

# POTENTIAL OF ANTIQUE MAPS AND AERIAL PHOTOGRAPHS FOR LANDSCAPE CHANGES ASSESSMENT – AN EXAMPLE OF THE HIGH TATRA MTS

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## Abstract

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The presented paper is aimed to introduce some results of a study *Historical landscape structure as a platform of landscape revitalisation in the wind-afflicted area of the High Tatras* which was carried out by Geoinformatic Laboratory UJEP together with Slovakian specialists. Being focused on antique maps and aerial photographs and their value for landscape-history assessment, the study has a strong cartographic aspect which is concentrated in this paper. The main attention is paid to the military maps and stable cadastre joined both by archive and recent aerial photographs to form the temporal series of reconstructed land-cover maps which enable us to observe landscape evolution of the studied area. Since an important role in methodology is played by Geographic Information Systems (GIS) the questions of georeferencing and interpretation of the data sources are referred to as well.

*Key words:* landscape history, military survey maps, stable cadastre, multitemporal analysis, GIS

## Introduction

Ancient maps of a medium and large scale present an invaluable source of information about nature of our landscape in the past. They are more and more frequently applied not only in the historical studies and cartography but also in a field of landscape ecology and engineering, geographical disciplines and other branches concerned with landscape. Significance of the information included in these unique sources consists not only of involving time aspect as a subject of these disciplines but also in possibility of their practical applications (revitalizing projects, land-use planning, etc.).

The paper follows the results of the study *Historical landscape structure as a platform of landscape revitalization in the wind-afflicted area of the High Tatras* carried out by the Geoinformatic Laboratory UJEP together with Slovak partners for the Ministry of Environment of the Czech Republic. The study was focused on the evaluation of a potential use of old maps and aerial photographs for the landscape-changes assessment and on creating of reconstructed maps of the study area and conducting analyses of land-use development. The evaluation was mainly based on the first and the second military survey maps and the stable cadastre; the temporal series of sources was furthermore supplemented by both archive and recent aerial survey photographs. Since the Geographic Information Systems (GIS) form an essential instrument for the applied multitemporal analyses, this paper also deals with an issue of the georeferencing of old maps and aerial survey photographs and their further interpretation and evaluation.

## Material and methods

The map records available for the studied area and the likewise suitable for its development analysis consist of appropriate map sheets of the 1<sup>st</sup> and 2<sup>nd</sup> military survey (MS) dating back to 1769 and 1822, aerial photographs (1942 and 1992), and an orthogonalised aerial photographs (orthomap) created in 2002; for a more detailed view of the area the stable cadastre (SC) map was used. For an overview of the data and the methods of their processing, see Table 1.

Table 1. Data used.

Title	Scale	Date	Source	Methods used	
I. MS	1:28 800	1769	Arcanum	georeferencing	vectorization
SC Štrba	1:2 880	1866	GKÚ	georeferencing	vectorization
SC Mengusovce	1:2 880	1873	GKÚ		
II. MS	1:28 800	1822	Arcanum	georeferencing	vectorization
Aerial photos	1:28 000, 1:12 000	1949	TOPÚ	orthorectification	vectorization
Aerial photos	1:28 000	1992	TOPÚ	orthorectification	vectorization
Aerial photos	1:18 000	2002	Eurosense		vectorization

**Military survey mapping** (Fig. 1) came about due to demands of the Austrian Monarchy and, considering the time of their creation, represents a unique work both in terms of the cartographical methods used and the extent of the systematically surveyed area. Since the main aim was to record all military significant characteristics of the landscape, great attention was paid to slightly different elements comparing other maps, e.g. cadastral maps – marshes, rocks, etc. These maps show the landscape in a way similar to recent times in a term of the land cover, while the content of the stable cadastre maps (see below) corresponds rather with the term land use.

The originals of the military survey maps are housed in the Austrian State Archive/Military Archive (Österreichisches Staatsarchiv – Kriegsarchiv) in Vienna and their high-quality digital copies were published by the Hungarian company Arcanum Adatbázis (www.arcanum.hu) on a multimedia DVD.

**The first military survey** of Slovakia took place in two subsequent phases: the earlier phase happened between the years 1769 and 1772, when, among other regions, the county Spiš was mapped, where the area used in this study is situated (see below)<sup>1</sup>. The survey was finished a decade later (between 1782 and 1784), when the counties in middle and eastern Slovakia were mapped. The total area of the current Slovak Republic is depicted on 273 sheets that are supplemented by 11 volumes of military-topographical description (Kuchař, 1967).

Since the first military survey was not based on any net of precisely defined triangular points, it has lesser spatial accuracy. This was the reason why it was not possible to complete the map of entire Austrian Monarchy from the individual sheets, as was originally planned.

The second military survey mapping was already geodetically based on a triangular net, although its creation was not preceded by a cadastral mapping as was the case in Bohemia. The triangular works for Hungary began in 1821 (Timár, 2004) and a survey based on a such net is more easily – and with better results – convertible to contemporary used coordinial systems.

The second military survey of Slovakia also took place in two main phases: between the years 1819 and 1827 the north-Hungarian border regions (sections depicting the studied area date from 1822) were mapped, and the rest of the country was finished between the years 1837 and 1857. Only the region between the Moravian borders and villages Skalica, Senica, Pezinok and Šamorín was left unmapped. The total area of Slovakia is covered by 270 sections. (Kuchař, 1967)

For further information about the military survey maps, their content and legend see e.g. Brúna et al. (2002) or Vichrová, Čada (2005).



Fig. 1. Examples of the 1<sup>st</sup> MS (left) and the 2<sup>nd</sup> MS maps.

<sup>1</sup> The precise dating of the first military survey sheets is impossible to determine (contrary to the second survey); to indicate the time horizon we have chosen the older date.

The **aerial survey photographs** from 1949 and 1992 were obtained from the Topographical Institute in Banská Bystrica. The panchromatic photographs of medium scale, digitalized in a 1200 DPI resolution (\*.tiff format), are extremely well preserved and allow a detailed observation of the represented objects. The land pictured on the photographs is only very rarely covered with small clouds. Originally these pictures could be used only by the army and they were made accessible both to the professional community and the general public in 1990s.

The interpretation of the recent land cover was based on the colour aerial photographs taken by Eurosense Bratislava on 21<sup>st</sup> and 22<sup>nd</sup> of June 2002. The colour slides were digitalized on a high-quality scanner in 800 DPI resolution (\*.tiff format) and subsequently compressed into the \*.jpg format with a pixel side of 1 m.

The aerial photographs depict the landscape-image in its totality and great detail. Its interpretation is limited only by the quality and resolution of the picture. This feature differentiates them not only from the military survey maps but also from almost all cartographic works.

The **stable cadastre maps** of the Štrba and Mengusovce villages (Fig. 2) were obtained from the Central Archive of Geodesy and Cartography in digital form (\*.tiff format, 400 DPI resolution) including the coordinates of the map sheet corners. In the case of Štrba, the map originating from 1866 is uncoloured and depicts the urban area of the village and its surroundings. Although the map is relatively well preserved, it is quite frequently edited: the borders of new plots (ground plots, etc.), dissolutions of old plot borders, textual notes (stone quarries, roads, railways, fields, etc.), or culture marks (woods, grassland) have been added over time.

The urban area of the Mengusovce village is depicted on partly coloured map sheets from 1822<sup>2</sup>. Their legend is very similar to the original maps of the stable cadastre with colour coded ground plots (yellow for wooden buildings, red for those made of flameproof materials, and crimson for public buildings and churches), watercourses, communications, and cadastre borders. Only the colour filling of the forested plots is absent. They are designated by clusters of trees whose size and type probably illustrate the character of the plant cover of the plot. Fields and grasslands are differentiated only by letters. Local names (watercourses and certain fields) are cited in Hungarian.

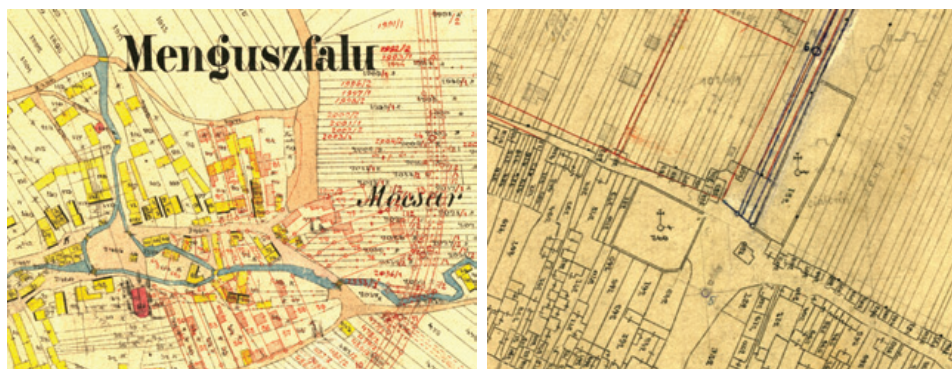


Fig. 2. Examples of the SC maps (Mengusovce cadastre in the left, Štrba on the right).

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**Transformation of map sources into the GIS environment.** To enable processing of the digitalized data within the GIS environment and their comparison, it is necessary to transform them into one of the used coordinate systems, the S-42 system in this case. Basically, there are two main methods of transformation – simple georeferencing and orthorectification. The former utilizes the so-called control points that are identifiable both on the transformed map and also on the reference map already converted into the selected coordinate system. Thus, it represents a relatively simple process workable on majority of the accessible GIS softwares. Among its disadvantages belongs the lesser accuracy which is of some importance mainly when aerial photographs (the colour aerial photographs were orthorectified by the above mentioned Eurosense Company) were taken in vertically diversified terrain and thus are considerably distorted in comparison with vertical projection. In this case, the second type of transformation – the so-called orthorectification is more appropriate. This method is relatively time- and work consumptive and requires specialized software; the method's output is represented by the orthophotomaps.

The stable cadastre maps were transformed by simple georeferencing since only a small area is depicted on the individual maps and since the original maps had already been created as normal projection of real elements to reference plane. The aerial photographs were orthorectified using the ERDAS Imagine 8.4 software together with the digitalised terrain model used in the process of the aerotriangulation; the military survey maps were transformed in the Image Warp module of the ArcView 3.1 software and the aerotriangulation was omitted.

**Interpretation and vectorizing.** The old maps and aerial photographs were globally vectorized using the ArcView software into the CORINE Land Cover categories (Feranec, Ofaheľ, 2001). As results we obtained comparable reconstruct transect maps from corresponding time horizons that were further analyzed. Due to the problematic interpretation of the stable cadastre (see below), only selected categories of land cover of the Štrba cadastre were vectorized. Since the SC data do not cover the whole transect area, this time horizon was not transformed into the CORINE categories and thus also not included into the multitemporal analyses, it is used here only as an example of large-scale map interpretation. Also the SC map of Mengusovce was not interpreted since it is located outside the transect.

Methodology of the MS maps interpretation was already defined (Brůna et al., 2002; Olah, 2000; Olah et al., 2006) and represents the crucial starting point for our interpretation. In contrast to the above-mentioned methodology, the CORINE Land Cover classification is applied and its correlation to the categories identified on the military survey maps is suggested. Their overview and correlations are given in Table 2.

Due to their current character and elevation of the studied area above sea-level, the forest stands that were undistinguishable on the military survey maps between the evergreen and deciduous forests were all included in the 312 category. The data concerning the categories 322 (moors and heathland), and 333 (sparsely vegetated areas) were adapted after a map dated from slightly later time horizon (1949) since they occur mainly in the northern part

Table 2. Correlation of the CORINE categories to the military survey maps.

CORINE land cover categories	CLC code	MS categories
discontinuous urban fabric	112	built-up area
non-irrigated arable land	211	other areas (arable lands)
meadows and pastures	231	meadows and pastures
coniferous forests	312	forest stands (in the MS maps undifferentiated)
bare rocks	332	bare rocks
water bodies	512	water bodies

of the transect that underwent nearly no changes during the selected period of time (see below). Only the waterways were interpreted out of the line-elements.

Orthophotographs, as well as the military survey maps, were vectorized using the visual interpretations method that was in this case based on the analysis of interpretative features of individual objects depicted on the photographs – a typical process of interpretation and evaluation of the remote sensing data (Feranec, Ofaheř, 2001).

Besides categories interpreted on the military survey maps, other categories were identified on the orthophotographs such as industrial or commercial units (121) or sport and leisure facilities (142).

On the stable cadastre map of Štrba, following categories were interpreted (Fig. 3):

- groundplots were identified mostly according to the plot's shape. It should be noted that their identification remained questionable mainly in the densely build-up urban area since the solitary buildings were more easily identified. Although it was not possible to distinguish which buildings were wooden and which were made of stone or mud-bricks, the situation may be considered similar to the neighbouring Mengusovce cadastre, where wooden buildings (yellow colour) predominate;
- communications were mainly identified due to their shape and their connective function (if they run "from somewhere to anywhere"). Bridges over watercourses and barrages (one occurrence) were also included in the communication category. Within the build-up area the communications gradually fade into the village greens, public places around churches and farmyards, etc. that were if possible differentiated and interpreted within an independent layer;
- other areas were specified above;
- watercourses were in fact identifiable without questions according the groundplots shapes. The small watercourses represented only by a line were separated into an independent layer;
- cemeteries were identified by their map sign (cross) and the representation of a wall;
- other categories (e.g. arable land, grasslands, and forests, etc.) were not interpreted since their identification on maps is either inaccurate or completely impossible.

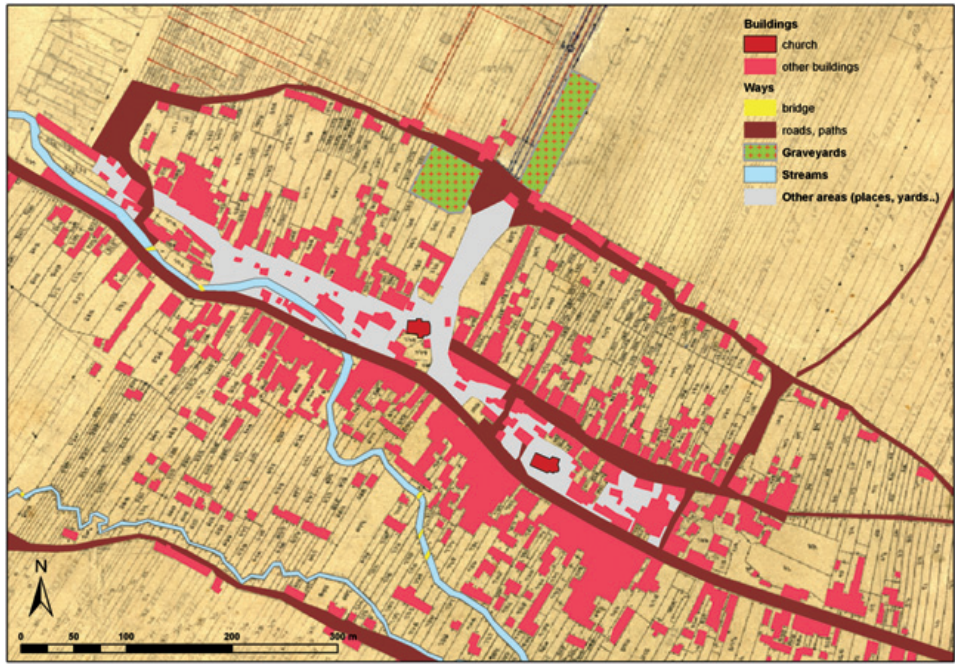


Fig. 3. Vector layers interpreted on the raster map of the SC – Štrba.



Fig. 4. Studied area within the High Tatras National Park.

## Results

The studied area is formed by a transect measuring approximately 5 km in width and 15 km in length that leads from the Štrba village towards northeast and ends in the area of the Vysoká peak. The total area reaches almost 80 km<sup>2</sup>. Thus, the transect covers all vertical gradient levels from the High Tatras foothills to their peak levels. The elevation ranges between approx. 810 (in the area where the Štrbský potok stream leaves the studied area) and 2370.5 meters above the sea-level (Volia veža). From the administrative point of view, the transect covers the western part of Prešov district with parts of Šuňava, Štrba, Tatranská Štrba, Štrbské Pleso and Vyšné Hágy cadastres (Fig. 4).

**The landscape changes till the year 1769.** A relatively late settlement of the studied area was mainly caused by its unfavourable natural conditions (rough climate, poor soils of cambic, gley, pseudogley, and podzolic types of soils). Thus, the earliest traces of human settlement originated only from the high Middle Ages, approximately from the second part of the 13<sup>th</sup> century. According to Švorc (1979, 1996), the earliest landscape-cultivation was initiated by Germans and Slovaks around the year 1267 when the foundation of the village of Štrba was codified in the written evidence.

As a matter of fact, the landscape structure of the southern part of the studied area that had the most favourable natural conditions underwent a series of changes since the earliest traces of human settlement. Considering the accessible sources and possibilities of the natural conditions, it is supposed that the main population support was mainly formed by logging and agriculture. Both activities unquestionably influence the landscape character. After the analogies from both the Trenčianska kotlina basin (Chrastina, 2005a, b) and areas with scattered settlement in Pohronský Inovec and Tribeč (Petrovič, 2005), Poľana (Olah, 2003) or in the northeastern part of the Bakony forest in Hungary (Chrastina, Boltížiar, 2006), it is certain that the human settlement in these regions had to face serious problems not only with the soil erosion on the deforested slopes of Štrba Hills, but also the extensive forest exploitation in the drainage area of the Štrbský potok stream and its affluents. The soil erosion was reinforced by extensive cattle forest grazing and, furthermore, the situation was worsened since the 14<sup>th</sup> century by the climatic changes (strong precipitation increase).

**The studied landscape between 1769 and 2002.** Settlement continuity and the stabilization of the politic-economical conditions in the later part of the 18<sup>th</sup> century supported the effects of the anthropogenic factors on the landscape within the studied area. Their subsequent results are recorded in the structural changes of the landscape cover. Reconstructive maps (Figs 6, 7, 8, 9, 10) created by the interpretation of the above-mentioned map sources, their multitemporal analyses, and the statistical processing of the land-cover changes in time (Fig. 5) enabled us to establish the following landscape development tendencies:

- changes in grassland percentage between 1769 and 1822 very probably illustrates only alternation of mapping methods (greater generalization), the other changes are surprisingly featureless;



- the most distinct shifts in the land-cover character passed off between 1822 and 1949. The image is considered to be biased by both diverse analyses potential of the available map sources and also by the real shift from landscape of 1822 with reduced anthropogenic impact to landscape rather extensively agriculturally used that was, moreover, in the vicinity of Štrbské pleso tarn largely destroyed by windthrow disaster. The earlier time horizon was influenced by combination of several factors, among others by the occurrence of cattle plague, cholera epidemic, or by large population emigration to America (Švorc, 1996);
- comparison of the 1949 and 1992 time horizons clearly shows the image of regenerated forests on one hand and on the other influence of the tourist industry that enabled, for example significant development of the built-up area of Tatranská Štrba that was supplemented by a decrease in agricultural activities in this village. From landscape structure point of view, a recovery of tree corridor following the Mlynický potok stream is worth mentioning;
- landscape changes between 1992 and 2002 are nearly imperceptible and are represented mostly by transitions of small plots from transitional woodland/shrubs (324) to permanent forests. Only in the last decade, there are more significant anthropogenic interventions that would influence the landscape structure. They are represented by construction sites CORINE category (133) visualized by the construction of parts of D1 motorway from Važec to Svit.

The above-mentioned landscape changes illustrate the development tendencies of the entire transect. However, it is possible to define three regions within the studied area with distinct landscape history:

- the most northern part (slopes and peak levels of the High Tatras) that underwent minimum changes in the selected period of time and thus represents a stabile environment that was very probably only slightly influenced by anthropogenic impacts. The spatial distribution of individual land cover categories is also within the studied area, more or less, stabile, including rocky areas (332), regions with sporadic vegetation (333), peat bogs (412), and water bodies (512). The two last categories were not depicted on the military survey maps in their entirety. The peat bogs in such inaccessible regions were either simply omitted or were regarded completely insignificant from the military aspect and thus were not depicted in the maps. Furthermore, water bodies cover smaller area (38 ha) on the military survey maps than on the aerial photographs (42.7 ha) since the Nové Štrbské pleso tarn and the reservoir on the Mlynický potok stream located to the north of Štrba were not depicted on the military survey maps.
- in the central part of the transect (in the area covered mainly with coniferous forests) two types of changes are observed: alternations within the studied area that were predominantly caused by natural factors and those that were evocated by anthropogenic causes. The former are represented mainly by the windthrow disaster in 1949 when vast forest areas were damaged by a large windbreak in the vicinity of Štrbské pleso tarn and to the north of Tatranská Štrba. The later type of changes was caused by human activities in the region and especially by their in- and decrease and led in distinct shifts of the southern

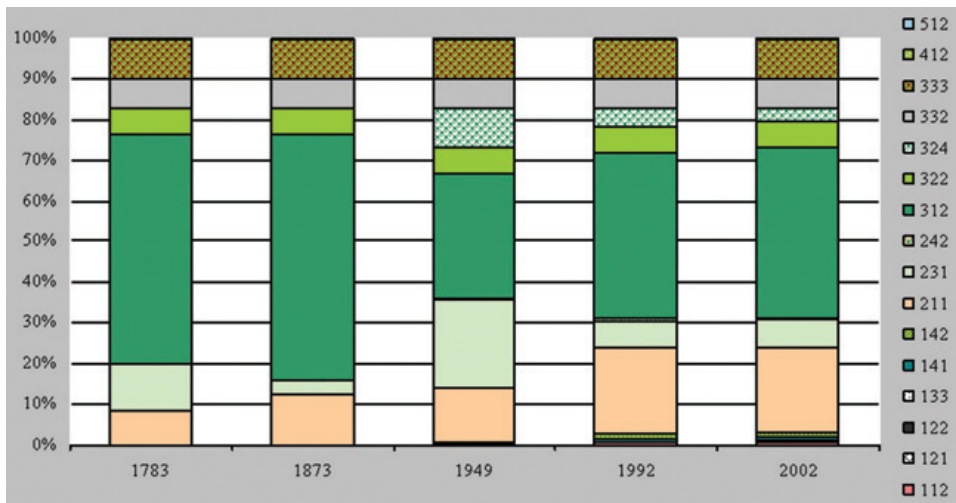


Fig. 5. Land use changes (areal percentages) in the studied area.

border of the continuous forest that are significant mainly between the years 1822 and 1949, respectively 1949 and 1992, with the increasing influence of the newly (in 1949) established village of Tatranská Štrba;

- development of the southern part of the transect (in the vicinity of Štrba village) is strongly influenced by human activities and predominantly by agriculture that were most extensive between the years 1992 and 2002. In this horizon, the landscape diversity is provided by forest strips following the watercourses. This differs significantly from the situation in 1949 when such areas were used only as grasslands.

**The first military survey** represents one of the earliest map sources that are transformable into the GIS environment and thus available for multitemporal analyses – disregarding its certain spatial and content inaccuracy and herewith associated georeferencing inconveniences. Unlike the second military survey, it still partially captures the continuum of landscape (fuzzy transition between forests and non-stocked forest land etc.) and therefore it probably shows the reality more accurately than later map sources, e.g. the second military survey or rather schematic cadastre maps (Sádlo, Karlík, 2002). Thus, the first military survey could optimally be used as raster basis depicting the so-called ‘horizon zero’, i.e. the earliest mapped source in a time series. Due to almost total absence of distinct borders between individual categories, the rather difficult vectorization causes unavailing simplification that is well-founded only in the case of the quantitative analyses of land use changes.

Regarding the accuracy of defining the categories, the **second military survey** is clearly more distinct and its georeferencing causes no significant problems. Thus, the individual map sheets were very simply unitable into a single seamless map. Therefore, in the opinion of the authors, the second military survey is predestined as a basis for creating continuous

1769

Corine 1769

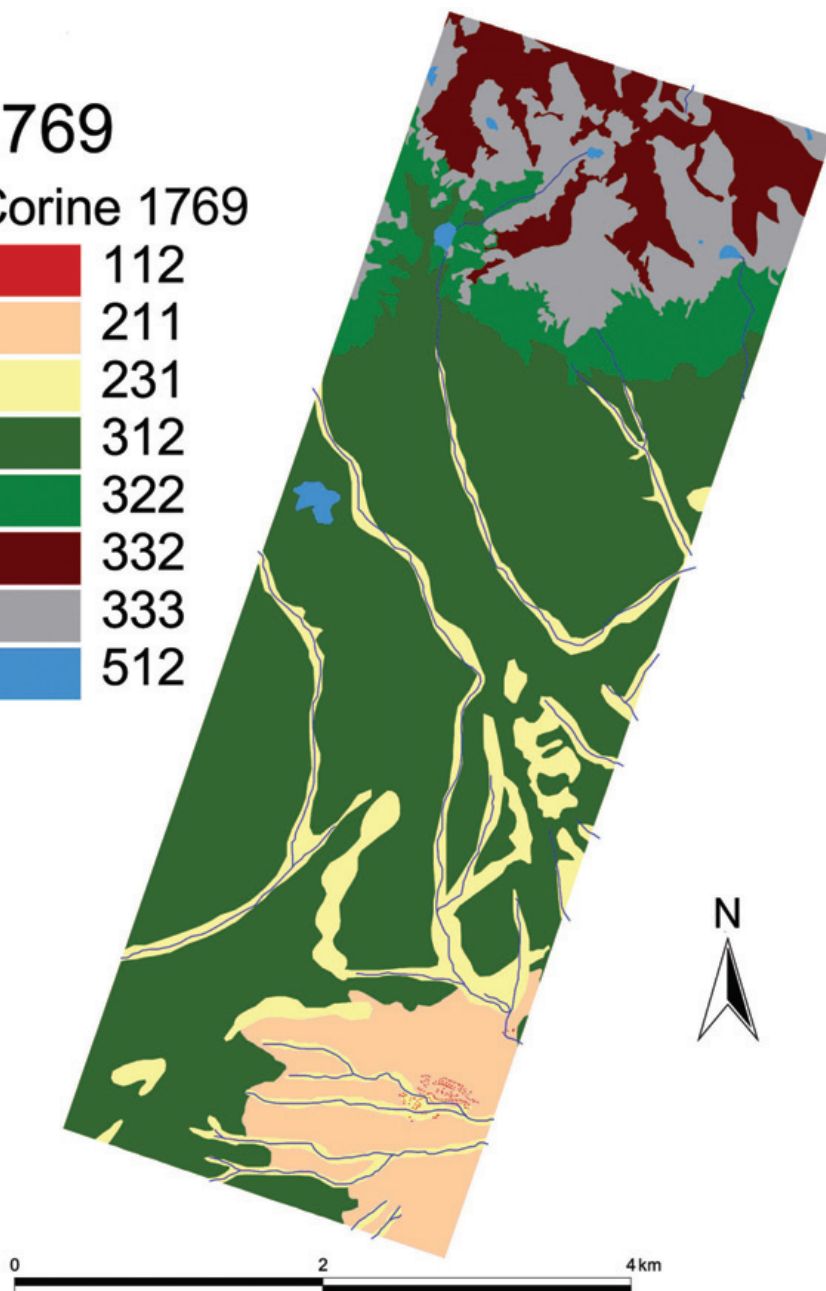


Fig. 6. Land cover in the horizons of 1769.

# 1822

## Corine 1822

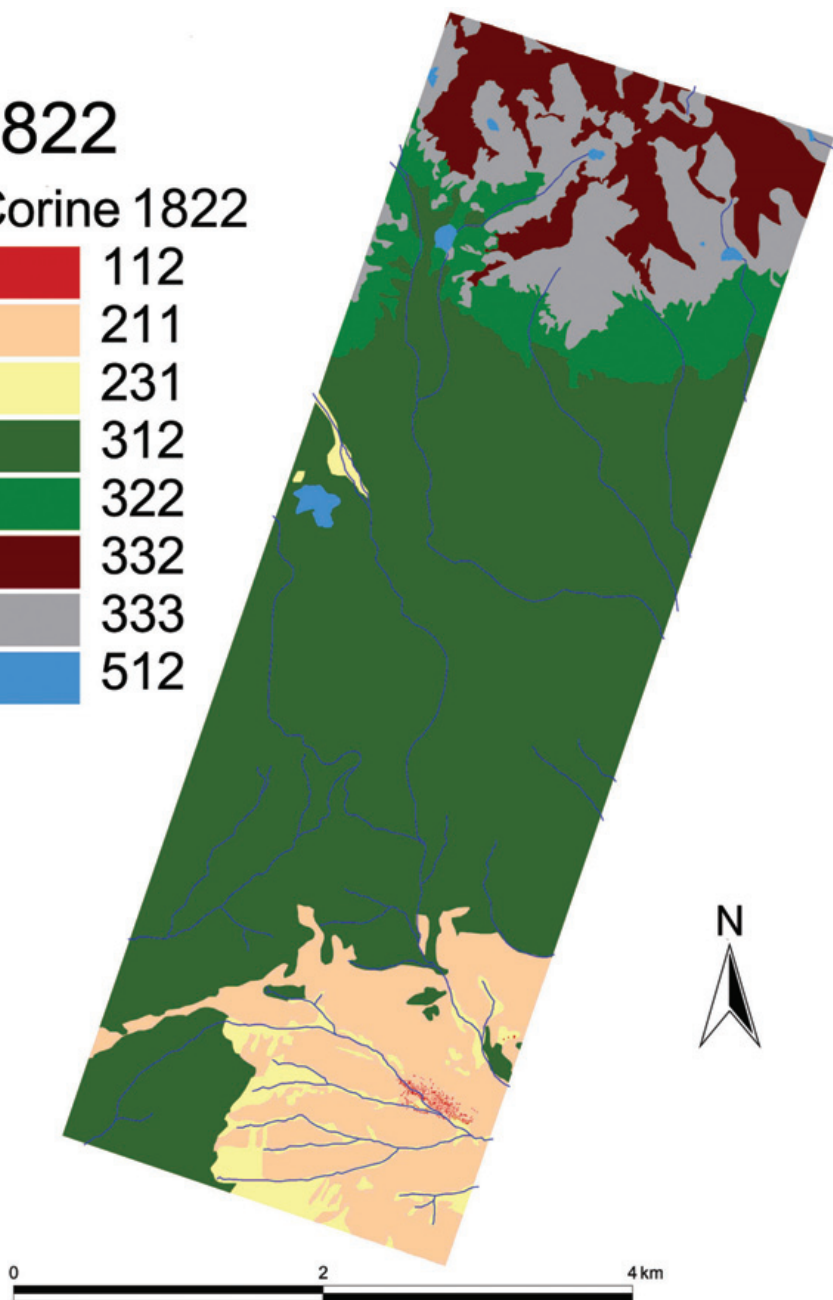
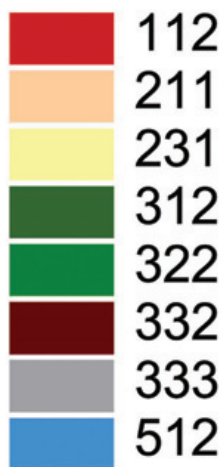


Fig. 7. Land cover in the horizons of 1822.

# 1949

Corine 1949

- 112
- 121
- 122
- 141
- 142
- 211
- 231
- 242
- 312
- 322
- 324
- 332
- 333
- 412
- 512

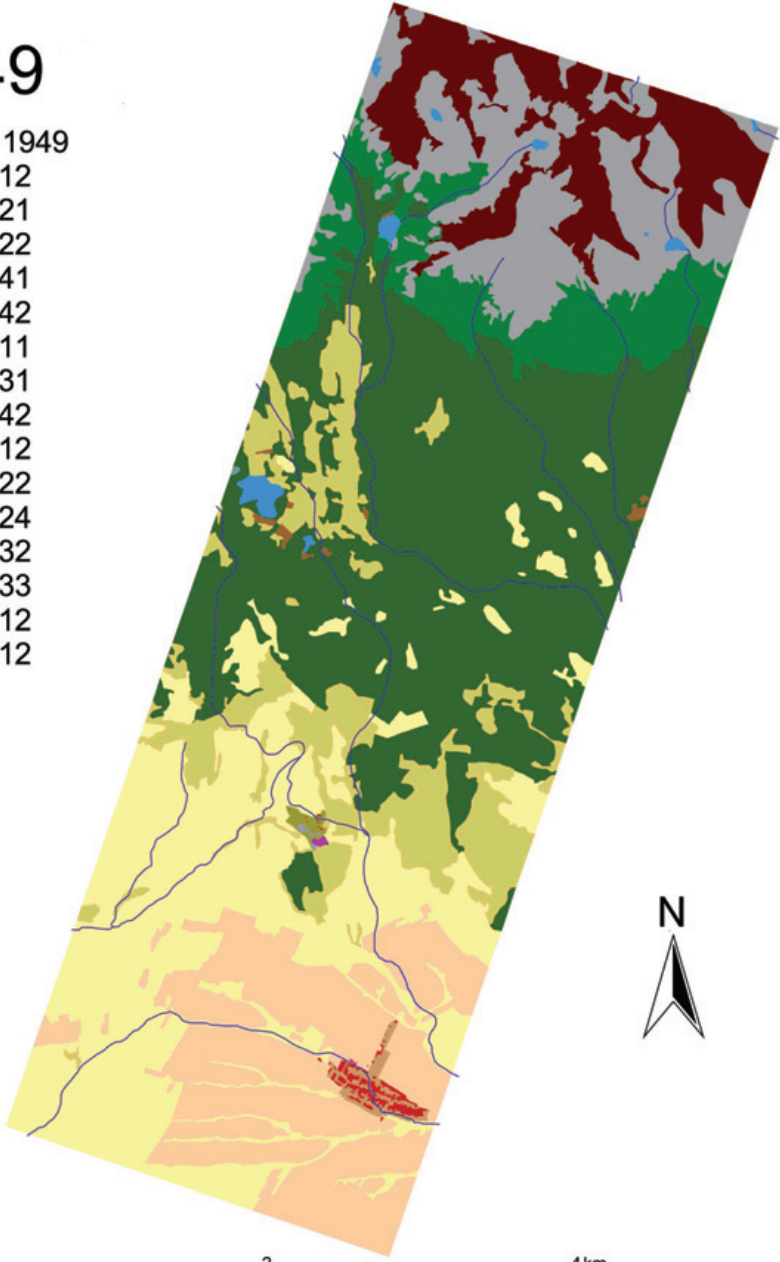


Fig. 8. Land cover in the horizons of 1949.

# 1992

Corine 1992

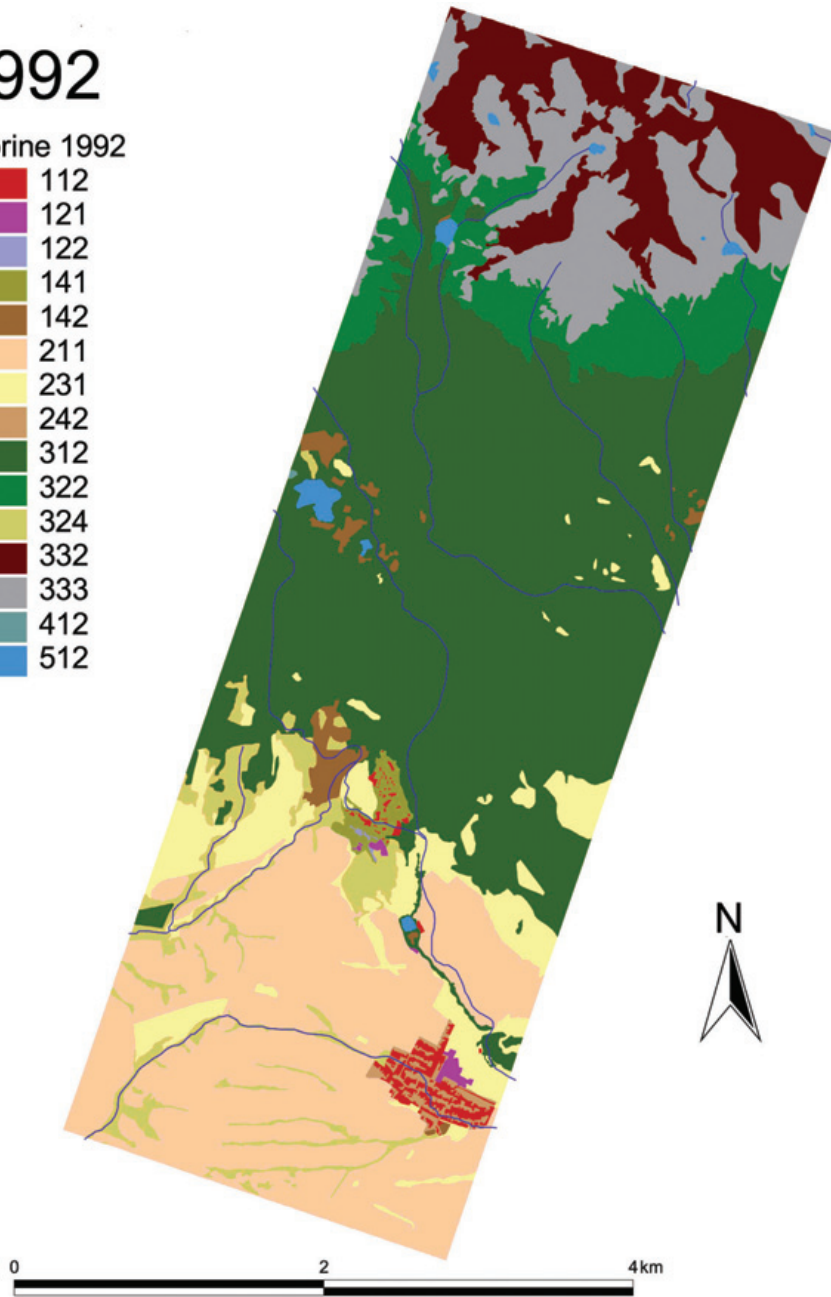


Fig. 9. Land cover in the horizons of 1992.

# 2002

Corine 2002

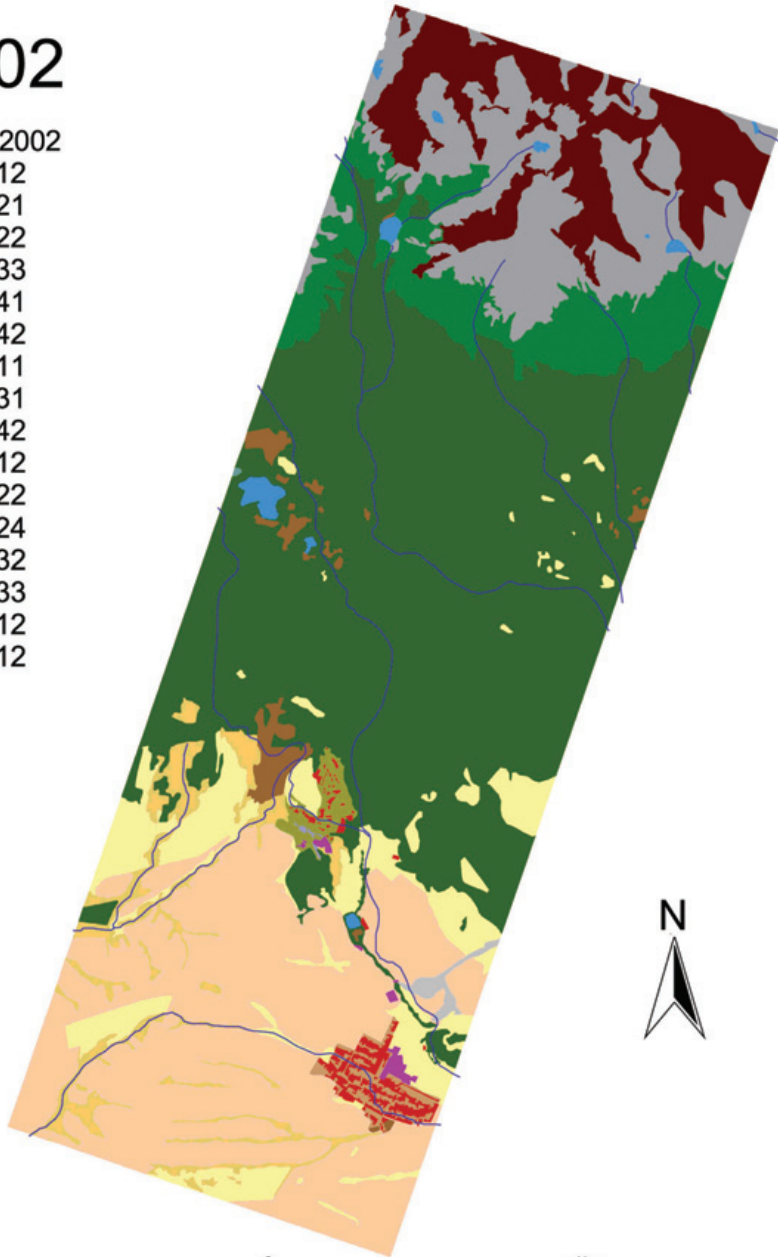
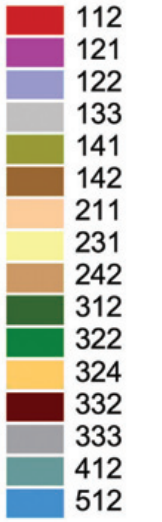


Fig. 10. Land cover in the horizons of 2002.

vectorized map of the studied area (e.g. TANAP), using either the original map legend or the CORINE Land Cover categories. For the purposes of any further usage it would be most useful to process the basis for its accurate georeferencing, i.e. layer of points defining the corners of individual map sheets; as was already done for the second military survey of the Czech Republic (Veverka, 2005).

The role of **remote sensing data** for any landscape-ecology studies is naturally unexceptionable and their significance for landscape change studies is furthermore confirmed by the date of their origin. The photographs taken in the year 1949 depicted the landscape just before the collectivization process had started; and those taken in 1992 show the influence of decreasing agricultural intensity. This trend could be even more distinguishable if the aerial photographs taken e.g. in the 70ies would be involved. Especially for the high-altitude part of the High Tatras the aerial photographs represent an irreplaceable source of accurate aerial information that could hardly be, if ever, obtained by traditional mapping methods.

Disregarding their 'imperfection' (they are not coloured, often overwritten etc.), the **stable cadastre maps** represent a very valuable source of information mainly due to their convenient scale (1:2880) and consequently great degree of punctuality mainly in urban areas. If it was necessary to incorporate the stable cadastre maps into a time series of full-area vectors, for example for the purpose of the land cover changes monitoring, evaluation and their quantification, it is possible to specify comprehensive categories of forests, grassland, and arable land even on the uncoloured maps, eventually only the last two categories.

*Translated by K. Křováková and M. Boltžiar*

## Conclusion

Results of the presented study refer to the significance of old map sources and archive aerial photographs for the evaluation of landscape development. Undoubtedly, it is not a unique study since in the last years the number of such aimed research projects very significantly increased. Therefore, increased emphasis should be paid on the methodological aspects of these sources usage and their potential should be appraised in its maximum possible degree. If approaches and stimuli mentioned in this study would contribute, effort invested in its preparation was not wasted at all.

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