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LANDSCAPE METRICS AS A TOOL FOR EVALUATION OF LANDSCAPE STRUCTURE, A CASE STUDY OF HUBENOV REGION, CZECH REPUBLIC

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Abstract

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The present paper contains the evaluation of rural landscape development in model territories by means of landscape structure analysis. Based on the computed values of landscape ecology indexes, development and typical and specific features of analysed territories are interpreted in defined time horizons. The territories differ in the intensity of their use, natural conditions and different social requirements. Two territories have intensive agriculture in different natural conditions, the third model territory is situated in the protective zone of a water resource, and the fourth model territory is a protected area. For all localities, the studied baseline period was that of the Stable Cadastre mapping (1825–1839), followed by the sixties of the 20th century and the present time. The method of processing and evaluation of four model territories is described and a detailed analysis and interpretation of one territory – Hubenov region is presented. Agricultural land formed the landscape matrix in Hubenov territory in the past and at present. There is a significant reduction in the number of plots of the landscape classes and the increase in the average size of agricultural and non-agricultural plots between year 1825 and 2009. Spatial distribution of agricultural land has changed. Area of arable land decreased after the construction of water reservoir Hubenov. The area of permanent grassland, forests and water bodies increased. It was reflected in an increase of ecological stability. In the context of the change of landscape structures decreased the length of ecotone edges of the categories arable land and PGL and categories arable land and forest.

landscape structure, landscape metrics, GIS, Stable Cadastre, aerial photos, geodatabase, Hubenov

Processes in landscape, its functioning and character are bound to the configuration of landscape, its arrangement and actual situation. Any change in the landscape structure, either spatial or temporal, influences the pattern of energy and material flows in landscape, affects landscape passability and habitability, influences its ecological stability and other properties and characteristics. If we are solving crucial problems of landscape and prerequisites of its conservation in the future, our solution should not be based on the present situation only but we should use available reliable historical materials mapping trends of landscape development. Taking into account heritage of the past (radical change in the spatial arrangement of landscape structure and flattening of landscape functions) and fluctuations of temperatures and precipitation in the last years, an increasingly greater emphasis is laid on the polyfunctionality of landscape, its accessibility and last but not least, on its aesthetics.

In the past, landscape was not “fragmented” either functionally or spatially as it is known from contemporary landscape studies. It means that it is divided into functionally separated parts. In historical times (before the introduction of large-scale production) the landscape structure influenced the methods of land use while at the present time, the situation is opposite, production activities are moulding landscape according to their needs. If we want to return into landscape its essential feature – polyfunctionality, we should approach its planning on the basis of the knowledge of its development both in general terms and in specificities of particular territories.

Trends of development and significant landscape changes in analysed territories can be derived by the analysis of landscape structure and obtained characteristic values. The interpretation of these trends in the context of historical development (social, political and economic conditions) represents an important source of information for landscape development and planning.

When studying historical changes in landscape in time horizons of tens to hundreds of years, we investigate changes caused almost exclusively by anthropic activities. Anthropogenic processes alter the appearance, structure and functions of landscape either directly (open mining, construction) or indirectly by influencing natural processes and their intensity (erosion, water regime, cycling of matter, energy flows, etc.).

Changes in the landscape structure, e.g. ploughing of grasslands, interruption or liquidation of local corridors, substantial enlargement of fields, construction of roads (its causes landscape fragmentation and barrier effect) have an immediate influence on the movement of organisms in landscape and also e.g. on erosion processes, landscape retention capacity or water runoff regime.

Overall changes in landscape, especially in land use, are very significantly monitored by time series of aerial and/or satellite photos that clearly represent disturbances, great devastations, dynamics of enclave development and other parameters of the landscape structure. Methods of remote sensing of the Earth (RSE) can be applied also in the monitoring of changes in the particular environmental components.

Historical maps have an information potential suitable for landscape study from different aspects and for different landscape types. Possibilities of application of these materials have been documented by many realized researches on changes in landscape and landscape structure, e.g. revitalization of the High Tatras land cover after a wind disaster (Boltiziar, Bruna, Krovakova, 2008), investigation of the horizontal landscape structure development in a selected time segment (Kubeš, Mičková, 2003), changes in land use from the aspect of ongoing succession and anthropogenic processes (Spulerova, 2008), including processing by GIS tools (Girel, Barguet-Duport, Pautou, 1997; Xu Jian-hua, Lu Yan, Ai Nan-shan, Yue Wen-ze, 2001).

One of the important projects (due to the large size of the solved territory) is a research project realized at the Faculty of Geography of the Moscow State University. Its objective was to evaluate and to map land use and land cover of Russia by combining remote sensing, traditional maps and field surveys of various spatial and time resolutions as geographic indicators of the environment condition and its dynamics (Milanova, Lioubimtseva, Tcherkashin, Yanvareva, 1999).

Fukalová and Pokladníková (2009) described a retrospective evaluation of land use in the area Hustopečsko (Žabčice). They focused on changes in land use over time and the results of their study confirmed the trends of changes in land use.

Guth, Kučera (1997) stated that an important source of data on temporal changes in landscape is military photogrammetry that has been repeatedly performed in this territory at regular intervals since the end of the thirties or the forties. Satellite images are more suitable for small-scale synoptic maps while aerial photos are more suitable for the evaluation of more detailed landscape structure and landscape elements.

Juhás (1991) wrote that the analysis of the spatial distribution of landscape structure elements, and information on area structure, representation and proportions in a very precise ground plan projection belong among the most frequently used interpretations of aerial photos. Overall information concerning the spatial structure of stands, land areas, settlements, roads, watercourses, linear technical elements, structure of scattered vegetation and production activities is significant for landscape evaluation.

The contribution and application of data from remote sensing of the Earth in landscape creation and conservation consist especially in the inventory and revealing of the actual condition of elements of interest; thanks to a time series it is possible to investigate developmental changes and to improve proposals of essential protective and management measures. Among the publications that dealt with remote sensing of the Earth in nature and landscape conservation we should cite the article "Evaluation of changes in landscape using remote sensing of the Earth" (Hais, Brom, Pecharová, 2006) in which methods of remote sensing, its pros and cons were described. Data from RSE are the most suitable material for the 2nd half of the 20th century documenting detailed development of landscape structure (Lipský, 2000).

The Stable Cadastre is an essential source for all landscape ecology researches, landscape evaluation and planning e.g. in the definition of territorial systems of ecological stability, registration of significant landscape elements, landscape mapping, watershed revitalization, evaluation of landscape character and in land consolidation measures (Lipský, 2000).

One of the approaches to landscape evaluation is the use of so called indexes. These indexes reduce the scope of quantitative data and facts and contribute to a decrease in the number of variables with the same informative capacity. The method of landscape evaluation by means of indexes is very suitable for the assessment of landscape structures and functions and other facts (Lipský, Romportl, 2006; In Pérez-Soba, Wascher, 2005). Landscape evaluation is based on so called matrices – areas that take up a dominant position in landscape (Forman, Godron, 1993; Fladmark, Mulvagh, Evans, 1991; Zonneveld, 1979).

Landscape evaluation by metrics is a frequently used method of evaluating the ecological stability of landscape. Palmer (2004) used the metrics to assess scenic perception by the population in time and he found out that a half of the changes in scenic perception can be revealed by metrics and that this method has high prediction efficiency.

In its variability, landscape structure is related to the dynamics of natural and anthropogenic processes conditioning it, and at the same time, they are presented in landscape through its mediation. Open cultural landscape in the territory of the CR that is not used specifically, e.g. for the extraction of mineral resources, is influenced to a different extent by measures taken in order to improve the production functions of landscape (agricultural, forest, hydrological, etc.). Considering the increasing frequency of extreme natural phenomena in the last years attention is more often paid to a possibility of improvement or revitalization of natural stabilization functions, processes and elements of landscape that have been changed or fully eliminated by anthropic activities.

MATERIAL AND METHODS

Model territories were chosen with respect to the continuity of the solution in long-time managed experimental watersheds and areas of Research Institute for Soil and Water Conservation considering the availability and possibility of acquiring background materials necessary for the solution and accessibility of these territories from the aspect of field surveys. In line with the solution contents the choice of model territories was conditioned by assumed changes in landscape structure and development of its arrangement in relation with changes in land use during the chosen time periods.

The analysis of landscape structure was performed for four territories of interest, differing in their development and land use in relation with different natural conditions. It is an area with intensive agriculture in the Dolnomoravský úval valley (Hustopeče territory; 92.4 km^2), Bohemian-Moravian Uplands (Žejbro watershed; 115.3 km^2), the Protected Landscape Area (PLA) (Železné hory; 36.1 km^2) with specific protection conditions.

The area Hubenovsko (83.1 km^2) presented in this paper is situated in the protection zone of a watercourse Maršovský and Jedlovský Brook which flows into a drinking water reservoir Hubenov. It is situated in the Bohemian-Moravian Uplands, with humid and cold climatic conditions combined with a steep land and altitude between 530–709 m a.s.l. The average annual temperature is 7 °C. Annual precipitation is in the long-term average above the 630 mm (Tolasz, 2007).

The delimitation of the territories, and/or the area of chosen territories in tens of km^2, was conceived with respect to the scales of historical materials (maps, RSE), certain area coherence and representativeness of territories with a possibility of mutual comparison.

Time horizons were chosen to work with three series in order to describe crucial changes in landscape and/or in landscape structure from historical times to the present time.

For all territories, the 1st half of the 19th century was chosen as a baseline period while the present time is at the opposite end of the time span. The period between these two time points was covered by historical aerial photos from the sixties of the 20th century.

Necessary databases were processed in the years 2009–2010. Analyses were performed in several steps:

- acquisition of maps and materials of RSE for the chosen territories of interest in required time periods,
- georeferencing and orthorectification of these materials into a coordinate system for subsequent use in GIS environment,
- digitization (creation of vector map layers of LU/LC),

1: *Chosen model localities in the Czech Republic*

2: *Examples of maps of a part of the Hubenov model territory in the studied time horizons (from left the years 1825, 1961 and 2009)*
Source: Czech Geodetic and Cadastral Office (ČÚZK)

- creation of structured digital database and the own analysis of landscape structure in GIS environment,
- creation of map outputs and their appendixes (graphical, tabular data).

Digitization of historical map sources and adjustment of input digital data so that they will be applicable in subsequent analyses are the crucial and the most time-consuming phase of processing.

Vectorization and database creation

The process of manual vectorization by means of geographic information systems (GIS) was used to acquire thematic information on land cover from background data. Manual vectorization is a highly time-consuming process but compared to automatic classifications its advantages are the exactness and distinguishability of particular patches. Digitized vector layers represent land cover and land use.

Analyses of landscape structure by means of calculations of landscape ecology indexes

The defined method of calculations of landscape ecology indexes within landscape structure analysis was performed for LU/LC classes in identified categories, spatial and compositional relations of landscape elements – patches, corridors, matrixes.

The analyses were done in ArcGIS environment using standard tools and tools that were specifically developed for the analysis of landscape structure. These are Vector Based Landscape Analysis Extension for ArcGIS (V-LATE) and Patch Analyst.

Calculated coefficients (indexes) can be classified according to the type of evaluated characteristic into categories of indexes: of shape, size, diversity, proximity, edges and statistical indicators.

Nearest neighbour analysis (index) – belongs among distance analyses that are used to determine the proximity of objects of a given category. In this case it is the proximity of objects of the same LU/LC category determined by the nearest neighbour method. Map representation of the calculated values of nearest neighbour analysis provides an overview of the distribution of particular LU/LC categories and of the mode (type) of their distribution in the territory.

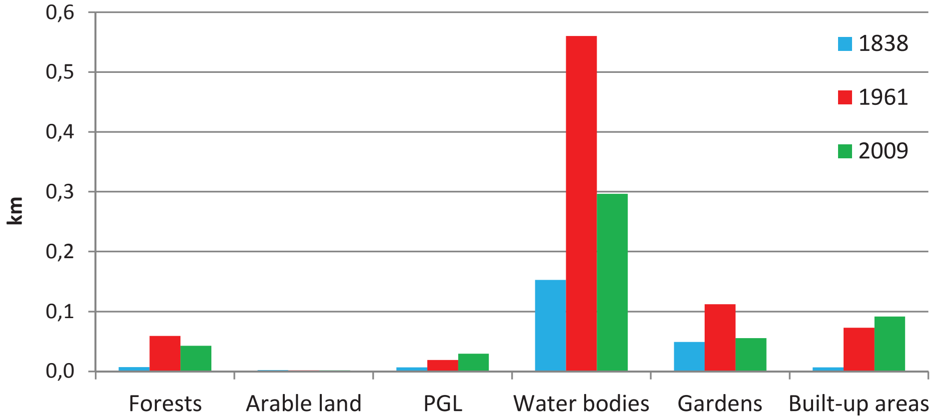
Area analysis (index) belongs among the basic spatial analyses. Using the patch area analysis it is possible to describe landscape graininess on a scale from very fine (patch area less than 0.05 ha), fine (patch area 0.05–0.9 ha), medium (patch area 0.9–35 ha) to coarse graininess > 35 ha). Besides, patch area is a very important variable influencing diversity and land cover.

Shape analysis (index) belongs among further metric analyses of landscape space describing landscape changes over time in the best way. These indicators are calculated for the particular categories: patch number, average patch shape, patch perimeter to area ratio, average fractal dimension. Shape indexes are significant from the aspect of dissection or, on the contrary, of geometrization of spatial structures. The higher the values of shape index, the more complicated the patch shape while their borders get longer. On the other hand, the lower the value of this index, the simpler the shape that can be described by basic geometric shapes, expressing the simplification of particular shapes of patches. Intervals of the patch shape index: 1.00–1.12 – almost circular shape, 1.12–1.16 – almost square shape, 1.16–1.90 – almost rectangular shape, > 1.90 distinctly elongated and irregular shape. The shape characteristics are also important from the aspect of edge effect, i.e. mutual interaction of two adjacent areas with different mode of use (e.g. arable land and PGL, arable land and forest, etc.).

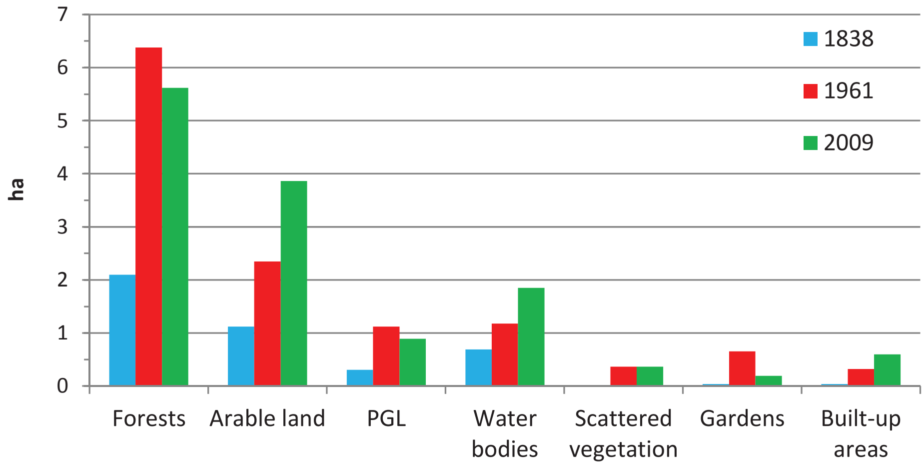
Diversity analysis (index) is aimed at the evaluation of diversity and heterogeneity of analysed patches. In the particular categories the computation generates the total number of patches in each category, their total area and the index Proportion – ratio of areas of a given category to total area (or the percentage proportion of a given category in relation to the whole studied territory). Determination of these indexes is important for the evaluation of landscape heterogeneity and contrasts.

RESULTS

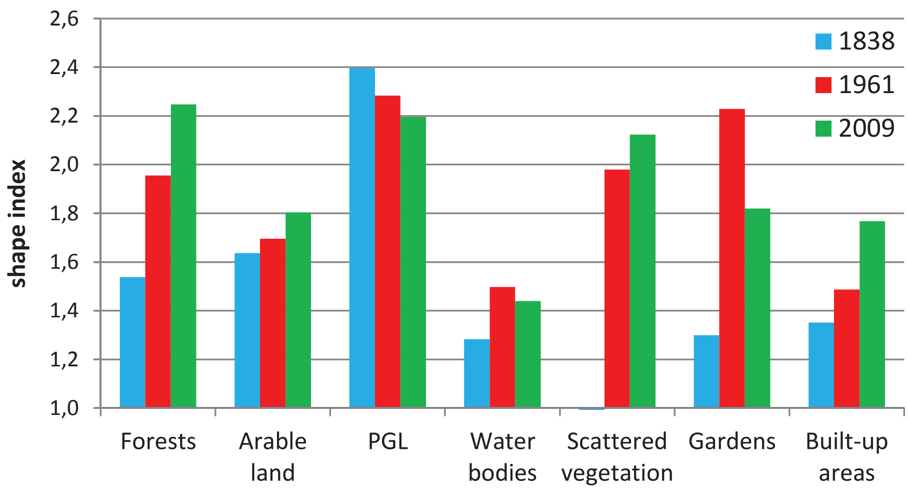
In line with different origin of used materials the informative capacity of information that can be obtained from them and applied for the purposes of the solution is different. During digitization and creation of vector layers different legend adapted to a specific map was used for each time segment. The particulars of the legend and its details result from the scale of a given map. Hence, the digitized layer of the Stable Cadastre maps is the most detailed because it has the most comprehensive legend. The legend of LU/LC classes obtained by digitization of historical and contemporary materials was reduced to the basic standardized form applicable to a subsequent detailed comparison of all processed materials.



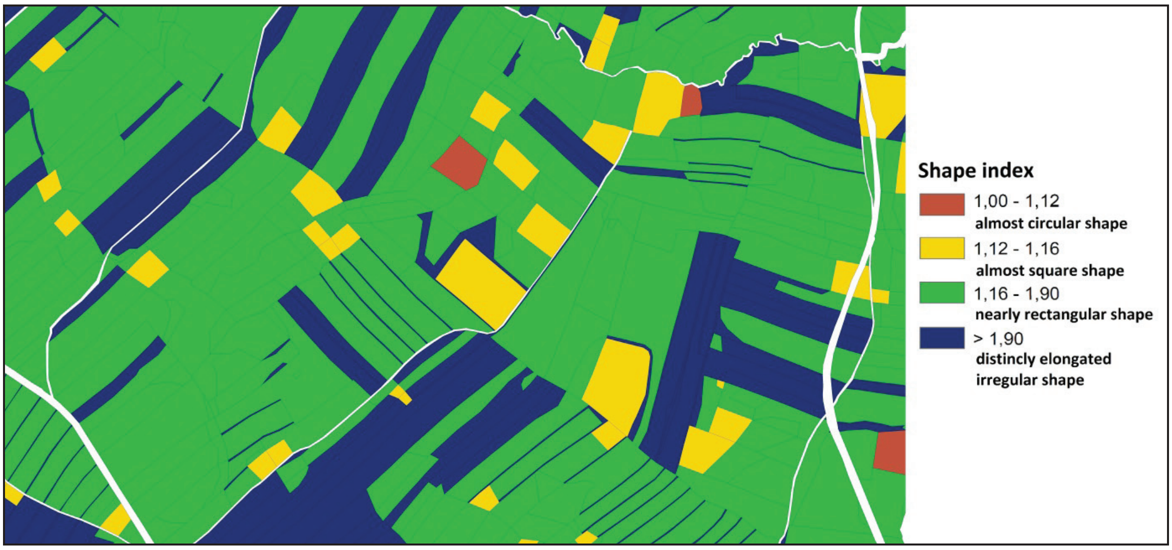
3: *Average distance (nearest neighbour) of two patches of the same land use category in Hubenov model territory in 1838–2009*



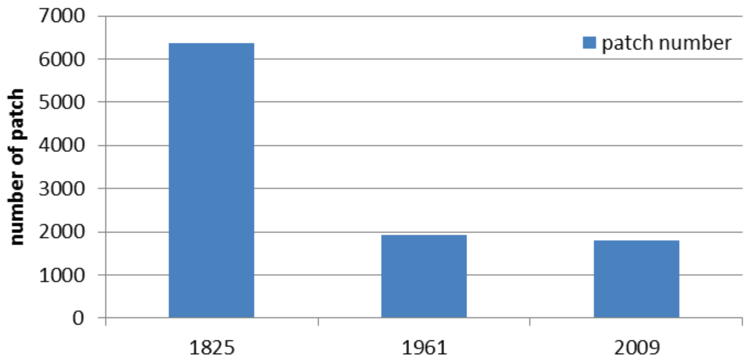
4: *Average area of patches (graininess) of LU/LC categories in Hubenov territory in the period 1838–2009*



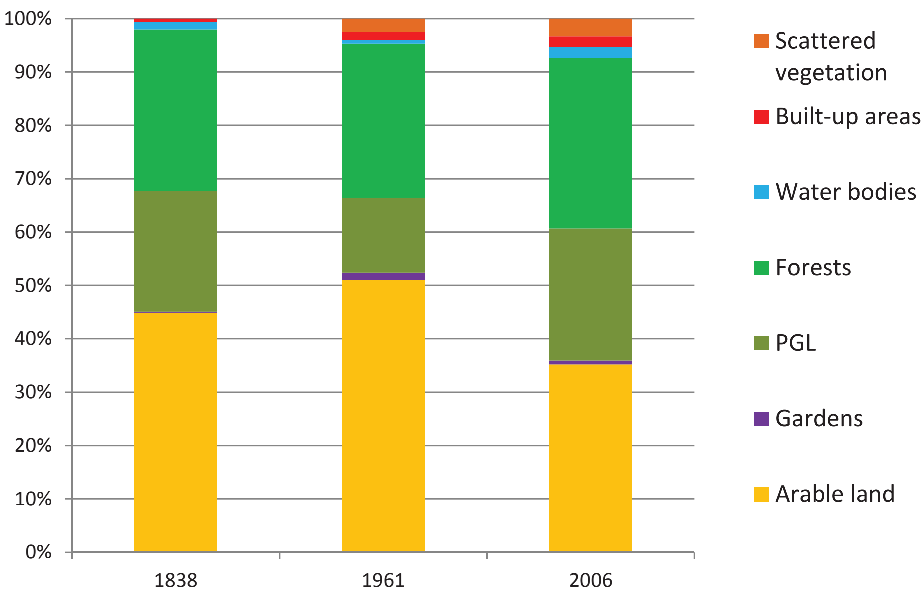
5: *Average shape of patches of LU/LC categories in Hubenov territory in the period 1838–2009*



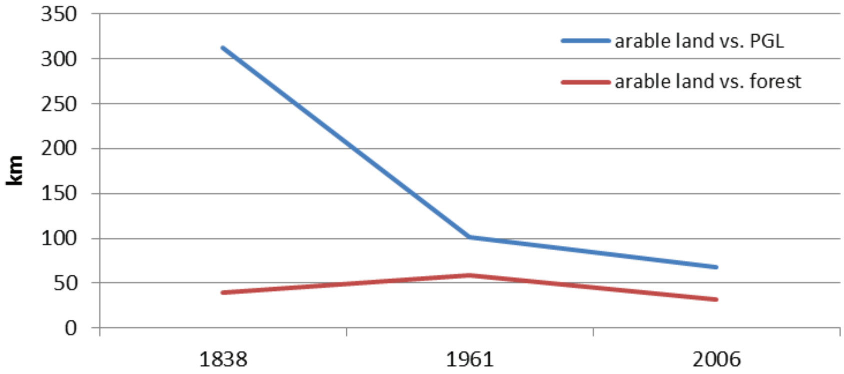
6: *Map interpretation of patch shape in a part of Hubenov model territory in the period of 1838–2009*



7: *Changes in patch number in Hubenov model territory in the period 1838–2009*



8: *The proportion of the areas of LU/LC categories in the total area of Hubenov territory in the period 1838–2009*



9: *Development of edge effect in Hubenov territory in the period 1838–2009*
Interpretation of the results of landscape structure analysis (Hubenov example)

In the text below the most distinct phenomena and characteristics of landscape structure are described that are determinant and significant for the particular time periods. Taking into account the volume of evaluated facts (four model territories) their presentation would be quite extensive. This is the reason why only one model territory – Hubenov is evaluated in the present paper.

The following description is focused on specificities of the model territory, not on the detailed analysis of all computed values.

Stable Cadastre period (1838)

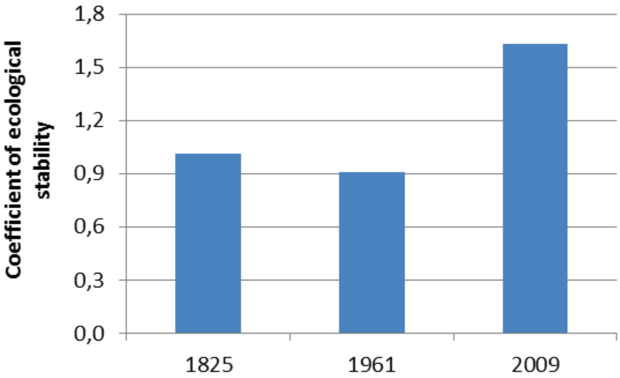
In that period a number of determined metric indexes reached much higher values than in the next periods (the number of patches of dominant categories was several times higher, the length of ecotone edges of arable land and permanent grasslands reached the highest values, etc.). It indicates very pronounced changes in the arrangement of landscape structure in the next period. The most distinctive within LU/LC categories were the patches of PGL and arable land, i.e. agricultural land, which constitutes the landscape matrix. The percentage proportions in this territory were 45% of arable land, 30% of forests and 22% of PGL. The resultant values of edge effect indexes were consistent with the above data: the highest lengths of edges were determined in the categories of PGL, arable land and forest. The average distance of two blocks of the same land use category was several time shorter than at present (e.g. PGL, forests). This was related with very fine graininess (a high number of patches of small area distributed over the whole territory). The mesh density was almost 4x times higher than in the next periods. The average area of patches was 1.12 ha in arable land, 2.1 ha in forests, 0.31 ha in PGL and 0.69 ha in water bodies and it was substantially lower than in the same categories in the next periods. The average shape of patches was most rectangular, only permanent grasslands had an irregular shape, markedly elongated. In the Stable Cadastre period permanent grasslands were often pastures of linear type along dirt roads and streams. In the next periods the shape of the majority of categories became elongated.

The sixties (1961)

Compared to the preceding period, great intensification of agricultural production occurred while the total number of patches decreased to a third. The proportions of arable land (51%) and forests (29%) were dominant unlike permanent grasslands (14%), while the landscape structure was simplified, which led to landscape homogenization. The average area of patches considerably increased and landscape graininess became coarser (in arable land there was a twofold increase in the average size of production block to 2.4 ha, in PGL it was a fourfold increase to 1.12 ha and in forests a threefold increase to 6.4 ha). The characteristics of edge effect underwent substantial changes compared to the preceding period. In common borders of arable land and PGL there was more than a threefold reduction in common borders of these categories. In common borders of arable land and forests it was an increase by about 50%. This trend can be attributed to an increase in the area of arable land. Generally, this favourable trend of an increase in the common borders of arable land and forest cannot compensate a massive decrease in the common borders of arable land and PGL. In total, in this territory there was a reduction in the number of ecotone sites and a reduction in overall biodiversity. In shape characteristics the majority of the categories changed their shape from rectangular patterns to elongated ones. Only in permanent grasslands a gradual change of the elongated shape to rather a rectangular shape was observed.

Present time (2009)

In comparison with the preceding period the number of patches and total area of arable land (35% of the territory) also decreased. However, the proportion of permanent grasslands in the territory increased to 25%, while the number of patches increased by about 30%. The increase in PGL areas can be explained by overall establishment of grasslands in the watershed of the Hubenov



10: *Changes in Coefficient of ecological stability in Hubenov model territory in the period 1838–2009*

Water Reservoir as a reservoir of drinking water for the town of Jihlava. Grassland establishment was carried out in former water protection zones or in present protection zones of a water resource. The increase in the area of grasslands was also supported by subsidies granted for grassland establishment in less-favoured areas, nitrate directive, etc.

A moderate increase in the area of forests and water bodies was also a result of the construction of Hubenov Water Reservoir. An increase in the proportion of scattered vegetation is probably connected with this fact as a consequence of realized protection measures of the water resource. The indexes of edge analyses show a trend of gradual shortening of common borders of arable land and PGL (by more than 30%) and arable land and forest (by nearly 50%). This situation can be explained by a reduction in the area of arable land and by a further increase in the average size of the arable land block to 3.9 ha of rectangular shape. In the other categories the trend of shape characteristics was the same as in the preceding period. As a result of an increase in the scattered vegetation area the shape characteristics moderately changed toward irregular shape and higher diversity of patches. The average distance of two patches of the same land use category slightly increased in arable land (also due to a reduction in the area and an increase in the average size of the block), and an increase in PGL was evident in the entire studied period.

Grassing of arable land in the catchment reservoir Hubenov is positively reflected in the increase of ecologically stable areas. Coefficient of ecological stability (Míchal, 1994) increased from 1.01 (in 1838) to 1.63 (at present).

If we generalize the findings not only from Hubenov territory but also from all four analysed model territories, we can state that in all analysed territories and in all time horizons the landscape matrix is composed of arable land (it is dominant by both its area and the number of patches). Although the landscape matrix consists of arable land, the studied territories differed in the arrangement of landscape structure in the baseline period (1st half of the 19th century).

A distinctly linear structure of very narrow strips of patches of very fine graininess, very low porosity and considerable, almost complete continuity was typical of Hustopeče territory at the beginning of the studied period. The distribution of patches of non-agricultural LU/LC classes was markedly clustered, bound to a watercourse and adjacent floodplain forests and wetlands. Thanks to this pattern, it was a highly contrast landscape compared to the other territories with different diversity and heterogeneity. Over time until the present the landscape has undergone significant changes in the arrangement of landscape structure. The construction of the Nové Mlýny water reservoirs practically led to the complete liquidation of floodplain forests and wetland communities while the linear structure of arable land patches was eliminated and extensive production blocks of arable land, many times larger than 30 hectares, were created.

A distinctly elongated linear structure was typical of Hubenov territory at the beginning of the studied period but the particular patches of arable land were arranged radially around settlements. The distribution of patches of the other LU/LC classes was almost regular within the landscape matrix. The landscape matrix was characterized by high porosity, incomplete continuity with high heterogeneity, dissection and diversity. During the intensification of agricultural production in the sixties of the 20th century the area of arable land increased to the largest extent to the detriment of permanent grasslands. Currently, the trend is more favourable because a large acreage of arable land was converted into grasslands.

In Žejbro watershed the regular arrangement of mostly rectangular patches of arable land is contrasting with irregular, elongated dissected patches of PGL copying small streams and settlements mostly in the north-southern direction. Forest patches are distributed on the edge of the model territory. Intensive agriculture has existed in the territory until now and so arable land is a dominant landscape category.

In Železné hory PLA there has been a pronounced decrease in the area of arable land and an increase in PGL from the 1st half of the 19th century to the present time. Forests have had a dominant position in all three time periods, with an upward trend. The grain size of landscape classes largely differs from the Stable Cadastre period.

If the 1st half of the 19th century is taken as the baseline period for landscape structure evaluation, in the next periods it is possible to find the basic features of land composition at least in fragments in all four model territories. Nevertheless, a change in all metric characteristics is obvious: reduction in patch number, dissection and heterogeneity, geometrization, unification, structure simplification and an increase in landscape grain and scale coarseness. Narrow strips of agricultural land turned into rectangular patches of considerable size. Landscape structure development corresponds to the expected trend that reflects social and economic development from the Stable Cadastre period to the present time. This trend is generally applicable to all CR areas of the type of agricultural, agri-forest landscape.

Orientative proposal of the use of Hubenov territory (including linear elements)

The Hubenov territory is represented by the Maršovský brook watershed. This watershed is an infiltration territory of the Hubenov Water Reservoir. From the aspect of functional use hydrological and ecological functions should be preferred first of all. The production function of this territory should not be a priority. As for the landscape structure, an emphasis should be laid on revitalization of watercourses (diverted into conduits, straightened and reinforced) including the establishment of riparian and companion stands. It is also desirable to support construction of new ponds, creation of wetlands, consistent realization of proposed land conservation measures (hedgerows, infiltration belts), refinement of landscape graininess, and construction of dirt road network with companion tree alleys.

In comparison with the present situation (35% of arable land, 25% of PGL, 1.4% of water bodies, no wetlands, 3.6% of green vegetation), the proportion of PGL should increase (by 5% at least) and wetland communities should be restored (on 5% of the territory area at least). It is recommended to stop the trend of arable land afforestation. The reconstruction of natural meandering stream beds would certainly improve the overall stabilization of ecosystems in the given area. Newly constructed dirt roads as well as reconstructed existing dirt roads should fulfil criteria of the erosion-control function and criteria for an increase in the aesthetic and ecological impact of these facilities on surrounding landscape. Dirt roads with erosion-control and ecological functions (companion vegetation, tree alleys) are one of the ideal features for refinement of the landscape structure grain. The same applies to hedgerows. They were planted in Hubenov territory in the framework of land consolidation recently, but their number was several hedgerows. It is to note that in large blocks of land it would be necessary to realize more hedgerows and/or linear tree plantings around the existing or newly constructed linear elements.

CONCLUSIONS

Agricultural land formed the landscape matrix in Hubenov territory in the past and at present. There is a significant reduction in the number of patches of the landscape classes (from 6386 plots in 1838, to 1805 at present). The average area of a production block of arable land decreased from 1.1 ha in 1838 to 3.9 ha in 2009. Spatial distribution of agricultural land has changed. Area of arable land decreased (in 1825 – 45% of model territory, in 1961 – 51% of model territory, in 2009 – 35% of model territory) after the construction of water reservoir Hubenov. The area of permanent grassland (in 1838 – 22% of model territory, in 1961 – 14% of model territory, in 2009 – 25% of model territory), forests and water bodies increased. It was reflected in the increase the ecological stability expressed by the coefficient of ecological stability (CES) from 1.0 (1838), 0.9 (1961), to 1.6 (2009). In the context of the change of landscape structures decreased the length of ecotone edges of the categories arable land and PGL (in 1838 more than 300 km, at the present only 67 km) and categories arable land and forest (in 1838 – 40 km, in 1961 – 59 km, in 2009 31 km). In the sixties there was an almost 50% increase in the lengths of common edges of arable land and forests compared to the Stable Cadastre but a decrease at the present time compared to the sixties of the 20th century was 47%. This decrease is a result of grassland establishment on arable land in the watershed of the Hubenov Water Reservoir (in former water protection zones – WPZ, currently in protection zones – PZ).

The analysis of landscape structure and processing of its results provide specific background materials for the implementation of objectives planned in the related field of evaluation of changes and proposals of functional land use. It is a thematically complex set of background materials that can be applied both in the field of research and in practice (land use planning, land consolidation, landscape planning).

The analysis of landscape structure in the time span from historical times to the present meets the requirements to acquire an effective background material applicable in land use and landscape planning. The used historical materials are, in spite of some problems, a very valuable source of unique and fundamental information for influencing the future character, functions and quality of landscape in this country. Digital processing of such information corresponds to the present method of work with data, allowing the creation of maps and statistical outputs according to requirements of planning documentations. Evaluated analyses and computed landscape ecology indexes can be corrected in line with specific realizations in practice, e.g. design of a chosen detail of the territory, change or choice of another attribute of the analysis, overlay analyses in the required range of characteristics, territories, time spans, etc.

The return to historical landscape is not possible but particularly in some types of landscapes or in the territory focused on other aspects of land use than production ones, it is possible to apply the knowledge to polyfunctional proposals and to improvement of non-production functions of landscape.

The understanding of spatial configuration and its development in the context of anthropic activities provides better conditions and prerequisites for interpretation and prediction of the functional potential of landscape with all consequences influencing these activities retroactively. Based on the evaluation of trends, a "middle-course" version of the proposal of the new arrangement and functional use of landscape in the given territory can be chosen and by approximation of landscape structure characteristics it is possible to define an optimum landscape structure with regard to non-production functions of landscape.

SUMMARY

The paper is focused on the evaluation of land use of agricultural land and an analysis of the changes the landscape structure in the study area Hubenov at different time horizons (1825, 1961, 2009). Input data have been taken from historical and contemporary materials. Among historical materials, imperial obligatory prints of the Stable Cadastre maps were processed for the purposes of this solution. A set of black-and-white aerial photos from the sixties of the 20th century (the period when substantial interventions were realized in landscape that influenced the arrangement of landscape pattern) was used as a further source of information on the historical situation of landscape. The evaluation of the present situation on the basis of coloured orthophotomaps covers the last analysed period. Between the analyzed landscapes metric were chosen: area of landscape classes, number of plots, average size of plots, shape index.

Biodiversity of model territory was evaluated through the lengths of common edges of arable land and PGL and arable land and forests. The area of permanent grassland, forests and water bodies increased. While the lengths of ecotone edges of arable land – PGL in model territories measured hundreds of kilometers in the 1st half of the 19th century, they reach only tens of kilometers at the present time. This situation indicates a substantial decrease in the number of ecotone sites inhabited by small animals, insects and plants and reduces biodiversity of the territory and significant influence of these communities on agricultural production. Changes in the lengths of common edges of arable land – forests in time do not show such an unambiguous downward trend as changes in arable land – PGL. There has been a diminishing area of arable land in time and an increasing share of the category of forests and PGL. Changes in the lengths of common edges of arable land and forests have occurred by 21% in Hubenov territory (constant reduction in the area of arable land, moderate increase in the area of forests). The area of arable land decreased. It was reflected in the increase the ecological stability. Coefficient of ecological stability (CES) was calculated by the ratio of ecologically unstable and ecologically stable landscape classes. The ecologically stable area increased. CES increased from 1.0 (in 1838) to 1.6 (in 2009). Analyses results illustrate long-term continuing landscape utilization for agricultural production. There is a positive trend in increasing ecological stability of the territory.

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REFERENCES

BOLTIZIAR, V., BRUNA V., KROVAKOVÁ, K., 2008: Potential of antique maps and aerial photographs for landscape changes assessment – an example of the High Tatra Mts. Ekologia/Ekology, 27, 1, 65–81.

FLADMARK, J. M., MULVAGH, G. Y., EVANS, B. M., 1991: Tomorrow's Architectural Heritage: Landscape and Buildings in the Countryside. Mainstream Publishing, Edinburgh and London.

FORMAN, R. T., GODRON, M., 1993: Krajinná ekologie. 1. vyd. Praha: vyd. Academia, nakl. AV ČR Praha, 583. ISBN 80-200-0464-5.

FUKALOVÁ, P., POKLADNÍKOVÁ, H., 2009: Vývojové trendy ve využití půdy v katastrálním území Žabčice. Universitatis agriculturae et silviculturae Mendelianae Brunensis. LVIII, 2, s. 69–76. ISSN 1211-8516.

GIREL, J., BARGUET-DUPORT, B., PAUTOU, G., 1997: Landscape Structure and Historical Processes along Diked European Valleys: A Case

Study of the Arc/Isere Confluence (Savoie, France). Environmental Management. 21, 6, 891–907.
GUTH, J., KUČERA, T., 1997: Monitorování změn krajinného pokryvu s využitím DPZ a GIS. Příroda, Praha, 10, 107–124.
HAIS, M., BROM, J., PECHAROVÁ, E., 2006: Evaluation of Landscape Changes by Remote Sensing. Životní Prostředí, 40, 2, 80–83.
JUHÁS, I., 1991: Metódy dialkového prieskumu Zeme pri tvorbe krajinno-ekologických podkladov. Záhrada – Park – Krajina, 2, 17–19, 3, 17–19.
KUBEŠ, J., MIČKOVÁ, K., 2003: Development of horizontal landscape structure in the Pohořsko region (the Czech-Austrian frontier) between 1938 –2000. Ekologia/Ecology. 22, 3, 269–283.
LIPSKÝ, Z., 2000: Sledování změn v kulturní krajině. ČZU, LESNICKÁ PRÁCE, s. r. o., Kostelec nad Černými lesy. 71. ISBN 80-213-0643-2.
LIPSKÝ, Z., ROMPORTL, D., 2006: Krajinné indikátory pro hodnocení změn krajinného rázu. In: Ochrana krajinného rázu – třináct let zkušeností, úspěchů i omylů.... Sborník z příspěvků konference. Praha, 51–56
MÍCHAL, Igor., 1994: Ekologická stabilita. 2. rozš. vyd. Brno: Veronica. ISBN 80-85368-22-6.
MILANOVA, E. V., LIOUBIMTSEVA, E. Yu., TCHERKASHIN, P. A., YANVAREVA, L. F., 1999: Land use/cover changes in Russia: mapping and GIS. Land Use Policy 16, 153–159.
PALMER, J. F., 2004: Using metrics to predict scenic perception in a changing landscape: Dennis, Massachusetts. Landscape and Urban Planning 69, 201–218.
PÉREZ-SOBA, M., WASCHER, D., M., (eds), 2005: Landscape Character Areas. Places for building a sustainable Europe. Policy Brochure as deliverable from the EU's Accompanying Measure project European Landscape Character Assessment Initiative (ELCAI), funded under the 5th Framework Programme on Energy, Environment and Sustainable Development. (4.2.2), vi + 26 ss.
SPULEROVÁ, J., 2008: Land use changes in the Veselovianka river catchment in the Horná Orava region. Ekologia/Ecology. 27, 3, 326–337.
TOLASZ, R. et al., 2007: Atlas podnebí Česka. ČHMÚ: Praha a Olomouc, 1. Vyd., 255, ISBN 978-80-86690-26-1.
XU JIAN-HUA, LU YAN, AI NAN-SHAN, YUE WEN-ZE., 2001: A study on landscape mosaic structure in urban-rural area in Northwest of China with RS and GIS. Chinese Geographical Science. 11, 4, 366–376.
ZONNEVELD, I. S., 1979: Land Evaluation and land (scape) Science. International Training Center, Enschede, (Nizozemsko).

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