

Quantitative analysis of landscape development and mapping of drainage network based on historical maps: case study of the surroundings of the Kašperské Hory town (Czech Republic)

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Abstract

The authors studied landscape development and dynamics of land use changes in a model area of Kašperské Hory in the period 1878–1989. Changes of drainage network were quantified on one map sheet in the scale 1 : 25 000 in the period 1843–2005. The Kašperské Hory study area is located in the southern part of the Plzeň Region, 10 km southward of the Sušice town. Computer processing of the digital map has shown that the model area of Kašperské Hory represents a harmonic cultural landscape, with a long history and high aesthetic value. In comparison with a relatively stable drainage network, the analysis of land use has shown several changes in landscape development in the last 100 years.

Key words: dynamics of landscapes, historical maps, Šumava Mts.

INTRODUCTION

A modern society must have adequate information about many complex interrelated aspects of its activities in order to make decisions. Land use is only one such aspect but knowledge about land use has become increasingly important as society plans to overcome the problems of haphazard, uncontrolled development and deteriorating environmental quality. Land use data are needed in the analysis of environmental processes and problems of sustainable development. One of the prime prerequisites for a better use of land is information on existing land use patterns and changes in land use through time.

The study of land use development in landscapes represents part of a long-term research project – Research of Biodiversity Sources and Indicators in a Cultural Landscape in the Context of its Fragmentation Dynamics. An important part of the research project is the study of land use changes and development of the cultural landscape in the period of 1763–2005, which is based on analyses of historical military topographic and topographic based large-scale maps with application of GIS methods. This paper is part of the sub-project Quantitative Evaluation of the Cultural Landscape Development of the Czech Republic.

Quantitative evaluation is based on a cartographic research method. One of the goals of the research project is evaluation of land use in a certain period by compiling digital maps of land use, which is aimed at delimitation of stable and unstable plots and elements in the landscape.

METHODS

The research runs in two levels. The first level concerns the whole territory of the state in the map scale 1 : 200 000. The second level is aimed at detailed research in model areas in different parts of the Czech Republic, in the scales of 1 : 10 000 and 1 : 25 000. The evaluation of the land use is based on historical topographic maps. There are complete sets of maps of the 1st and 2nd Austrian Military Survey in the scale of 1 : 28 800, 3rd Austrian Military Survey in the scale of 1 : 25 000 and Czechoslovak and Czech Military maps from the 20th century (aprox. 1930, 1950, 1990) and Basic Map of the Czech Republic in the scale 1 : 10 000 available in digital form. Map sets are georeferenced into the system S-JSTK. Eight model areas as basic types of Czech, Moravian and Silesian landscapes were chosen for detailed evaluation of land use changes. The research, as previously stated, concentrates on the analysis of historical maps in digital form. That is why aerial photographs have not been used.

We analyzed individual maps from 1763 (1st Austrian Military Survey) up to the present time. A compilation of digital polygon maps of land use in individual time periods served as a basis for analysis. The minimum area (element) identified on maps and studied was 0.1 hectare. For comparison of map sets, we differentiated areal and linear elements by clearly delimited polygons and lines on the map. We compiled a unified legend of land use map, which was based on the analysis of map keys. The legend contains 10 categories; 1 – fields, 2 – grasslands (meadows), 3 – orchards, 4 – vineyards and hop-gardens, 5 – forests, 6 – fishponds, 7 – villages, 8 – towns, 9 – leisure areas, and 0 – others. These categories with the exception of category 9 (leisure areas), can be distinguished in all map sets. Their choice results from the specific development of the Czech Republic in the second half of the 20th Century. Linear elements are divided into 3 categories: drainage network, railways and roads.

We studied landscape development and changes in land use in Kašperské Hory during the period 1878–1989. The authors also quantified development of the drainage network on one map sheet in the scale of 1 : 25 000 during the period 1of 843–2005. Due to digital processing of maps, information about the spatial extent of individual land use types and comparison of the length of water courses in the mentioned period were obtained. Based on this information, it is possible to show cartographically the number of land-use changes, which again show dynamics or stability of landscapes. From the point of view of landscape development, it will be important to define stable cores of landscapes in which the land use has not changed during the whole studied period.

MODEL AREA

The model area of Kašperské Hory covers 2000 hectares. It is situated in the southern part of the Plzeň Region, 10 km southward of the Sušice town. The area is located between the Otava River, the Losenice, Zlatý Potok, and Opolecký Potok streams. The historically important town of Kašperské Hory is situated in the central part of the area at 739 m a.s.l. The SW part of the area belongs to the Šumava National Park on the boundary with the Šumava Protected Landscape Area (PLA). Elevations in the area range from 541 m in the Otava River valley to 962 m on the Chlum hill. The western boundary forms a deep incised valley of the Otava River. To the SE deep valleys of the Losenice and Zlatý Potok streams are apparent. Morphologically, it is a rugged highland with many forms of weathering and removal of crystalline bedrock (Fig. 1). In terms of regional-geomorphologic division, the area belongs to the Šumava geomorphological system and is situated between the Bohemian Forest

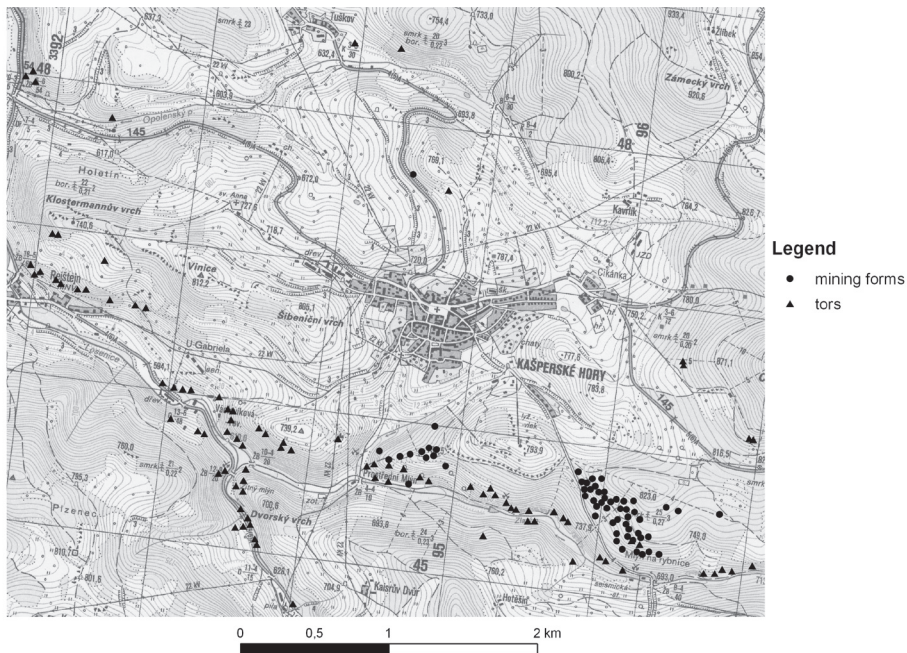


Fig. 1. General map of the model area with special regard to tors and mining forms.

(=Šumava Mts.) and its piedmont. The northern part of the area is called the Svatoborská Hornatina highland and the southern part belongs to the geomorphic subunit of the Šumavské Pláně plateau (DEMEK 1987). Potential vegetation (NEUHAUSLOVÁ 2001) is represented by herb-rich beech forest with Drooping Bittercress (*Dentario enneaphylli-Fagetum*). In the contemporary landscape, an important role is played by forests that cover the steeper part of the territory. Grasslands (meadows and pastures) are also important; balks with agricultural heaps, often with rich tree cover are typical. Fields are rare and occur on less inclined slopes in the surroundings of settlements. They are often lined by trees. Some scattered trees can also be found in the fields. According to regional climatic division (QUITT 1970), the area belongs to the cold climatic area CH7 (mildly cold and cold mountainous region). The area is drained by the Otava River into the North Sea. The Losenice stream, which springs in peat bogs in the surroundings of the Horská Kvilda village near the Zlatá Studna place, is an important tributary of the Otava River in the village of Rejštejn. To the NE of Kašperské Hory town, another right tributary of the Otava River – the Opolecký Potok stream, which empties into the Otava River in the village of Radešov – can be found. The water courses have shallow beds at the bottoms of deep incised valleys. River beds and the majority of their longitudinal profiles are in a disequilibrium state.

The model area was chosen as a landscape type that is strongly influenced by gold mining and by the transfer of the German-speaking population after World War II. For the colonization and development of the landscape, the most important factors were business and mining. Mining forms from panning and gold mining can be found everywhere in the surroundings of the Kašperské Hory town (Fig. 1). Surface and subsurface gold mining started after depletion of gold-bearing river sediments. Mining also influenced the foundation of mining towns – Kašperské Hory and Rejštejn. Originally, settlements of Kašperské Hory and Rejš-

štejn formed one town called as Hory Rejštejnské Horní and Hory Rejštejnské Dolní, respectively, which received royal rights as a mining town in 1584. Mining settlements were founded along paths, often as settlements of miners, founders, glassmakers and forest workers. The main zone of mines is situated to the south of the Kašperské Hory town. This mining zone is 4 km long from the Suchý Vrch hill and runs towards the Rejštejnský village. There are many preserved anthropogenic mining forms such as mine adits, shafts and pits up to the present time (ANDĚRA & ZAVŘEL 2003, HORPENIAK et al. 1990, RUDA 1980).

Mining influenced not only land use but also drainage patterns. Water management works especially in relation to construction of water mills (ore mills) and later of saw-mills and iron-works in the valleys were carried out from medieval times. Streams and rivers were dammed by weirs and water was derived to sites or their storage reservoirs by mill-races. River training works also involved bank stoning and cross sills (e.g. on the Losenice stream). On the Zlatý Potok stream cascades of storage reservoirs were constructed to regulate tributaries of the Losenice stream because spring and flash floods caused extensive damages. But this work did not principally change the lengths of water courses in the study area.

After the end of gold mining in the second half of the 16th century, glass and iron manufacture, cattle breeding and wood exploitation developed in the area. Further development of these branches and increased use of wood influenced landscape development. The area of forests declined and also their species composition changed. Agriculture originally had only a supplementary function and was of a self-subsistent character. The peak of forest decline was reached in the second half of the 19th century. A parallel decline of wood exploitation and agriculture became the most important source of subsistence (www.npsumava.cz). This information is confirmed by the analysis of historical maps.

ANALYSES OF LAND USE CHANGES

Quantitative development of land use changes in the model area Kašperské Hory has so far been analyzed on four map sets from 1878 (the 3rd Austrian Military Survey) up to 1989.

We were not able to compile a land use map from the map of the 1st Austrian Military Survey (1763–1783) due to difficult georeferencing and absence of a trigonometric net (Fig. 2). Due to faded colours on maps, the identification of spatial and linear elements was diffi-



Fig. 2. Topographic Map of the First Austrian Military Survey from 1763–1783.

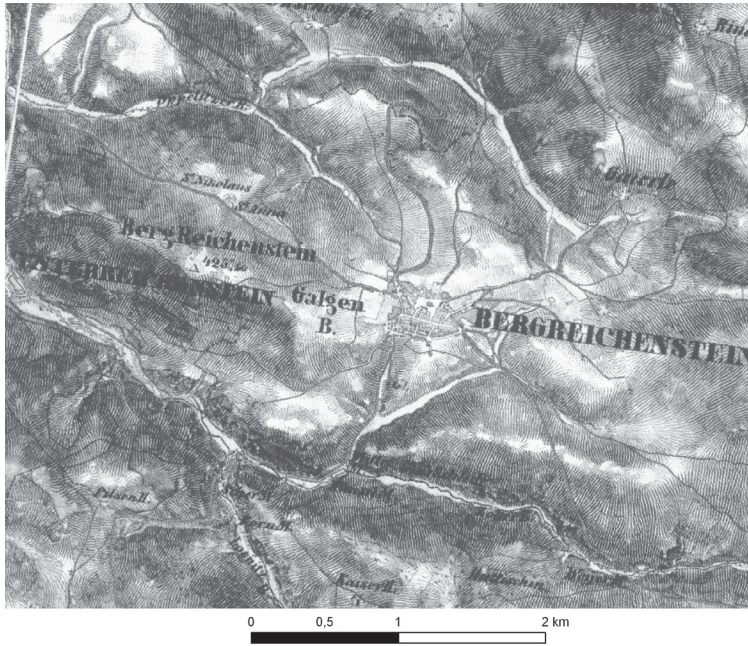


Fig. 3. Second Austrian Military Survey (1843).

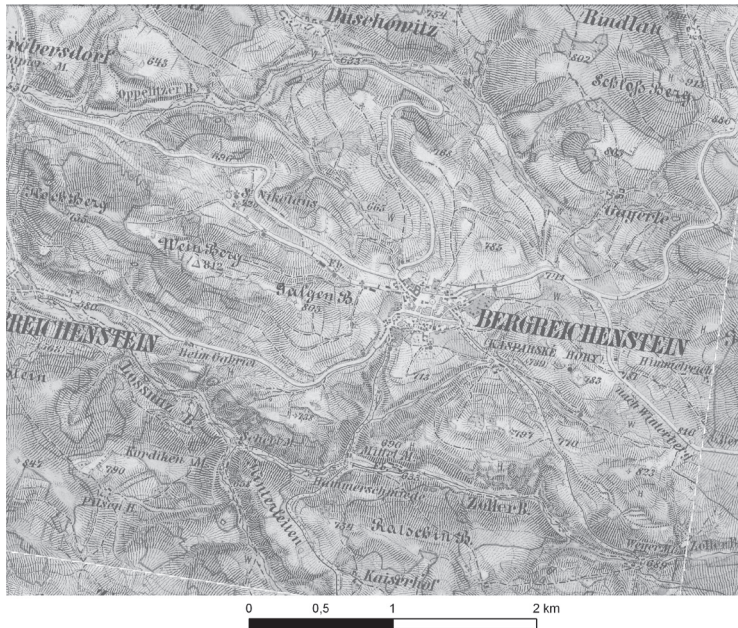


Fig. 4. Third Austrian Military Survey (1878).

cult. Generally large areas of arable land are mapped. Grasslands are concentrated along river and stream floodplains. Streams, rivers and roads can be well recognized.

There were also problems with the interpretation of the 2nd Austrian Military maps. Due to the rugged relief, the identification of areal elements was difficult because hatches merged into dark spots (see Fig. 3). In comparison with maps of the 1st Survey, maps of the 2nd Survey are precise. The map shows a small proportion of forests as deforestation at this time (1843) reached its peak.

Maps of the 3rd Austrian Military Survey were the only continuous map set of the Czech Republic up to the first half of the 20th century (Fig. 4). Digital maps of land use of the studied area in the 1878 show a high proportion of arable land and grasslands (Fig. 5). Agricultural landscape is divided into a large number of tracts, separated by balks with agriculture heaps or roads. Forests show the smallest proportion in the analyzed time period (1878–1989). This is in agreement with historical development, because deforestation reached its peak in the second half of the 19th century and later the trend changed. After the decline in wood harvesting at the end of the 19th century, agriculture became the most important source of subsistence for the local population.

Due to the location of the study area in a mildly cold climatic region, a major part of agricultural land belongs to mountainous agricultural production type. The majority of the (mostly German speaking) population practised agriculture even at higher elevations. This traditional (but relatively intensive) agricultural type existed up to World War II (ANDĚRA & ZAVŘEL 2003, www.npsumava.cz). The evidence is a map set from 1937 (Figs. 6 and 7), which shows a slight decline in arable land, a more evident decrease in grasslands and, on the contrary, increase in forested land.

The map set from 1953 (Fig. 8) shows a decrease in some economic activities as the result

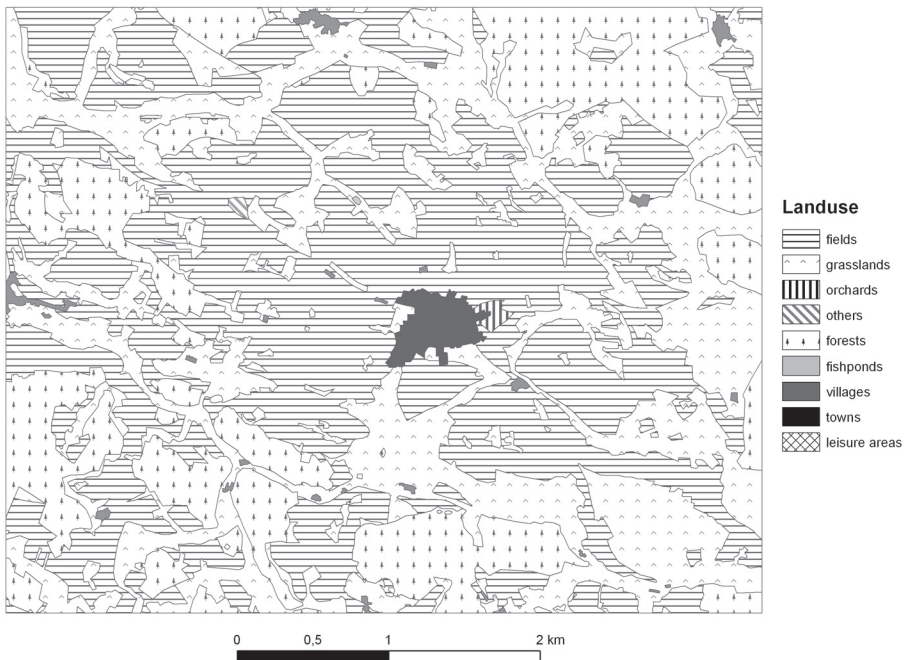


Fig. 5. Land use map constructed on the basis of Topographic Map 1878.

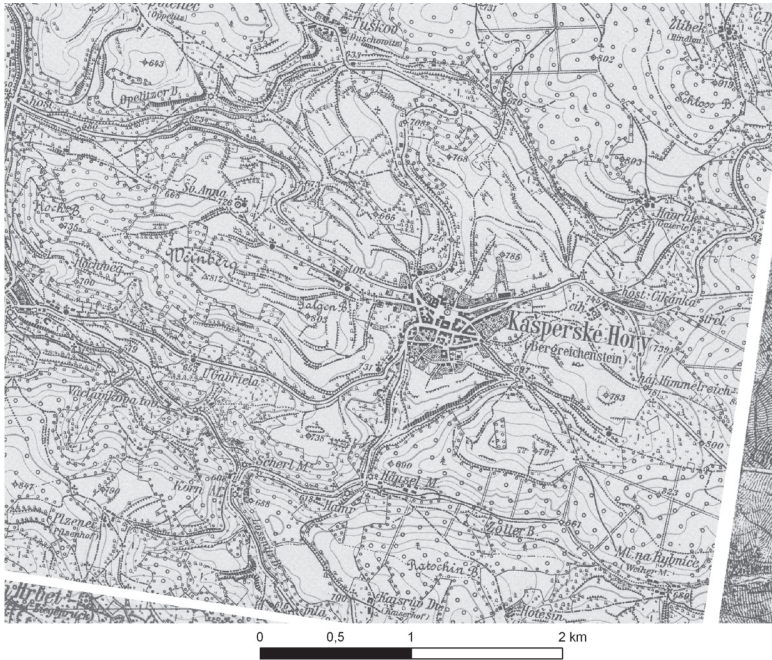


Fig. 6. Revised maps from 3rd Austrian Military Survey (1937).

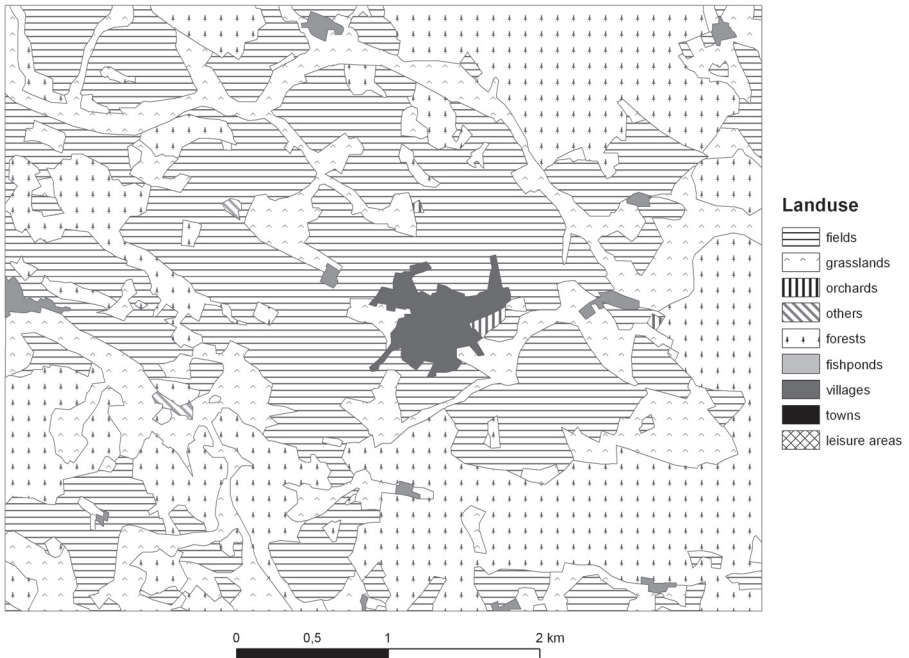


Fig. 7. Land use map constructed on the basis of Topographic Map (1937).

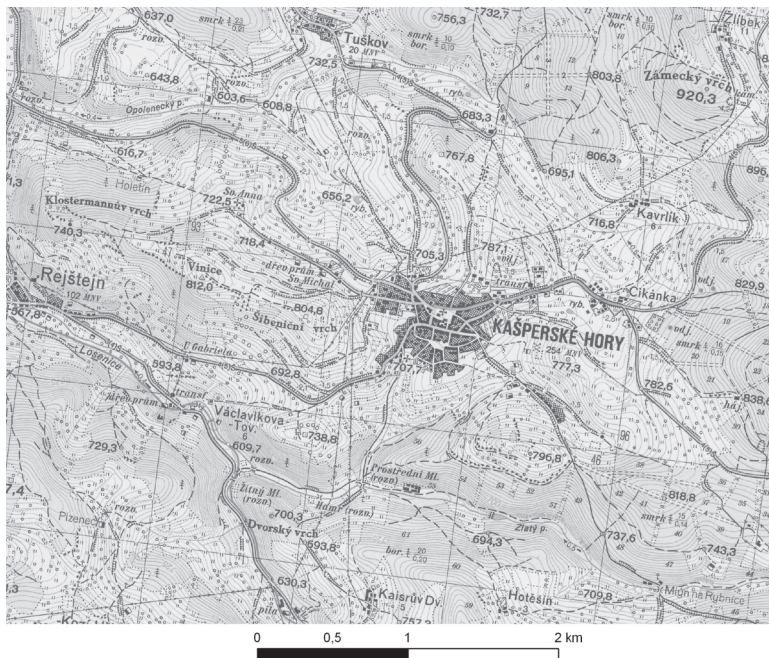


Fig. 8. Czechoslovak Military Topographic Map (1953).

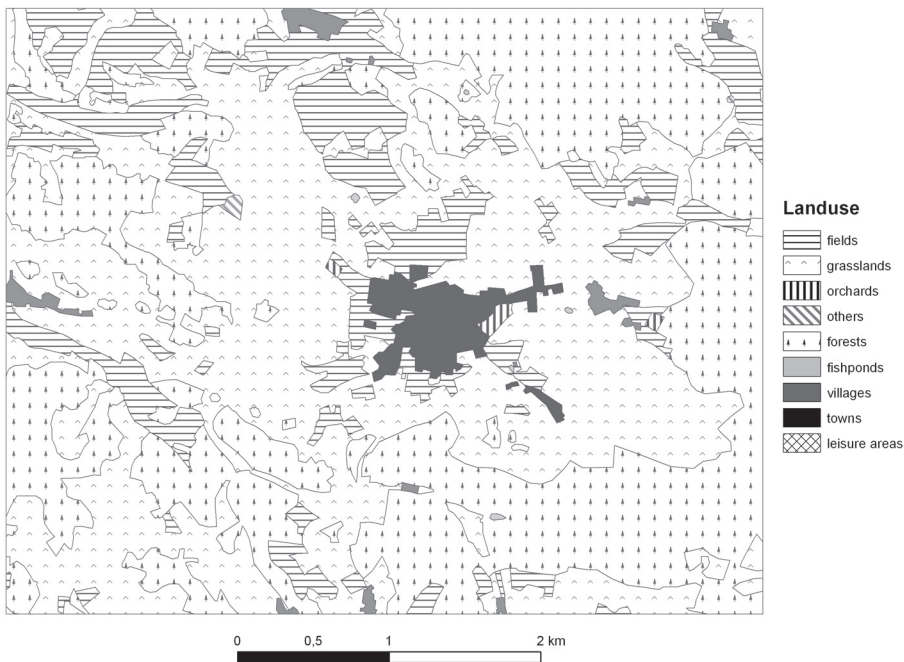


Fig. 9. Land use map constructed on the basis of Topographic Map (1953).

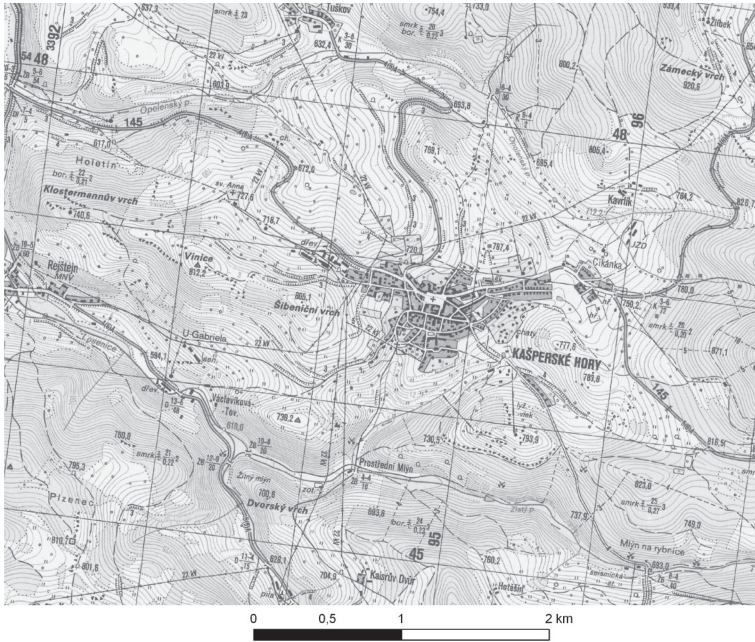


Fig. 10. Czechoslovak Topographic Military Map (1989).

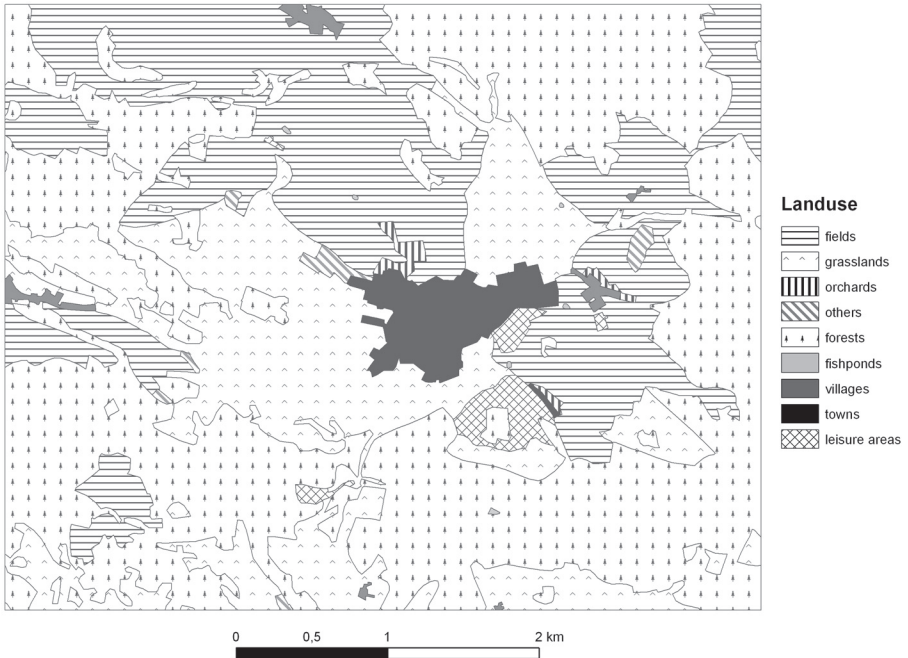


Fig. 11. Land use map constructed on the basis of Topographic Map (1989).

of the transfer of the German speaking population after World War II. The analysis of digital historical maps has shown that some villages and farms were abandoned. The type of agricultural activities changed into meadow cultivation and pasture farming. The proportion of arable land radically decreased in favour of grasslands and forests (Fig. 9). Small and narrow fields nearly disappeared and hedgerows developed in abandoned fields. The landscape has become overgrown by self-seeding woody species, especially around linear landscape elements, which have not been maintained.

Features and processes accompanying collectivization of agriculture were documented by the next map set from 1989 (Fig. 10), when small fields were joined into larger units. Balks and roads were eliminated. The aim of these activities was to reach a maximum proportion of agricultural land in the landscape (Fig. 11). The land use map shows a relatively high proportion of agricultural land but very few meadows. However, we have some doubts about the accuracy of the mapping. The land use map was based on a set of military topographical maps, for which this information probably was not essential.

Quantitative analysis and a digital land use map from 2005 has so far not been compiled because we do not have the basic map (ZABAGED 2006) at our disposal yet. From preliminary analysis of the vector thematic layer, a sharp increase in grasslands and a decrease in arable land down to a minimum can be seen. This development is in agreement with the reality because since 1990 the trend has been to abandon agriculture land, leave it fallow or grass it, and the result is the radical decrease in arable land as mentioned above. Aerial photographs of the model area from 2003 show the landscape with forest complexes passing to varied agricultural land with small villages, typical solitary houses and historical towns. Several old landscape structures, outstanding constructions, settlements and other features important for reconstructing the historical development of the landscape have been preserved in the area. At the present time, the territory of the Kašperské Hory town is, due to its location, history, number of cultural monuments and preserved natural environment, an important centre of culture, leisure and tourism in the Bohemian Forest.

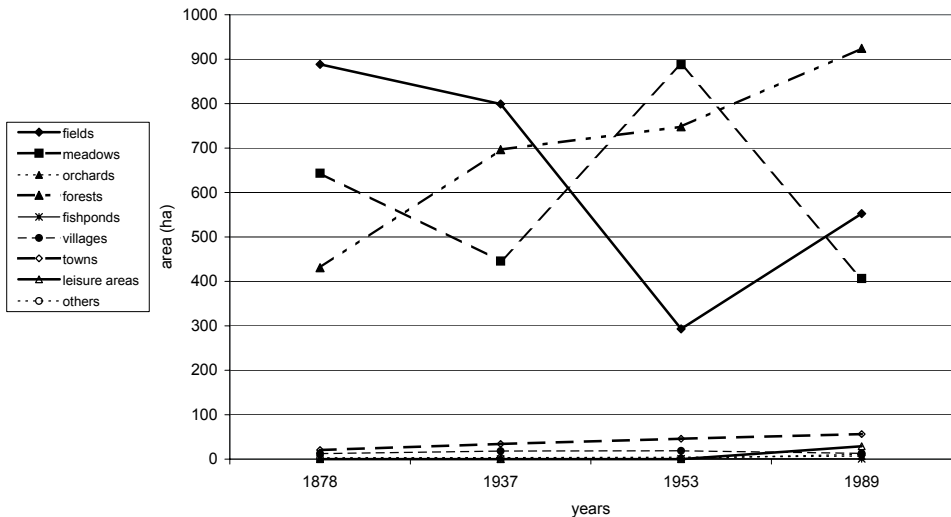


Fig. 12. Changes of areal extent of land use types based on analyses of topographic maps from 1878–1989.

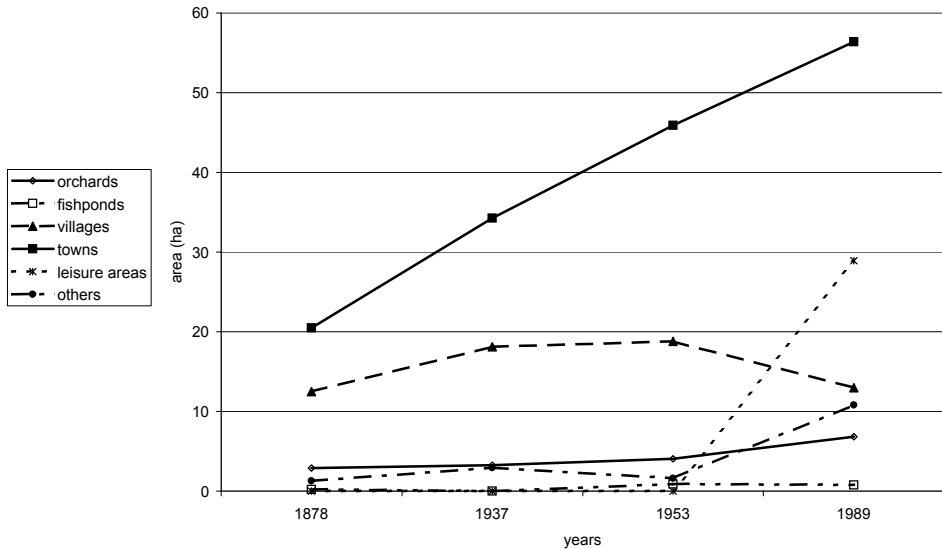


Fig. 13. Changes of areal extent of land use types based on analyses of topographic maps from 1878–1989, without fields, meadows and forests.

Table 1. Changes in land use based on topographic maps from 1878–1989 (in hectares).

Landuse categories	1878	%	1937	%	1953	%	1989	%
fields	888.40	44.42	799.13	39.96	293.15	14.66	552.46	27.62
meadows (green lands)	643.45	32.17	445.80	22.29	887.70	44.39	406.55	20.33
orchards	2.89	0.14	3.24	0.16	4.06	0.20	6.81	0.34
forests	430.80	21.54	696.53	34.83	747.90	37.40	924.36	46.22
fishponds	0.19	0.01	0.00	0.00	0.88	0.04	0.75	0.04
villages	12.50	0.63	18.10	0.91	18.80	0.94	12.96	0.65
towns	20.50	1.03	34.26	1.71	45.91	2.30	56.38	2.82
leisure areas	0.00	0.00	0.00	0.00	0.00	0.00	28.93	1.45
others	1.27	0.06	2.94	0.15	1.60	0.08	10.80	0.54
Total	2000	100	2000	100	2000	100	2000	100

Quantitative analysis of digital maps enabled the comparison of the spatial extent of individual types of use in the period 1878–1989 (Figs. 12 and 13, Table 1). The most apparent changes appeared in the categories which are typical for the model area – fields, forests and grasslands. The growth of the urban landscape of the Kašperské Hory town is the most apparent for categories with a lower area. In 1989, the most apparent feature was the increase in leisure areas (Fig. 13). The quantitative analysis of digital land use maps showed a decrease in the area of fields from 1878 up to 1953 in favour of grasslands and its increase in 1989. At the same time, permanent growth of the area of forests, which doubled since 1878, was typical. The spatial extent of grasslands fluctuates in wide limits (Fig. 12) and shows a slight

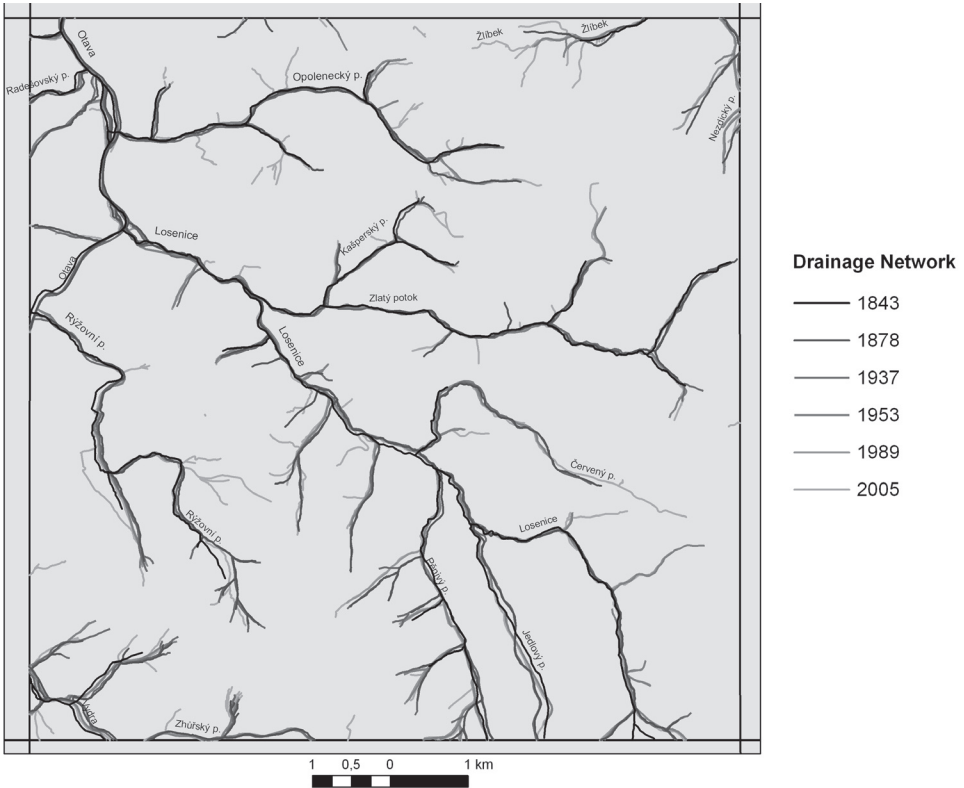


Fig. 14. Comparison of the drainage net.

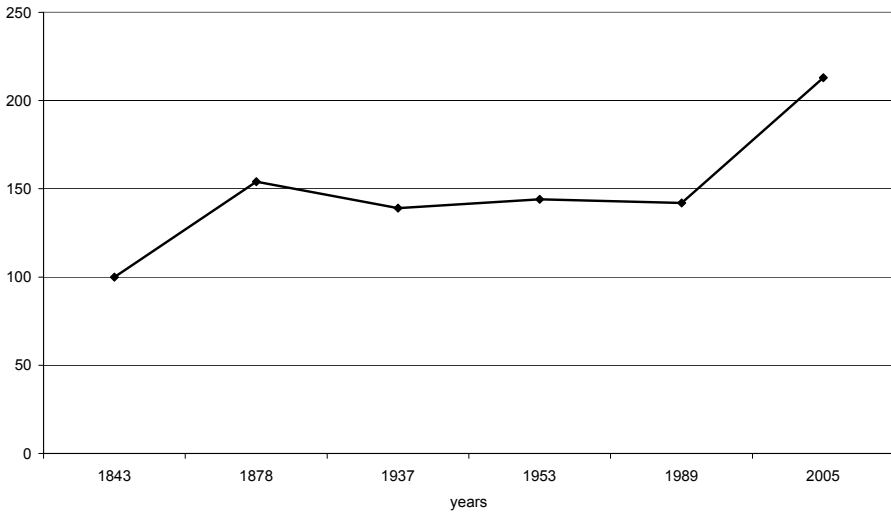


Fig. 15. Total changes of the length of water courses based on the maps from 1843 to 2005.

decrease from 1878 up to 1937. On the other hand, from 1953 there was a rapid increase in the proportion of grasslands. This trend changed in the 1989, when the analysis showed a decrease in grasslands again. This conclusion may change when the land use map from 2005 is compiled. The digital thematic layer from 2005 together with field work shows radical increase in grasslands and again a decrease in arable land, which reached its minimum extent in this period.

Changes in the drainage network were studied on 6 map sets from 1843 to 2005 (Fig. 14). The drainage network from the 1st Austrian Military Survey was not used for analysis for the reasons already mentioned in this paper. When comparing the lengths of the drainage network, the map from the 2nd Austrian Military Survey (1843) shows a relatively short drainage net. The reason is that this map shows only larger water courses and many tributaries are missing. The interpretation of this map set was problematic due to the very rugged relief of the study area. Terrain on this map is represented by grey or black hatches, which often merge and thus the identification of individual terrain elements is difficult. The most detailed drainage pattern is shown on the map from 2005, but this is due to a larger scale (1 : 10 000) and more precise methods of mapping (Fig. 15). The analysis has shown that the water courses are relatively stable. The field terrain reconnaissance has confirmed that the previously mentioned training works connected with mining activities at the bottoms of deep incised valleys did not substantially influence the lengths of the drainage network.

Analysis of number of land use changes

The digital form of land use maps enables to complete the maps of landscape stability. We used the land use maps constructed on the basis of topographic map sets in GIS ArcView programs (version 3.2 and 9.1) to compile the digital maps of landscape stability. Individual categories of tracts were assigned a numerical code from 0 (zero) to 9 according to the unified land use legend. Using Union function in the program ArcGis 9, which can calculate the

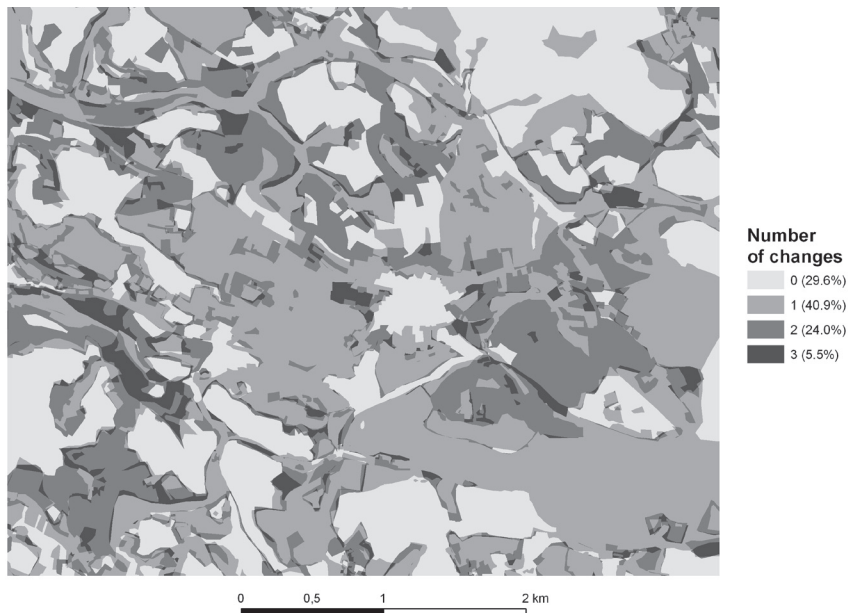


Fig. 16. Number of changes of land use based on four topographic map sets (1878–1989).

geometric intersection on the maps, we were able to calculate by simple analysis if any polygon changed for a given period. In the constructed shapefile, we were able to compare two maps and establish what percent of the land changed its use in a given period and also to plot out which type of land use changed in individual tracts.

For the model area of Kašperské Hory, we were able to compile the maps of land use changes (Fig. 16) based on only four map sets (3rd Austrian Military Survey, Czechoslovak military maps from 1937 and 1953 and Czech military map from 1989). We obtained 3 shape files of land use changes by using the described Union procedure. By combining these 3 shape files, a map of total changes of land use was compiled. It is possible to acquire information about the number of land use changes on individual tracts from this map. In this case, the number of changes is from 0 (zero) to 3. Further information concerns the total number of changes and actual type of land use change. The type of change can be defined from the numerical code which is assigned to every polygon on the map – e.g. the polygon with the code 2217 means that the land was used as a meadow (2) in the first and second map sets, as arable land in the third map set, and as an urban area (village) in the last set. The most stable landscapes in the model area are forest landscapes, which form part of larger forest complexes. Historical cores of settlements in the Kašperské Hory and Rejštejn area are also stable. Unstable (with 3 changes in the given period) are smaller tracts only, dispersed around the whole study area (5.5%). The growth of urbanized areas caused a change of land use on tracts situated at the periphery of the Kašperské Hory town. Tracts of arable land, which were later used as meadows and pastures and mostly forested in the end, were also less stable. One change of land use was characteristic for 25% of the model area (Fig. 14).

We plan to compile two more land use maps in the near future (from the maps of the 2nd Austrian Military Survey and from digital maps of ZABAGED 2006).

CONCLUSION

The result of the research shows that the model area of Kašperské Hory exhibits the dynamic cultural landscape of the Bohemian Forest foothills. In the period 1878–1989, the type of land-use changed in aprox. 40% of the area (Fig. 14), the study area exhibits a harmonic cultural landscape with a long development and with high aesthetic values. In comparison to a relatively stable drainage network, the land use analysis showed several changes during the last 100 years.

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