. The outstanding unit in terms of stability of settlement area (extremely low) and forest cover (extremely high) in the centre of the catchment is the Turnica forest. The villages on the eastern and the western edge of the study area show a proportionately lower dynamics of analyzed characteristics than the villages surrounding the Turnica forest.
Results of hierarchical cluster analysis indicate that in the Upper Wiar River catchment two main groups of patterns of change can be distinguished (fig. 5). The bigger cluster (17 villages) is more coherent than the smaller one (9 villages). Two villages from the smaller cluster represent slightly different pattern of change than the other villages in this cluster. Without additional information we can't clearly conclude, if we have to do with continuous, transformed or other groups of patterns of change only on the basis of the shape of a tree diagram, because linkage distances are relative and the length of the branches differ considerably depending on the used clustering method.

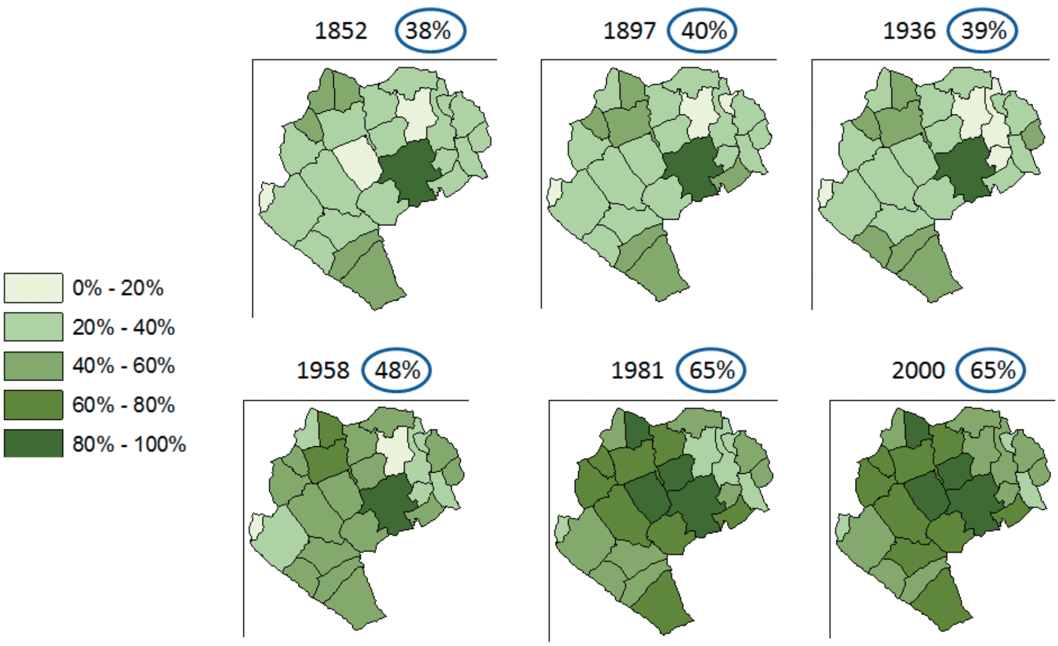

Fig. 3 Forest cover in percents (%) of total village administrative area in each section. In circles – mean percent of forest cover for the entire study area

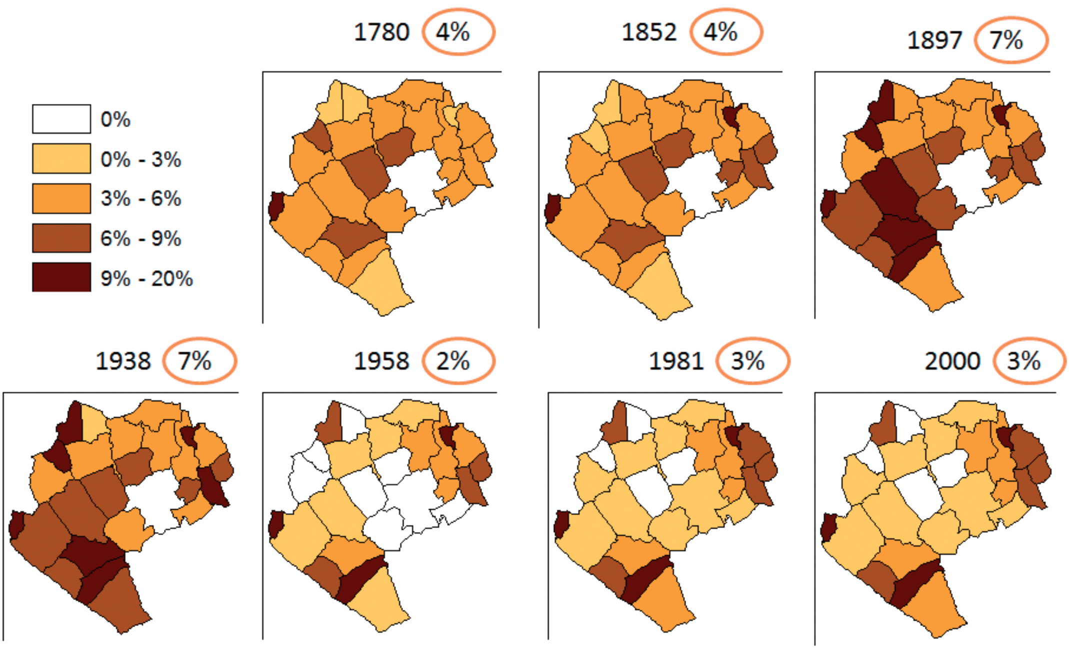

Fig. 4 Settlement area in percents (%) of total village administrative area in each section. In circles – mean percent of settlement area for the whole catchment

For detailed analysis k-means algorithm was used with two cluster solution chosen a priori (for other similar use of this method see Reger et al. 2007). The villages were allocated into different clusters by minimizing the variability within clusters and maximizing the variability between clusters (fig. 6).

This method gives almost the same results as the hierarchical clustering. Only one village (Leszczyny) was

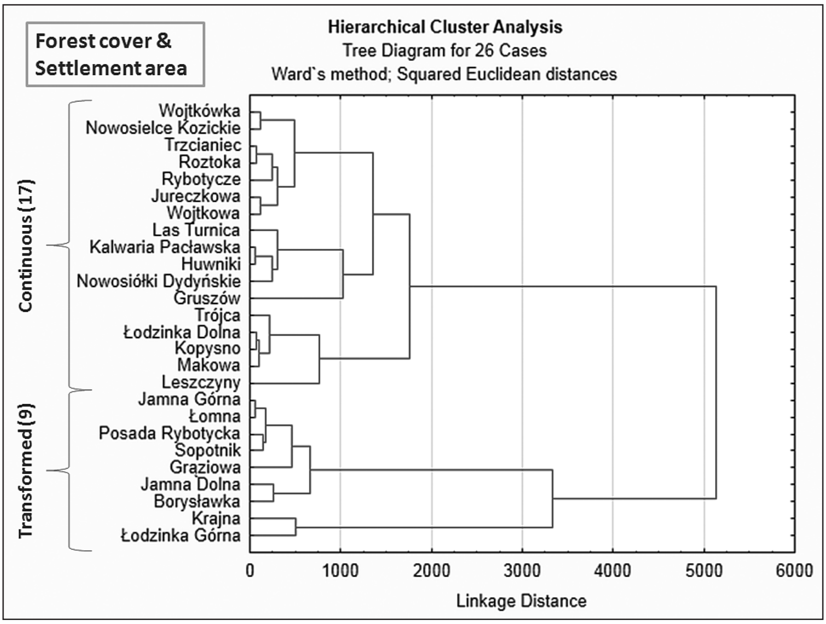

Fig. 5. Tree diagram representing two main clusters

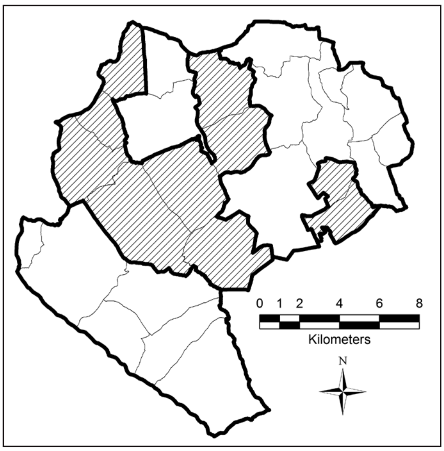

Fig. 6. Villages assigned to two clusters using k- means algorithm: hatch – landscape transformation, hollow – landscape continuity

assigned to the other cluster. Plot of means for each cluster (fig. 7) shows that in case of three variables pairs of means lie out of other means, they have much higher magnitude of change.

Moreover, the difference between clusters in each of this pair of means is statistically significant ($|t|>3$, $p<0.01$) and the direction of difference is the same. This clearly shows, that the bigger cluster of villages can be described as the continuous one, where the magnitude of change in the transformation period is significantly lower than in the other cluster (the transformed one). In the period of continuous changes differences between clusters are insignificant and the magnitude of changes is less than 10%. This case precisely fits the third solution described above: some villages experienced continuous changes and others experienced transformation.

Comparison of means of total changes between clusters results in a significantly higher amount of total changes in the “transformed” cluster ($t=-3.92$; $df=24$; $p=0.0006$). This result shows that the grouping proceeded on one dimension, what confirms that the “continuity” and “transformation” are proper names for centroids of the received clusters.

Discussion and Conclusions

One of the first effects of land abandonment is the relaxation of natural systems (Wolski 2007). Massive increase in forest cover in the middle of the twentieth century is a direct result of displacement of indigenous inhabitants of the Upper Wiar River catchment. In the first period (1936-1958) secondary succession took place in mid-forest glades, ravines and shrublands. In the following period (1958-1981) young trees (natural and artificial afforestation) marked on the maps of 1958 formed the mature forest. Pronounced reduction in settlement area falls directly on the period of displacement. Nonetheless, it is still incomparable with the decrease in population density, that dropped by 85% in the study area. Similar patterns of change in land use after the Second World War took place also in other depopulated Carpathian regions, such as Bieszczady and Beskid Niski (Wolski 2007, Woś 2005).

Another period of noticeable changes not mentioned before falls on a second half of the XIX century. Increase in settlement area can be associated with progressive land estates parceling resulting in greater accessibility of land for settlers. Development of railway network and industry (oil mines, glass factories etc.) contributed to the formation of worker settlements (Soja 2008). Even though there was a constant population growth up to the Second World War due to a very high fertility rate of Ukrainian peasants (ibidem), only at the end of the XIX century settlement area did increase. In comparison with changes described above the remaining dynamics can be considered as fluctuation.

Villages that were assigned to the transformed cluster were inhabited in about 80% by Ukrainians before the Second World War. However, some (the minority) former Ukrainian villages were assigned also to the other cluster. This shows that the ethnic criterion is not sufficient to discriminate units. Villages that experienced landscape transformation were found to be generally less accessible. They lie outside the main communication routes and neighbor with large forested areas.

The above analysis is not free from limitations and possible misinterpretations. Errors can occur at various work stages. The transformation (scanning, georeferencing and vectorization) of old maps to numeric layers is always imperfect (Podobnikar 2009). Total uncertainty of the obtained result is a complex function of errors generated at each work stage and on each map layer. As a result of self-control serious unintended misrepresentations were detected on the old Austrian maps. Nevertheless, it should be emphasized that in this type of exploratory analysis errors distributed randomly and proportionally do not distort the results, in contrast to single systematic errors which, with proper self-control can be captured. Undoubtedly, the disadvantage of the study is the

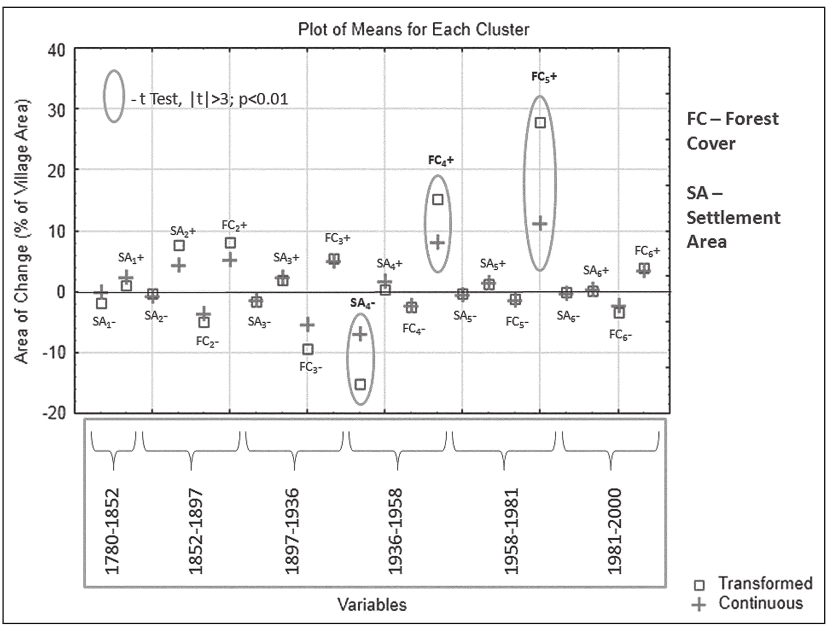

Fig. 7. Plot of means for two clusters in k-means cluster analysis

heterogeneity of map scales, which due to lack of accessible homogeneous materials could not have been eliminated. However, what was pointed out above, smaller-scale maps were characterized by greater accuracy than the older maps of larger scales. Also, analysis of shape and number of patches indicates that the diversity of map scales did not distort results in this case.

Cluster analysis proved to be a good tool to confirm the theoretical distinction between continuity and transformation. However, it should be realized that the distinction between clusters is relative and is based on relative difference between magnitude of changes. To place this groups of patterns of change on the general continuum of intensity of change further comparative studies should be carried out.

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