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ANALYSIS OF LANDSCAPE HETEROGENEITY CHANGES ON THE EXAMPLE OF HLINNÉ, VYŠNÝ ŽIPOV, AND ZLATNÍK VILLAGE (EASTERN SLOVAKIA) IN THE PERIOD 1826–2006

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Abstract

Ivanová M., Michaeli E., Boltižiar M., Juhaščíková J.: Analysis of landscape heterogeneity changes on the example of Hlinné, Vyšný Žipov, and Zlatník village (Eastern Slovakia) in the period 1826–2006. Ekológia (Bratislava), Vol. 30, No. 2, p. 269–280, 2011.

Contribution is aimed at the assessment of landscape heterogeneity by a grid approach, which is based on the monitoring of the occurrence of land cover classes in the individual squares and on the statistical-spatial analysis of the acquired data. Model region comprises cadastral areas of Hlinné, Vyšný Žipov and Zlatník village. They are situated at the contact zone of two genetically distinct entities: Panónska panva basin and the Carpathians. It is a markedly heterogenous area, which has undergone considerable changes from the aspect of landscape heterogeneity development, particularly under the influence of collectivisation of agricultural production, industrialisation, development of communication networks and with that connected rise of built-up areas.
The agriculture of the area and also land use since 1826 has undergone considerable changes. There are agrarian terraces and ramparts, the oldest relics of the agricultural land use, which remained after farming on small fields, respectively plots. From an analysis of historical sources and results of field research can be concluded that the landscape preserved this character till early 50-ties of the 20th century. The formation of agricultural cooperatives in the region and with this related intensification of agricultural production led to the disappearance of agrarian terraces and ramparts on the one side by inclusion of them into forest communities in areas with higher slope. The agrarian terraces and ramparts have been preserved only in areas with the most exposed slope at the foothills of Slanské vrchy Mts in Zlatník and Vyšný Žipov in Beskydské predhorie hilly-land.
Our presented methodology appears appropriate for evaluation of the heterogeneity of other rural landscape with occurrence of historical landscape structures not only in Central Europe.

Key words: land cover, landscape heterogeneity, changes, GIS, Eastern Slovakia

Introduction

Spatial heterogeneity can be understood as quantificative diversity of natural landscape elements (Forman, Godron, 1986). It is one of the basic attributes of landscape system, which can be expressed through the information about number, intensity and diversity of relations among system's components, which differ from one another in the type of ecosystem, extent, shape, origin and in other characteristics.

Real state of landscape structure is appropriately represented by the land cover classes (Oťaheľ et al., 2004) which are close to the landscape elements, i.e. suitable for the measurement of landscape heterogeneity (Forman, Godron, 1986). Utilisation of land cover for the purpose of the assessment of its spatial heterogeneity is frequent in the works dealing with landscape metrics – spatial composition and configuration of landscape elements (McGarigal, Marks, 1994, 1995; Herzog et al., 2001; McGarigal, 2002; DiBari, 2007; Araujó et al., 2008; Sundell-Turner, Rodewald, 2008; Boltižiar, 2007; Dobrovodská et al., 2010; Pucherová, 2004; Válkovcová, 2008a, b; Michaeli et al., 2009; Falťan et al., 2008). The knowledge of landscape heterogeneity is an extremely relevant topic, predominantly in the context of the influence of various activities of the society on the landscape and as well from the viewpoint of landscape potential, which natural landscape offers for its exploitation (Oťaheľ et al., 2004).

In the sense of Forman and Godron (1986), heterogeneity can be evaluated by the linear and grid-based approach. This contribution uses grid-based approach, which arises from the superimposition of a grid over the land cover maps and consequent recording of the occurrence of land cover individual classes in the squares of the grid. The analysis of the landscape heterogeneity in our contribution was elaborated for four time periods 1826, 1956, 1991 and 2006. Resultant maps indicate the development of landscape heterogeneity and creates space for further landscape ecological research, e.g. assessment of the landscape potential or landscape ecological stability.

Study area

The study area is located in the eastern part of Slovakia on the boundary line of tree provinces: Východné Karpaty Mts, Západné Karpaty Mts, Východopanónska panva basin (Mazúr, Lukniš, 1986). The study area is defined by cadastral areas of three villages: Hlinné, Vyšný Žipov a Zlatník (Fig. 1). It consists of three genetically different units: the volcanic Slanské vrchy Mts at the west of the study area, the flysch-neogen depression Beskydské predhorie hilly-land at the north and Východoslovenská rovina plain at the south. According to Lapin et al. (2002) climate classification in the Atlas of Landscape of the Slovak Republic, the study area is located in two climatic areas – warm and moderately warm. The warm area includes plains and uplands which may be characterized as warm, moderately humid with moderate winter. Western part (Slanské vrchy Mts) has a moderately warm and moderately humid climate.

Hydrologically the territory belongs to the Topľa river basin with the brooks Zlatníčok, Slaný, Hrabovec, Uhliskový, Hlinský, Petkovský and Jastrabie. The soil cover is presented by Cambisols, Luvisols and Fluvisols. Original vegetation cover was mostly removed and transformed into cultural steppe. The area has been transformed by human induced structures that include areas of sport and leisure facilities and industrial area.

The agriculture of the area and also land use since 1826 has undergone considerable changes. The second half of the 19th century was marked by great fragmentation of land, which did not bring sufficient sustenance for its

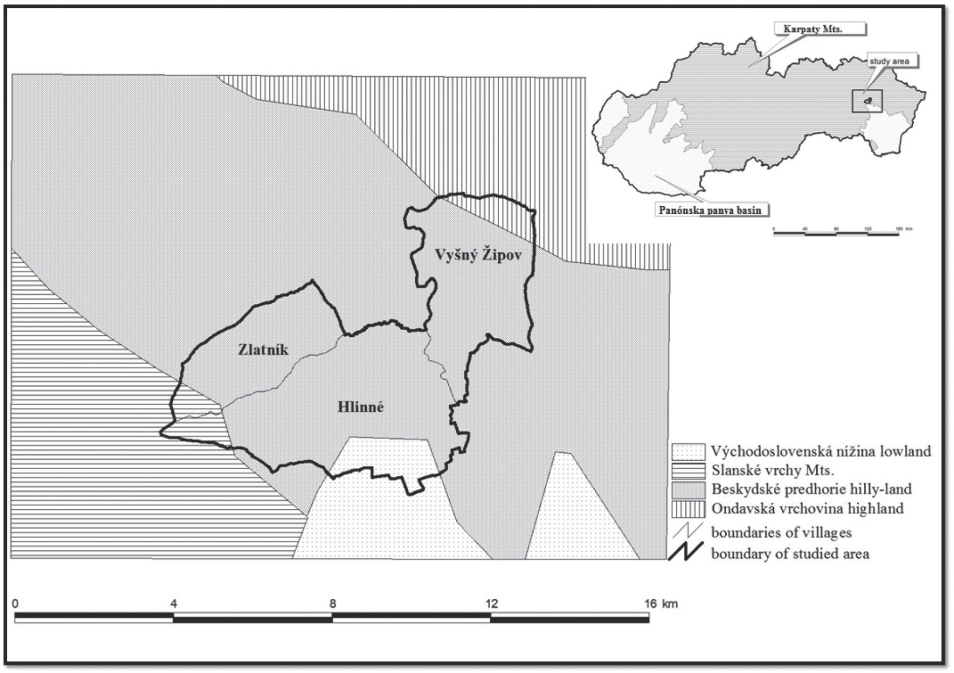

Fig. 1. Geographical position of the study area.

users. There are agrarian terraces and ramparts, the oldest relics of the agricultural land use, which remained after farming on small fields, respectively plots. They are located on NW cadastral territory of village Zlatník and on NE in Vyšný Žipov. They accounted for approximately 10% of the area. They formed as a necessary consequence of the change of forest to arable land, therefore in sloping terrain, as primitive anti-erosion measures. Later on agrarian terraces by raid and planting there were formed lines of trees with a significant anti-erosion effect. From an analysis of historical sources, a detailed statistical-spatial analysis of the topographic maps, as well as the results of field (terrain) research can be concluded that the landscape preserved this character till early 50-ties of the 20th century. The formation of agricultural cooperatives in the region and with this related intensification of agricultural production (chemicals, machinery) led to the disappearance of agrarian terraces and ramparts on the one side by inclusion of them into forest communities in areas with higher slope (Zlatník, Vyšný Žipov), but on the other side by artificial means, plowing and erasure of anthropogenic terraces in connection with the establishment of the large acres in hillock georelief. Disintegration of the agricultural cooperatives after 1989 ushered in a decline of agricultural production and decrease the proportion of arable land. The agrarian terraces and ramparts have been preserved only in areas with the most exposed slope at the foothills of Slanské vrchy Mts in Zlatník and Vyšný Žipov in Beskydské predhorie hilly-land. Their share of total land area is about 2%.

Determination of the aims and methods of the research

The preparation of the topographic base and construction of the layers of land cover arises from the main aim of the contribution, i.e. from the analysis and evaluation of the landscape heterogeneity changes during four above mentioned periods. We divided the main aim into two partial aims, whose task was:

- to analyse the landscape heterogeneity with respect to frequency of occurrence of land cover individual classes in the grid squares,

- to specify the land cover classes which filled the greatest part of the grid.

Selection of chosen time horizons was not accidental. It was based on the study of archive materials with an aim to detect the most significant changes in the landscape structure of the researched area, i.e. the changes in the utilisation of agricultural lands, development of industry and transition to market economy. Topographic maps at the scales of 1: 28 886 (year 1826) and 1: 25 000 (years 1956, 1991) and orthophotos from 2006 were used as base-layers.

For the identification of land cover classes, adjusted methodology Corine Land Cover was used. It consisted of 19 classes belonging to 5 primary groups of land cover areas: settlement and technical landscape, agricultural landscape, forest and semi-natural landscape and wetlands and water areas (Figs 2–5). CLC legend was intentionally adapted to the research aims, specific features of the territory and its extent (cca 3 027 ha). In comparison with CLC methodology, land cover classes were to some degree modified. They were identified through vectorisation of topographic maps and orthophotos in the environment of GIS software Arc View 3.2.

Landscape heterogeneity was assessed by the method of grid-based approach, where the thematic maps of land cover were overlaid by a grid with 162 squares. We created it through script, while the size of one square was 500x500 m (0.25 km^2). We chose this size based on the used map scale and detailedness of mapped land cover classes. Consequently, we were examining the occurrence of individual land cover classes in every square of the grid through Arc View 3.2 and Microsoft Excel software. The result of our research is a colourful mosaic of squares, which were a subject of statistical-spatial analysis. Further procedure required covering of the land cover layers. The results were processed into contingency Tables of land cover transformation, which were used for the research of the aspects of the landscape heterogeneity changes.

Landscape heterogenity assessment

First task we have set was the analysis of landscape heterogeneity with respect to the frequency of the occurrence of individual land cover classes in a square of the grid (Tables 1, 2, Figs 6–9). Analysed data shows that squares represented by 1–6 classes occur in every time horizon, squares with 7 and 9 classes occur in the grid of 1956, 1991 and 2006, squares with 8 classes in 1956 and 2006 grid. Only one square is represented by 10 classes, in the grid of 1991. It can be found in the intravillain of the Vyšný Žipov village. There is not a single square with all 19 classes in the grids of mentioned years.

Table 1. Number of land cover classes in the squares of the grid in 1826, 1956, 1991 and 2006. Source: own calculations derived from vectorised data.

Number of classes in a square	1	2	3	4	5	6	7	8	9	10	**Total**
1826	51	40	42	22	6	1	0	0	0	0	162
1956	22	34	33	30	21	13	6	2	1	0	162
1991	24	31	39	32	16	13	5	0	1	1	162
2006	24	35	43	25	18	10	4	2	1	0	162

Table 2. Percentage share of the occurrence of individual land cover classes in the squares of the grid in 1826, 1956, 1991 and 2006. Source: own calculations derived from vectorised data.

Number of classes in a square	1	2	3	4	5	6	7	8	9	10	**Total**
1826	31	25	26	13	4	1	0	0	0	0	100 %
1956	13	21	20	19	13	8	4	1	1	0	100 %
1991	15	19	24	20	10	8	3	0	1	1	100 %
2006	15	22	27	15	11	6	2	1	1	0	100 %

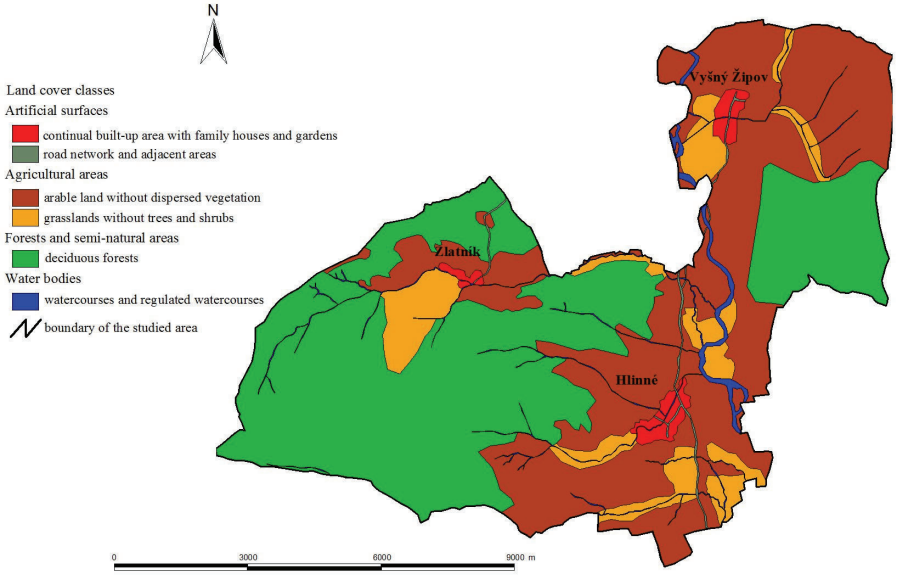

Fig. 2. Land cover in 1826.

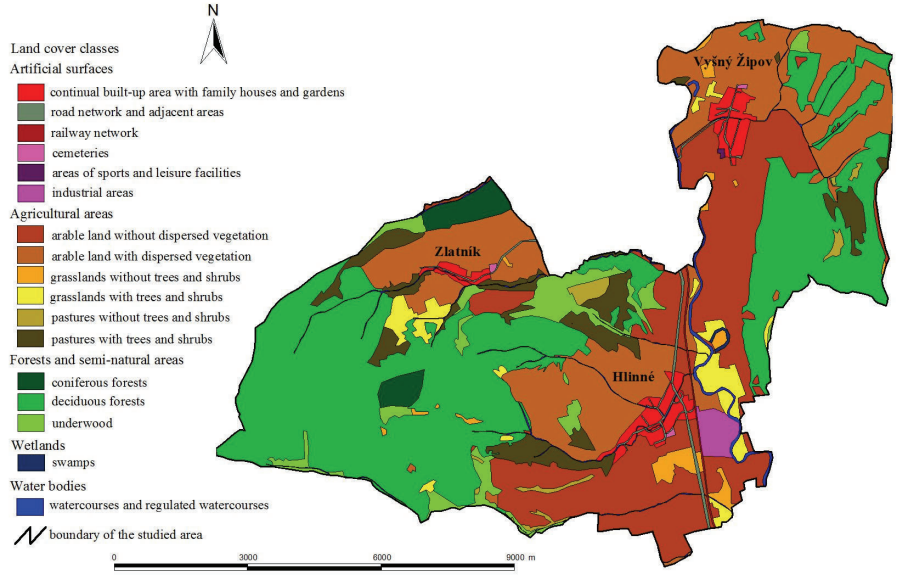

Fig. 3. Land cover in 1956.

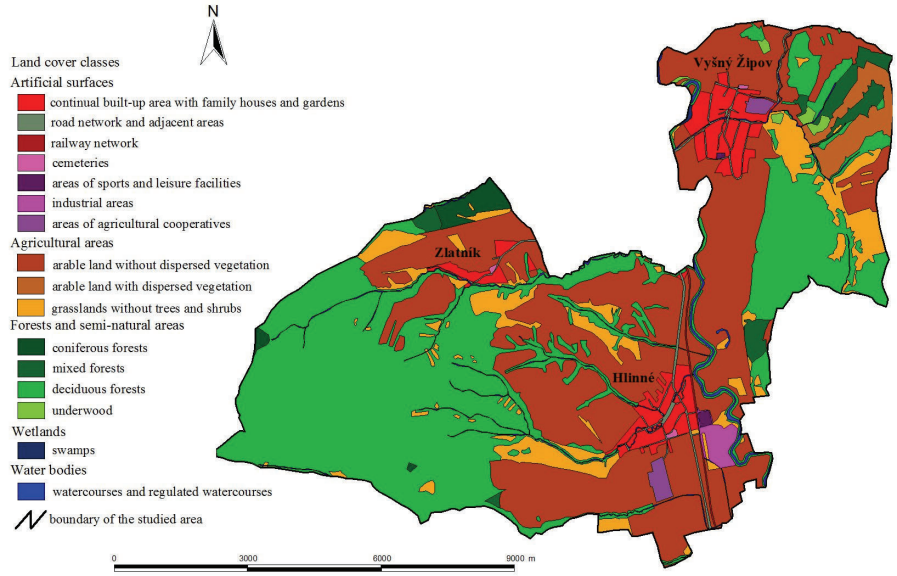

Fig. 4. Land cover in 1991.

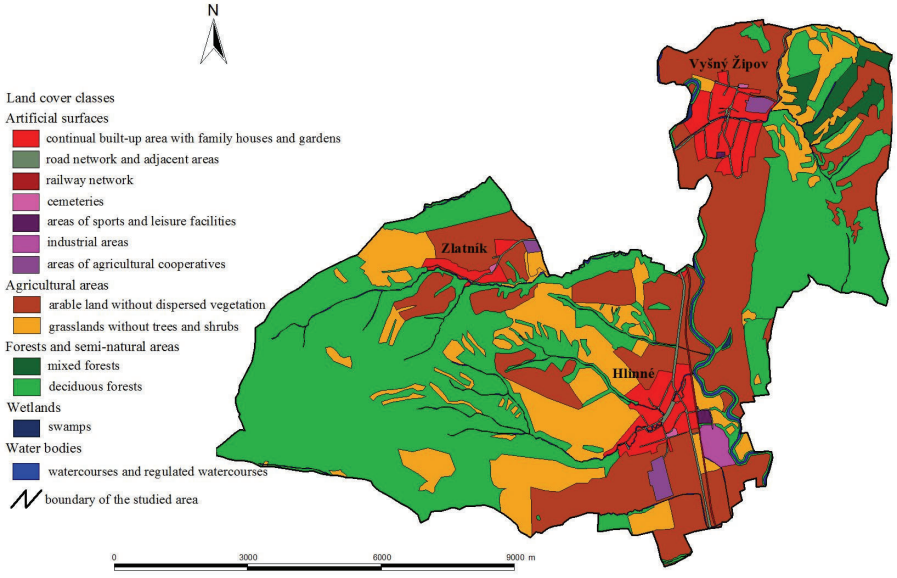

Fig. 5. Land cover in 2006.

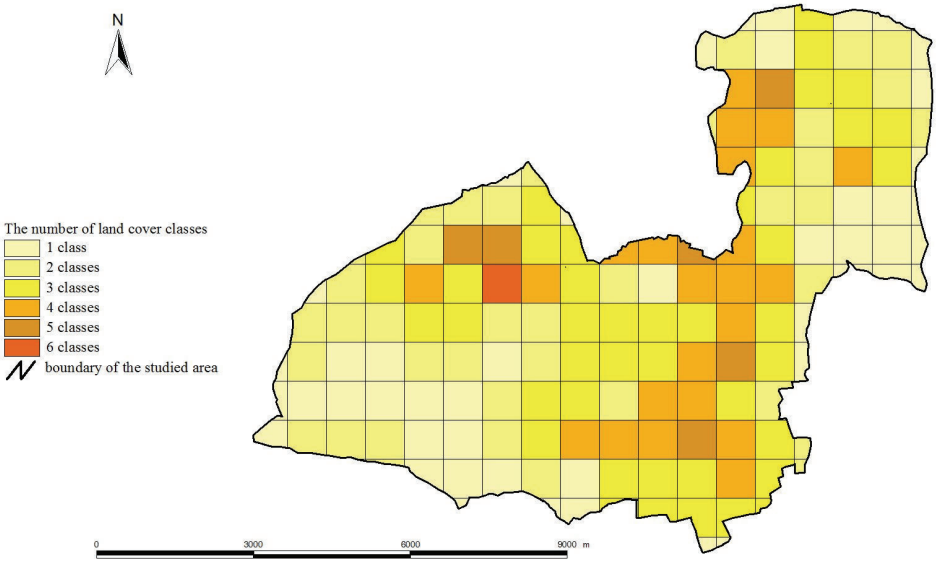

Fig. 6. The number of land cover classes obtained from a grid approach 500x500 m in 1826.

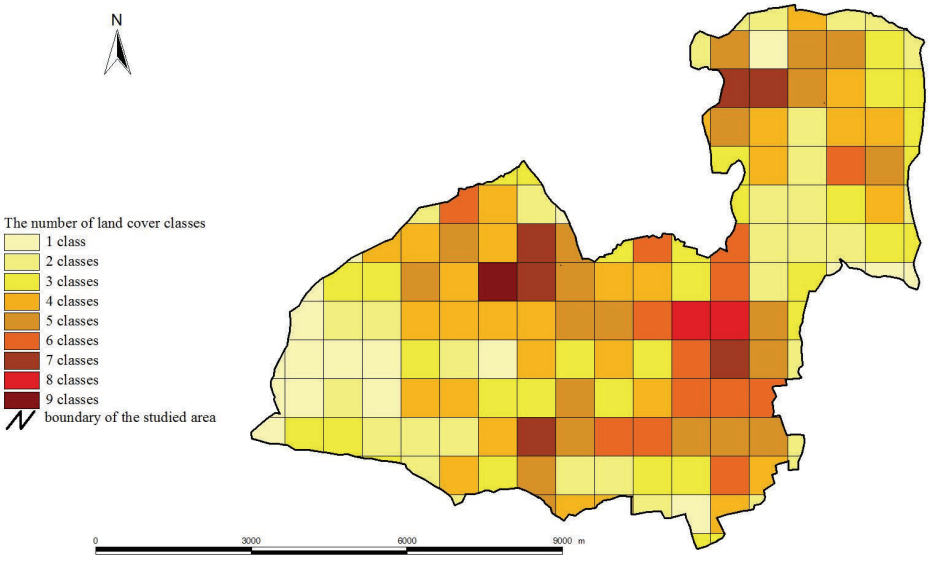

Fig. 7. The number of land cover classes obtained from a grid approach 500x500 m in 1956.

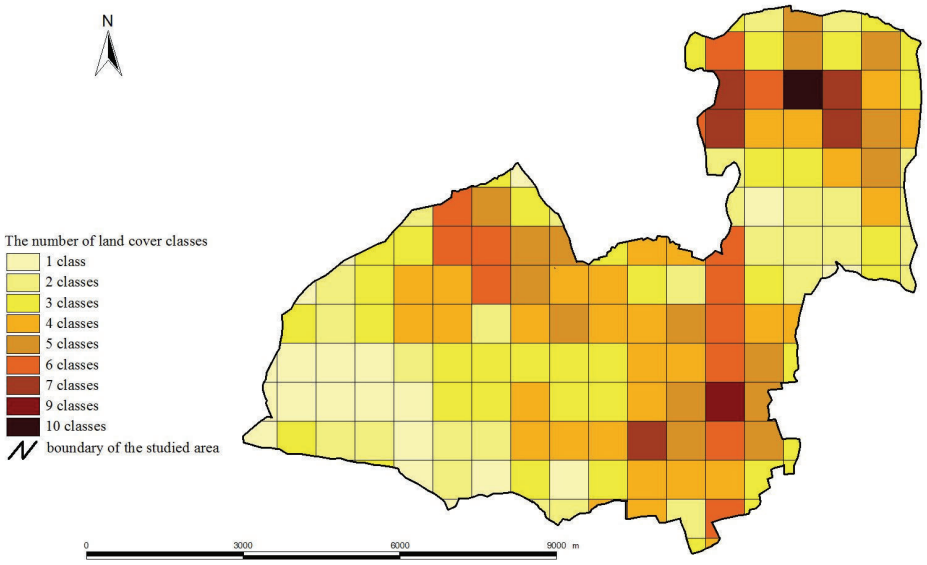

Fig. 8. The number of land cover classes obtained from a grid approach 500x500 m in 1991.

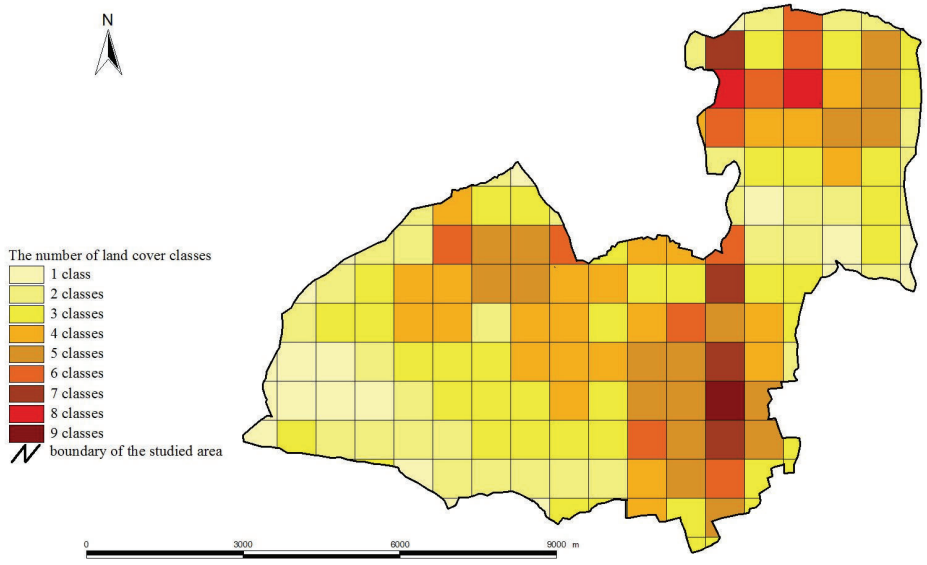

Fig. 9. The number of land cover classes obtained from a grid approach 500x500 m in 2006.

From the percentage viewpoint, landscape heterogeneity analysis proves that in more than 56% of squares in 1826, only 1 or 2 land cover classes occur. The grids of 1956, 1991 and 2006 have from the viewpoint of the frequency of occurrence of 1 or 2 land cover classes in the grid approximately balanced character. By the analysis of the number of 3 and 4 classes in the grid in 1826 and 1956, we can observe a total agreement (39%, Table 2), in 1991 and in 2006 only 2% difference occurs (44% in 1991 and 44% in 2006, Table 2). Representation from 5 to 10 land cover classes in a square of the grid shows distinct disproportions between1826 and other researched periods. While in 1826 only cca 5% of grid squares are in this category, in 1956 it is cca 27%. Slightly lower character shows when monitoring the occurrence of 5–10 classes in the grid in 1991 and 2006, where approximately 22% of squares occur here.

Second observational task was a spatial analysis of land cover classes with an aim to specify those classes, which have covered the most of the space (most of the squares) of the grid. Land cover grids of 1826, 1956, 1991 and 2006 reflect the fact that the most frequent classes are classes of arable lands without dispersed linear or point vegetation, deciduous forests, watercourses and regulated watercourses and the class of meadows without trees and bushes.

T a b l e 3. Presence of land cover classes in squares of network in study area.

year	**1826**		**1956**		**1991**		**2006**	
Land cover classes	**Presence in squares of network (count of squares)**	**Part in %**	**Presence in squares of network (count of squares)**	**Part in %**	**Presence in squares of network (count of squares)**	**Part in %**	**Presence in squares of network (count of squares)**	**Part in %**
Continual built-up area with family houses and gardens	15	9	18	11	26	16	27	17
Road network and adjacent areas	23	14	24	15	30	19	30	19
Railway network	-	-	8	5	9	6	9	6
Cemeteries	-	-	3	2	3	2	3	2
Areas of sports and leisure facilities	-	-	1	1	2	1	3	2
Industrial areas	-	-	3	2	4	2	4	2
Areas of agricultural cooperatives	-	-	-	-	4	2	4	2
Arable land without scattered (line and spot) vegetation	109	67	74	46	55	34	99	61
Arable land with scattered (line and spot) vegetation	-	-	70	43	11	7	-	-
Meadows without trees and shrubs	49	30	18	11	81	50	93	57
Meadows with trees and shrubs	-	-	25	15	-	-	-	-
Pastures without trees and shrubs	-	-	18	11	-	-	-	-
Pastures with trees and shrubs	-	-	42	26	-	-	-	-
Coniferous forests	-	-	9	6	7	4	-	-

Table 3. (Continued)

year	1826		1956		1991		2006	
Mixed forests	-	-	-	-	12	7	11	7
Deciduous forests	97	60	100	62	135	83	-	-
Underwood	-	-	43	27	8	5	-	-
Water flows and regulated water flows	83	51	85	52	87	54	89	55
Swamps	-	-	2	1	2	1	4	2

The class of **arable lands without dispersed linear and point vegetation** is in the grid of 1826 represented by 109 squares, what makes 67% of the whole grid (Table 3). Until 1956 the occurrence of this class in the grid has decreased to 74 squares (46%, Table 3). That was caused by its transformation into a class of arable lands with dispersed linear and point vegetation and class of deciduous forests, what has caused the rise of heterogeneity in the study area. The class of arable lands without dispersed linear and point vegetation in the grid of 1991 is represented only by 55 squares; however, in 2006 the number of squares again increases to 99, what makes 61% of the whole grid (Table 3).

The class of **deciduous forests** has during the whole observed period (1826–2006) an increasing tendency (Fig. 3). In the first time horizon (1826) it is represented by 97 squares of the grid. Until 1956 the number has increased to 100 squares. This slight increase has affected mostly arable lands without dispersed linear or point vegetation. The class of deciduous forests is in the grid of the third time period (1991) represented by 135 squares (83%, Table 3), the transformation takes place at the expense of the class of coppice. Until 2006 the number of areas of this class in the grid has only slightly increased to 139 squares (86%, Table 3).

Class with the third greatest representation of squares in the grid is the class of **meadows without trees and bushes**. In the grid of 1826 it is represented by 49 squares (Table 3). Until 1956 it has markedly decreased to 18 squares (Table 3), what was predominantly caused by its transformation to the class of meadows with trees and bushes, pastures without trees and bushes and pastures with trees and bushes. This change has contributed to the increase of heterogeneity of the study area. In 1991 the number of squares increases to 81 (55%) and until 2006 to 93 squares (57%, Table 3).

Comparing the grids of occurrence of the individual land cover classes we may state that there is a noticeable disharmony in the study area between the analysed year 1826 and the rest time periods. These show only little deviations in landscape heterogeneity; in comparison with 1826 the differences were noticeable. This phenomenon is a result of overall economic development of the territory, collectivisation, industrialisation, development of communication networks and with that connected development of build-up areas.

Conclusion

The contribution was focused on the analysis of the landscape heterogeneity by the grid-based approach. Main focus was laid on the monitoring of landscape classes occurrence in the squares of the grid and specification of land cover classes that filled the most squares of the grid. Model area comprised three east Slovakian villages: Hlinné, Vyšný Žipov and Zlatník.

By the comparison of the land cover classes occurrence in the individual squares of the grid we can state that during the observed period the **landscape heterogeneity has increased**. It was influenced by the above-mentioned economic development of the territory,

collectivisation, industrialisation, development of communication networks and with that connected rise of built-up areas. The increase of landscape heterogeneity was demonstrated on the decrease of the number of squares with 1 and 2 land cover classes. On the contrary, the number of squares with 5 and 6 land cover classes has markedly increased and since 1956 the squares with 7–10 land cover classes has occurred in the grid.

Comparing the grids of the spatial occurrence of land cover classes in 1826, 1956, 1991 and 2006 we have come to conclusion that the most frequent are classes of arable lands without dispersed linear and point vegetation, deciduous forests, watercourses and regulated watercourses.

The presented methodology appears appropriate for evaluation of the heterogeneity of rural landscape with occurrence of historical landscape structures.

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