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HISTORICAL MAPS AND THEIR APPLICATION IN LANDSCAPE ECOLOGICAL RESEARCH

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Abstract

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Historical maps represent a unique information source of the past landscape, its organisation and use in the last 250–300 years. They show the picture of no more existing landscape as viewed by their creators. In the paper there are presented sources of historical maps from the Slovak Republic territory, their informative value for landscape ecological research and an outline of their processing in geographical information systems. In the second part we focused on practical use of historical maps information in landscape ecological research, sustainable land use planning, nature conservation and ecosystem management.

Key words: historical maps, landscape ecological research, land use changes

Introduction

Survey and evaluation of historical landscape development are considered to be one of the basic steps in solving recent ecological problems (Lipský, 2002). Landscape development and land use/land cover changes occurred during the last centuries could be studied only from preserved cartographical bases. Historical maps represent adequate informational source for landscape ecological research focused on land use development, assessment of mutual relation between natural conditions and their economical use and for future prognosis or planning of sustainable land use (Žigrai, 1995, 2001). Landscape ecological research using historical maps is becoming more frequent mostly in countries with rich cartographical traditions, especially in the west (Skanes, Bunce, 1997; Cousin, 2001; Petit, Lambin, 2002; Bender et al., 2005; Leyk, Zimmermann, 2007) and Central Europe (Füleky, Major, 1993; Wrbka et al., 1999; Schönfelder, 2000). In Slovakia and in the Czech Republic there are known works of Žigrai (1971, 1995), Kolejka (1987), Oťaheľ et al. (1993), Lipský (1995), Žigrai, Drgoňa (1995), Boltižiar (2006, 2007), Boltižiar et al. (2008), Olah (2003a), Olah,

Žigrai (2004), Kolejka, Marek (2006), who used historical maps for landscape-ecological and socio-economical analyses of land use changes.

The increase of historical maps (cadastral and military) application is connected with their relative high accessibility and orientation of present research activities toward cultural landscape development. An important condition for use of historical maps is their information value and geographical accuracy. These attributes largely depend on the purpose and cartographical techniques of maps creation. Interpretation of historical maps has been rarely applied in a complex way. Mostly partial evaluations result from narrow research focuses. The detailed analyses of historical maps enable us to analyse all phenomena occurred in a landscape and thus uncover processes other ways hidden or appearing to be isolated.

Land use is a concrete expression of human activity in space and time which accumulates a certain historical, economical, social and cultural potential and represent an intersection of natural conditions and human knowledge and techniques (Žigrai, 1995). A proposal of sustainable land use has to be based on past land use analysis, which help us to define a landscape potential. In our landscape the main cultural, social and economical relations have been stabilised within last few centuries. Therefore this period is the most important for the study of landscape development.

Discussion

Historical maps

The oldest maps describing the contemporary Slovak territory were created in the 15th century (Prikryl, 1977). However their scale was very small and their accuracy low. Their potential application in landscape research is therefore very limited. The first large scaled maps were created in the first half of the 18th century by mining cartographers and they described mostly mining towns in central Slovakia and their surroundings. The leading cartographer of that time was Samuel Mikovíny who drew the Ugrian districts (župa) maps in scale approx. 1:150 000. On these maps settlements, fields, forests, rivers and water planes, mining buildings, roads and sacral buildings could be identified. Relief was hatched and their accuracy was low especially in hilly and mountain areas.

The first large scaled maps (1:28 800) covering the whole Austria-Hungarian Empire were the maps from the 1st military (ordnance) mapping (1763–1785), in the contemporary Slovak territory (1769–1784). On these coloured maps (Fig. 1) the following land use forms could be identified: forests, shrubs, trees and bushes, grasslands, wetlands, fields, vineyards, buildings and settlements, gardens, water, rocks and roads. Relief was hatched following slopes inclination. Although the cartographers used the same methods and techniques the maps from different parts of the empire vary in details and accuracy (Žigrai, 1995; Olah, 2003b; Chrastina, Boltižiar, 2006a, b).

Thank to exact geodetical measurements the maps from the 2nd military mapping (1806–1869) are more accurate and informative. The north and east Slovakia territory was

Fig. 1. 1st military mapping.

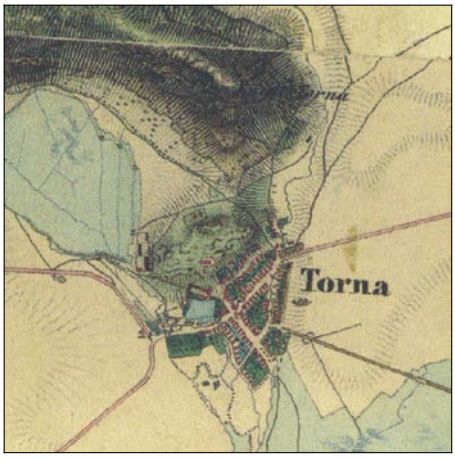

Fig. 2. 2nd military mapping.

mapped in 1819–1827, the central and southern part was mapped in 1837–1858. The scale was again 1:28 800. On these coloured maps (Fig. 2) the following land use forms could be identified: forests, forest edges, shrubs, trees and bushes, meadows, pastures, wetlands, fields, vineyards, buildings and settlements, gardens, water, rocks, roads and railroads. Relief was hachured. Apart from the former mapping the land use polygons were sharply outlined. Though these maps are relatively precise and accurate, their disadvantage lies in a multiple information (hachuras, colour, borders and texts) drawn on the same spot what sometimes cause interpretation problems. The maps display almost complex information on past landscape and its use and therefore have a significant information value (Žigrai, 1995).

The main reason for the 3rd military mapping (1869–1887) was to supply precise and higher quality maps for the Austria-Hungarian army. Their scale was 1:25 000. The Slovak part of the empire was mapped in 1875–1884. Altitude was derived from the Adriatic Sea level in Terst (Tierst) and relief was drawn for the first time by contour lines. The maps accuracy is very high. From these coloured maps the same land use categories as from the 2nd mapping can be distinguished. The availability of these maps is rather complicated due to their transport from Vienna to Prague in 1922 after the empire's collapse (Prikryl, 1977). Their black and white reambulations (1:25 000 or 1:75 000) used by the Czechoslovak army until the 1950s are more available (Fig. 3). Although the maps reambulations took place in 1930s, the comparison of the original and reambulated maps showed that the later ones refer to the landscape situation at the end of the 19th century. The land use information on these maps is drawn by hatches and cartographic signs.

The 4th military mapping (1896–1914) using already photogrametric method was realised only in the High Tatra Mts. The coloured maps were drawn in scales 1:25 000 and 1:75 000. The mapping was interrupted by the 1st World War.

In 1950s military topographical maps UTM 1956 (Universal Transverse Mercator) were created (Fig. 4). Their basic scale was 1:25 000 and from coloured maps the following land use categories could be identified: forests, shrubs, trees and bushes, meadows, pastures, fields, water, permanent agricultures, gardens, buildings and settlements, rocks, roads and railroads. Due to the exact cartographical projection and new geodetic technology these maps are very precise and easily processed in landscape ecological analyses.

Although military maps were primary assigned for army they contain a unique, but up-to-day rarely exploited, information potential on historical landscape structure, its use and scenery.

The first cadastral maps at our territory were created in years 1856–1867 in scale 1:2 880. In 1875 the definitive cadastre was established in the Ugrian Kingdom, using all existing and available maps. On the black and white cadastral maps the following land use categories could be identified: forests, meadows, pastures, fields, building, water and roads. The cadastral maps in the first half of the 20th century were in the Křovák's conical projection in scales 1:2 000, 1:1 000 and 1:500. After establishment of the Unified Land Evidence in 1956 the cadastral maps were drawn in scales 1:2 880, 1:2 000 or mostly 1:5 000 (Prikryl, 1977). Cadastral maps are very accurate and precisely document especially former land use patterns.

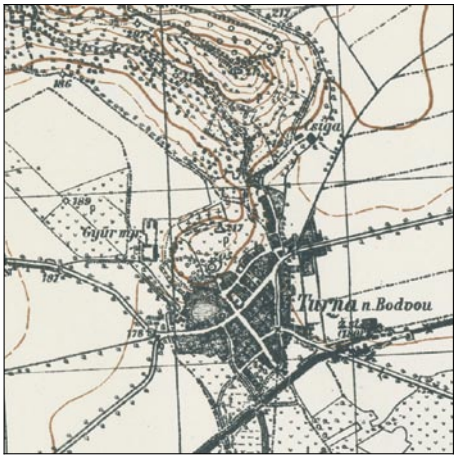

Fig. 3. Reambulation from the 3rd military mapping.

Fig. 4. UTM 1956 military mapping.

Processing historical maps in GIS

Geographical information systems (GIS) become a wide used, precise and fast tool for landscape analyses. It is a computer-based system and thus it works with digital data. Therefore the first step of processing non-digital (analogue) map data is their digitalisation. Maps are usually scanned using high resolution to a digital graphic format compatible with used GIS

software. It is recommended to scan paper maps using large scanners to avoid their later joining in graphic editors what causes decrease of map accuracy.

Next step is the map georeferencing – assigning geographical co-ordinates to historical maps. It is processed semi-automatically in specialised GIS software or modules. In Slovakia there are generally used 2 co-ordinate systems based on different cartographical projections. S-42 is a military system using UTM (or Gauss-Krüger) projection, S-JTSK is a civil system using the Křovák's projection. It is recommended to apply a system which has the same or similar projection as the referenced map. Conversion between these two systems is possible in GIS modules. There exist two basic ways how to georeference a map. When co-ordinates of map corners are known they are simply inserted into software. In case they are not available new co-ordinates must be obtained, either directly measured using GPS (global positioning system) or pairs of identical points on historical and reference maps (already georeferenced) must be found. These points are landscape marks which have not changed their location over the studied period and could be identified on both historical and present maps (churches, chapels, crossroads, bridges, mountain peaks. These reference points should be localised around and within the study area (Tuček, 1998). The number of needed points depends on used transformation method (polynomial transformation of 1st to 3rd degree, Koreň, 1996). Simpler methods only place and rotate a map in a co-ordinate system, more advanced methods even spatially deform it. Accuracy of transformation is expressed by RMS (root mean square) error. Accuracy and reliability of historical maps generally decreases with their age. RMS error of transformed maps from the 1st military mapping rises from 100 m in lowland to 500 m in mountains (in narrow valleys up to 800 m). It was caused by the cartographer techniques of map table easily used in open landscapes but difficult to apply in narrow mountain valleys (Brůna et al., 2002). Possible solutions to this problem are to transform a map in parts or to vectorise polygons following the relief and streams (Cousin, 2001; Bender et al., 2005; Olah et al., 2006b). Maps from the 19th century are processed in the same way but their accuracy significantly rises thank to their exact geodetical measuring (RMS less than 100 m).

Landscape ecological analyses of historical maps

Interpretation of historical maps mainly depends on their focus, details, accuracy and cartographical way of describing landscape phenomena. These facts are even more significant when comparing maps from different social or economic sectors and time periods. Historical maps interpretation must therefore be objectively critical. An interpreter must combine his knowledge on the studied landscape (or experiences of other authors who realised similar research) to evaluate possible localisation on spatial information shown on historical maps. Land use/land cover areas are usually processed as vector (object) data while continuous natural phenomena as relief are defined as raster data.

Landscape ecological evaluation of landscape development applies a method of superposition on thematic maps (resulting from historical maps interpretation) in the identical co-ordinate system. Due to spatial information differences on various historical maps in-

terpreted phenomena must be joined into comparable categories. The oldest and the most generalised maps are usually limiting comparison (Petit, Lambin, 2002). Categories, their quality and quantity depend on landscape character and research focus.

Superposition on thematic land use maps results into a spatial database of polygons with information on their past use. These attributes processed into contingency tables (using the categories areas) create land use transformation matrix indicating thus amount of change but also land use trends. Localisation of maximal areas (e. g. areas in ha) on matrix diagonal indicates relative stability of land use, their shift from the diagonal indicates intensification or extensification of land use.

Generally two possible land use change categories could be distinguished: a) areas without changes which represent stabile cores of the landscape in sense Kolejka (1987), Žigrai (1995), Antrop (1997), Brandt (2000), Olah (2003a, b), Olah et al. (2006b), and b) areas with land use change (with variations of changes). Each land use change reflects a change either in physico-geographic or socio-economic conditions of the studied landscape or both. Patches with permanent land use change indicate the localities without strictly dedicated conditions from a landscape (transition between lowland and mountains) or land use character (transition between agricultural and forest land use) point of view. A change in land use might indicate a change of one change of natural conditions of abiocomplex (e. g. drainage of wet meadows and their later use as arable land on a basin bottom). Only a temporal change of land use (as a rapid increase of fields' area) might be caused by higher demand for food in certain time period. Certain interpretation are valid for whole country, others reflect local phenomena (tourism boom in the High Tatra Mts in the 20th century, construction of water supply reservoir Starina (Olah et. al, 2006a, b).

Apart from patch content (land use) its size, shape and localisation (expressed by landscape indexes) also provide information on landscape processes (in sense Forman, Godron, 1986). Larger and regular patches indicate more homogenous natural conditions, smaller and linear polygons indicate more heterogeneous conditions, neighbourhood or transition of larger homogenous areas.

Land use changes and their direction might be expressed by intensity of land use change (e. g. Olah, 2003b; Olah, Žigrai, 2004; Olah et al., 2006a). Each land use form is assigned a land use intensity coefficient according to the amount of energy needed for change. Intensity of land use change is then calculated as a difference of the intensity coefficients between neighbouring time periods. Absolute intensity of land use change refers to total amount of change while relative intensity expresses their orientation to intensification or extensification of use.

Land use of the whole studied area might be characterised by landscape ecological stability coefficients (e. g. Drgoňa, 2004). Since these coefficients have a character of relative number (portion of ecologically stable to unstable land use areas) it allows comparing landscapes different in size as well as comparison of different time periods.

Historical maps are an important source of information on past settlement and communication development. They were founded as a result of socio-economic demand within existing natural conditions, which settlers were not technically able to change (relief, hydrology).

Therefore historical development analyses help to identify the risks and hazards respected by the former inhabitants (e. g. floods, landslides, soil erosion) and apply them in the present land use planning (Stankoviansky, 2003; Petrovič, 2005, 2006). Both settlements and communication lines localisation and its development are important factors affecting distance accessibility of landscape what reflex in land utilisation (Olah et al., 2006a).

Identification of patches with stabile land use and analysis of their natural conditions (in a form of geocomplex) allow us to propose the most suitable and therefore sustainable future land use on the identical geocomplexes (in sense of LANDEP, Ružička, Miklós, 1982). Analysing mutual relation of land use forms and geocomplex components (on stable patches) applying affinity index (Olah, 2003a) results into sustainable land use potential assessment.

Information on the past landscape situation, past land use and ecosystem distribution incorporates into practical nature conservation management the very important time aspect. It is applicable in assessment of originality of ecosystems, declaring or modifying natural reserves borders or biosphere reserves zones or restoration of ecosystems after natural disasters (Hronček, 2008; Olah, Boltižiar, 2009).

Conclusion

Historical maps represent a unique information source of past landscapes and their combination with aerial photographs and satellite images creates a plastic image on landscape and its historical use. While data from remote sensing (though they are very precise and accurate) cover only the last few decades of development historical maps allow to look back for few centuries. The 18th century was in our territory a period of significant changes. It represents a time when feudal age ended and capitalism and technical revolution begun, or in other words the end of old feudal rural landscape and the birth of new pre-industrial landscape.

Study of landscape development is very important especially for landscape ecological research aiming to proposal of sustainable land use. Identification of land use changes, their causes and consequences contributes to assessment of landscape potential and ecological carrying capacity. Spatial database of natural conditions, land use development and land use potential is applicable in landscape ecological planning and nature and landscape conservation management plans. Study of historical map is a lecture from history that might help to solve recent ecological problems.

Translated by the author

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