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LAND USE CHANGES WITHIN THE SLOVAK BIOSPHERE RESERVES' ZONES

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Abstract

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Biosphere reserves UNESCO represent the worldwide system of protected areas with three basic functions – nature conservation, research and sustainable development. Each biosphere reserve is divided into three zones according to their prevailing function. Zoning should correspond to the areas' rarity and originality of natural values. The topic of the study was identification of past land use and its changes within the declared Slovak biosphere reserves zones as indicators of their ecosystems originality. The land use development was identified from historical maps and aerial photographs. The most stable areas (with unchanged land use forms) as well as the intensity of land use change were identified within the BR zones. For a comparison of the 4 Slovak biosphere reserves study areas the coefficient of ecological stability was applied. The results in general justify the Slovak BR zoning and pointed out certain similarities of the studied areas.

Key words: land use changes, intensity of change, biosphere reserves, zones

Introduction

The aim of biosphere reserves (BR) within the UNESCO Man and Biosphere programme is to synchronise biodiversity conservation, economic and social development and local cultural values. Achieving this goal is possible only through sustainable use of landscape and its resources. The Sevilla strategy for biosphere reserves explicitly stresses the need to use BRs for research of sustainability indicators (UNESCO, 1996). Each BR is therefore divided into 3 zones which correspond to the local natural conditions and values (according to national nature conservation) and economic use. Core area should represent the most valuable parts of a BR dedicated to nature conservation and research activities. Buffer zone

protects the core area and its exploitation is realised in a sustainable way. Surrounding transition zone is an area where more intensive human activities (e.g. settlements, fields, roads etc.) are located and it serves for an everyday life of local inhabitants.

The Slovak national parks and protected landscape areas (as a national base for the BR programme) were protected only since 1950s and were declared biosphere reserves since 1977 and later (Fig. 1). The selection of the new BR zones followed knowledge on natural quality and conservation preference but the exact information on the previous land use of their parts was not available at that time. Results of a historical land use survey could therefore be applied in landscape and nature management (identification of possible unstable or sensitive areas), declaring new or adjusting borders of existing conservation areas or BRs' zones.

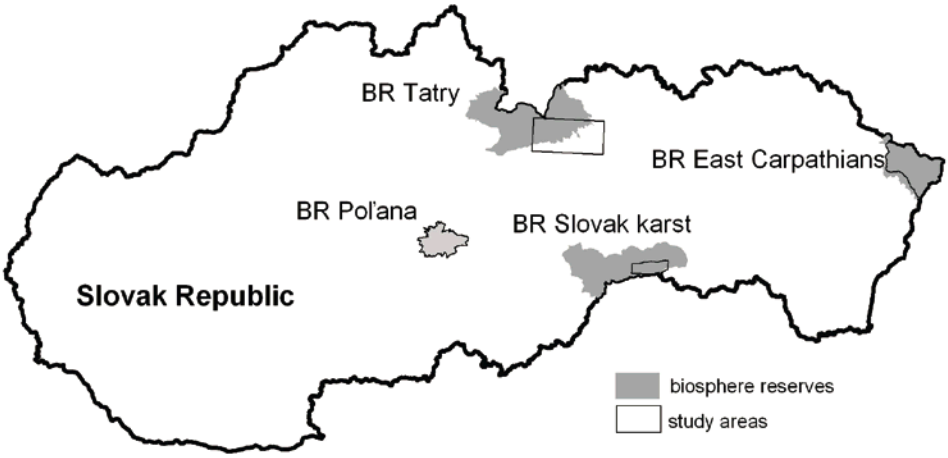

Fig. 1. The study areas of the Slovak biosphere reserves UNESCO.

Land use as a result of mutual relation between human society needs and natural conditions has undergone significant changes during the last centuries. These changes were caused mostly by technological development, legal territorial status or social preferences. Preserved historical data sources (historical maps) combined with present modern methods and tools (GIS, remote sensing) enable to relatively precisely identify the land use history of a certain territory. This method begins to be widely applied mainly in central European landscape ecological school as a result of the common scientific background and availability of historical maps (Kolejka, 1987; Oťahel et al., 1993; Žigrai, Drgoňa, 1995; Lipský et al., 1999; Holúbek, Kuzma, 2003; Olah, Žigrai, 2004; Kolejka, Marek, 2006; Olah et al., 2006; Petrovič, 2005, 2006).

Methods

Land use development

Land use in studied time periods was identified from historical military and present maps (years 1772–1784, 1822–1854, 1900, 1956 and 1988) in scales 1:25 000–1:28 800 (more Olah, 2003) and aerial orthophotographs (years 1949, 1987 and 2003) processed in GIS. Since the identified land use forms from different sources varied the final land use were unified into the following categories: forests, woodland/shrubs (area covered with a mix of grasslands, trees and shrubs), trees/bushes (solitary trees and/or bushes in fields), grasslands, vineyards, fields, built-up areas, water, wetlands, rocks and debris, alpine and subalpine vegetation.

Intensity of land use changes

Each land use form was added a coefficient according to an amount of subsidiary energy needed for a change from one form to another (or maintaining the present form against a secondary succession pressure): **1** – forest, water, rocks and debris, alpine and subalpine vegetation, **2** – woodland/shrubs, trees/bushes, wetlands, **3** – grasslands, **4** – fields, vineyeards, **5** – built-up areas, quarries. The intensity of land use change occurred between the studied time horizons was calculated as follows:

$$I = i_{2\text{-}1} + i_{3\text{-}2} + ...i_{m\text{-}n},$$

where: I – intensity of land use, $i_{2\text{-}1}$ – the 2nd minus the 1st time horizon land use intensity coefficient.

Relative intensity refers to a direction of land use change – intensification or extensification of land use. Absolute intensity pays attention to the total amount of change of a certain polygon.

Coefficient of ecological stability

The ecological stability (or general state) of the whole studied landscape can be described by the coefficient of ecological stability (Miklós, 1986):

$$Ces=(\sum p_i.k_i).p^{-1},$$

where: p_i – area of i-land use form, k_i – ecological significance of i-land use form, p – the total area.

Table 1. Interpretation table of Ces values.

Ces	Landscape stability
0.0 – 0.20	significantly non-stabilised landscape
0.20 – 0.40	non-stabilised landscape
0.40 – 0.60	partly stabilised landscape
0.60 – 0.80	stabilised landscape
0.80 – 1.00	highly stabilised landscape

Land use changes

Poľana Biosphere Reserve

The Poľana Biosphere Reserve is situated on the slopes of the Poľana stratovolcano and the Sihlianska planina plateau. Its altitude rises from 450 to 1458 m a. s. l. and the total area is 20 760 ha. The territory (especially the southern part) is specified for its preserved dispersed settlements with a unique traditional land use creating rare landscape character. The BR is almost ideally zoned – where the core area is circled by the buffer zone and the following transition zone.

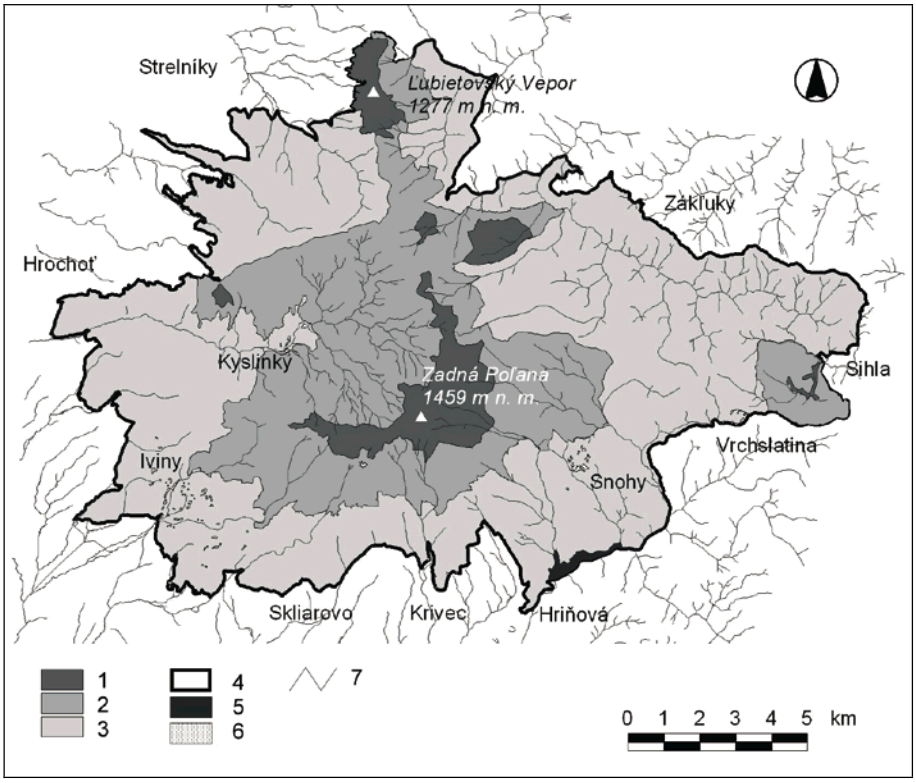

Fig. 2. The Poľana Biosphere Reserve (1 – core area, 2 – buffer zone, 3 – transition zone, 4 – study area, 5 – water, 6 – settlements, 7 – streams).

The land use development of the Poľana BR in years 1782–2003 is described in Fig. 3. The most significant changes occurred in the area of forests and grasslands. The stable land use (unchanged since 1782) covered 72% (14 964 ha) of the total BR area (almost 95% of it is forest, 5% grassland). The BR core area consists of stable forests (Fig. 4). The buffer zone is mostly covered with stable forests and grasslands while in the transition zone there are situated the less stable areas. Generally it follows the reason of BR zoning. The most stable and thus the most valuable ecosystems lay in the core area and the less stable (changed) and the more intensively used ecosystems lay in the transition zone.

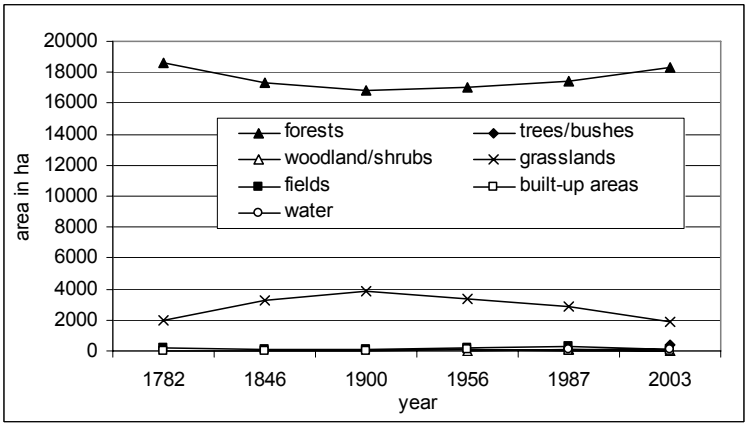

Fig. 3. Land use changes in the Poľana BR (1782–2003).

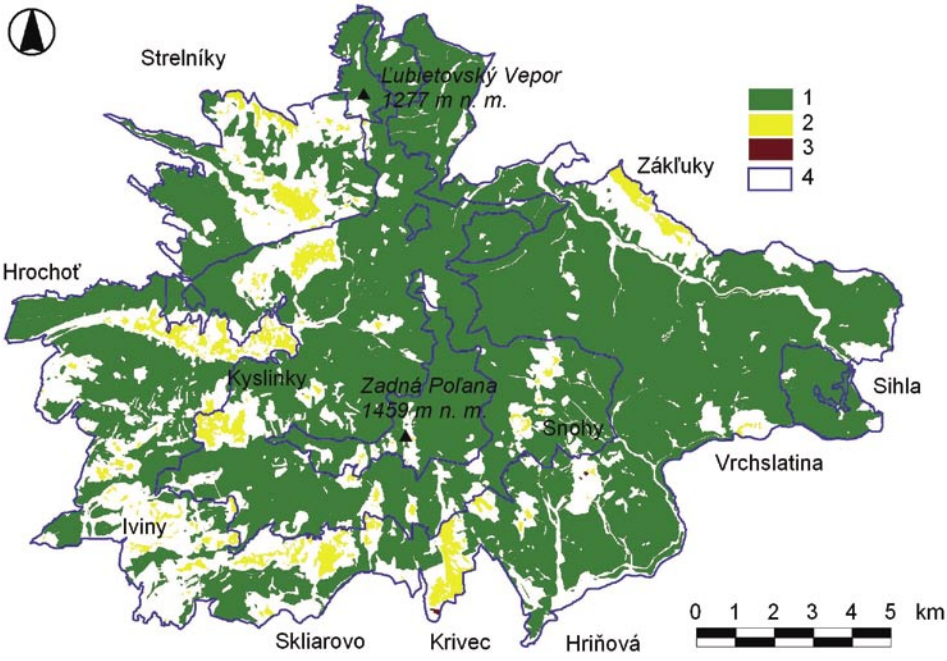

Fig. 4. Areas with stable land use in the Poľana BR in years 1782–2003 (1 – forest, 2 – grassland, 3 – field, 4 – BR zones).

The results of the land use absolute intensity analysis are presented in Fig. 5. The occurrence of the higher intensity polygons within the core area is very rare. In the buffer zone these areas are following the existing grass-

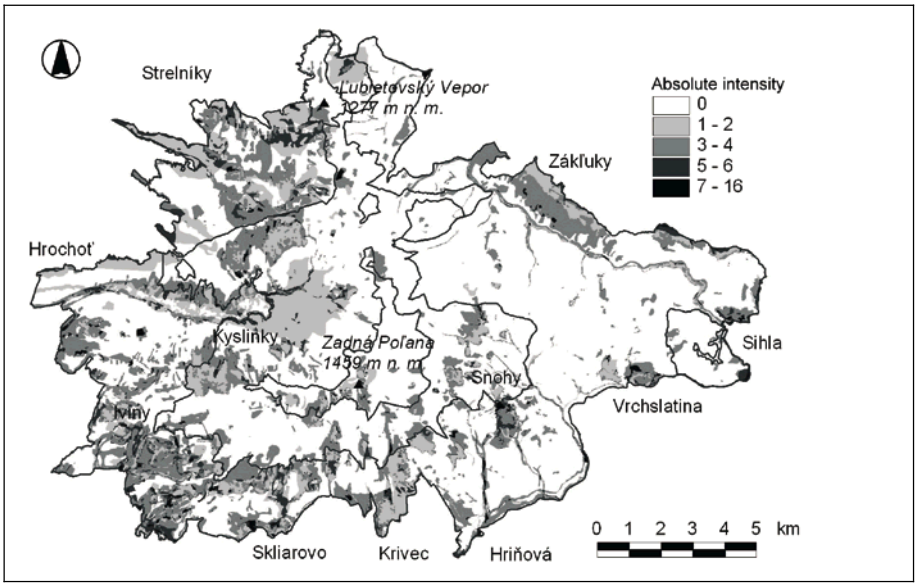

Fig. 5. Absolute intensity of land use change in the Poľana BR (1782–2003).

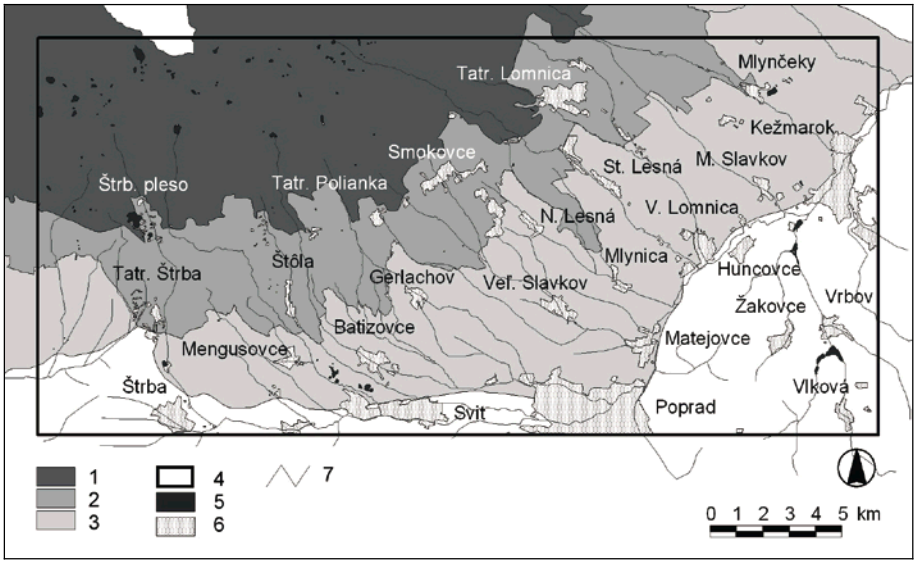

Fig. 6. The study area of the Tatry Biosphere Reserve (1 – core area, 2 – buffer zone, 3 – transition zone, 4 – study area, 5 – water, 6 – settlements, 7 – streams).

lands. The majority of the most changed (the darkest) areas are located within the transition zone (its southern and western part). These areas are in a close neighbourhood of local villages and dispersed settlements therefore their land use is the most intensive. The intensification of land use prevails on the location with lower altitudes and slope inclination, and S, SW and W aspect. On the other hand the extensified areas are mostly situated on higher latitudes, with steeper slopes and N, NE and E aspects.

Tatry Biosphere Reserve

The study area of the Tatry BR was chosen as a rectangle 32 by 15 km with the area 49 000 ha situated in the Popradská kotlina basin and the High Tatras Mts, the elevation range is 600–2656 m. Since it was not possible to analyse the whole Tatry BR the study area was designed in that way that it includes all the BR zones and nearby towns and villages – therefore a representative part of the BR.

The land use development of the Tatry BR is described in Fig. 7. The areas with unchanged land use covered 51% of the studied territory (Fig. 8). 36,9% of the stable polygons were fields and 33,2% were forests. Another almost a third of the study area was the high mountain landscape covered by subalpine and alpine vegetation and rocks and debrises. The stable built-up areas covered only 1,1%.

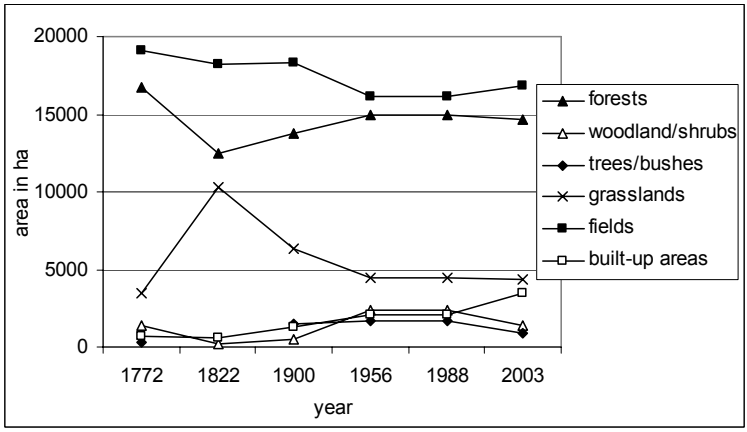

Fig. 7. Land use changes in the Tatry BR (1772–2003).

In the core area of the Tatry BR there prevail stable forests and high mountain areas. Areas with at least one change lied around the Tatry settlements (Štrbské Pleso, Starý Smokovec and Tatranská Lomnica) and documented the nature catastrophes (the burned patches under the Slavkovský štít peak) and deforested areas in the 18th and 19th cent. The core area recorded during last 234 years only minimal land use changes. Approximately a half of the buffer zone was covered with stable forests, another half has been significantly changed (dark red). The most of the changes occurred along the buffer zone and the transition zone border. It was the territory of permanent land use fluctuation – forests-shrubs-grasslands-shrubs-forests etc. Alarming are the changes towards more intensive (built-up) land use forms in and around the Tatry settlements. The basin bottom belongs to the more intensive land use form as villages, towns and fields. The higher parts (up to 800 m a. s. l) are more extensively used (grasslands and forest), but areas between 800 to 1000 m a. s. l. are again intensively used as tourism centres. Above 1300 m. a. s. l there are almost no land use changes.

Surprisingly in the area not belonging to the BR there were occurred less changes (with the exception of the towns Poprad and Svit) compared to the buffer and the transition zones. However, these zones did and probably will experience more land use changes due to the 2004 wind calamity and following tourism development plans. The land use development study results showed a close association of the most labile areas and the wind calamities areas and could be therefore applied as an argument for revitalisation and management of the BR area.

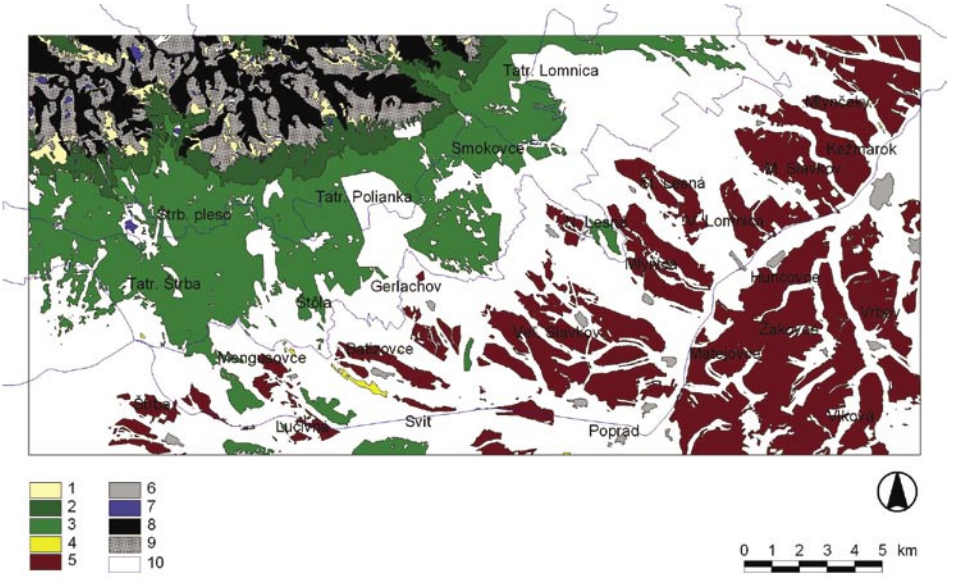

Fig. 8. The areas with stable land use in the Tatry BR in years 1772–2003 (1 – alpine meadows, 2 – sub-alpine vegetation, 3 – forest, 4 – grassland, 5 – field, 6 – settlements, 7 – water, 8 – rocks, 9 – debris, 10 – BR zones).

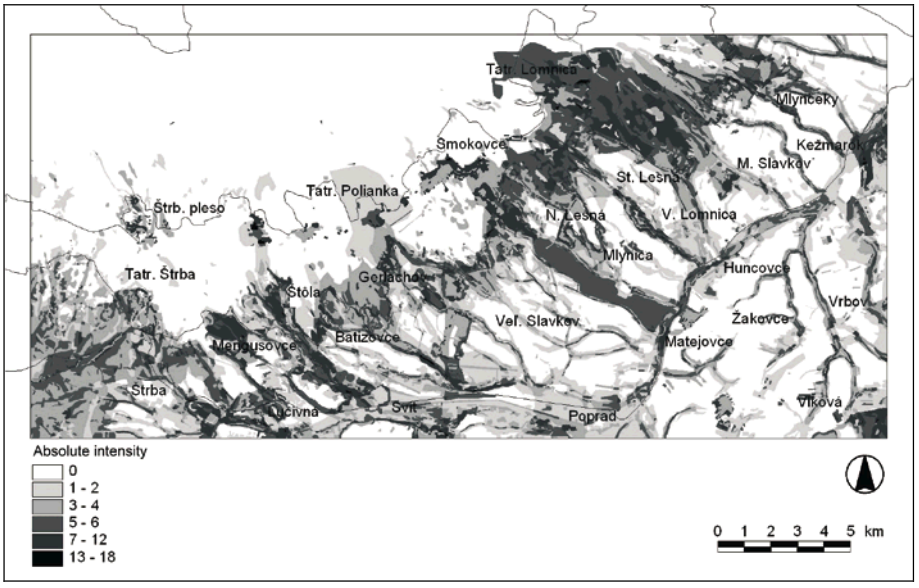

Fig. 9. Absolute intensity of land use change in the Tatry BR (1772–2003).

Slovak Karst Biosphere Reserve

In the Slovak Karst BR the Turnianska kotlina basin was chosen as a representative part for a land use development study. The study area covers the Horný vrch and Dolný vrch karst plateaus, their slopes and the basin bottom with local villages. The total area is 8285 ha and the altitude rises from 169 to 831 m a. s. l. The overall view on the Turnianska kotlina basin land use development is shown in Fig. 11. The most significant changes during the last 221 years occurred in coverage of fields, forests, grasslands and shrubs. Other categories balanced almost on the same level, only built-up areas raised in 2005. The areas without land use changes (Fig. 12) covered 34.6% (2865,7 ha) of the study area (out of it forests 49% and fields 43%).

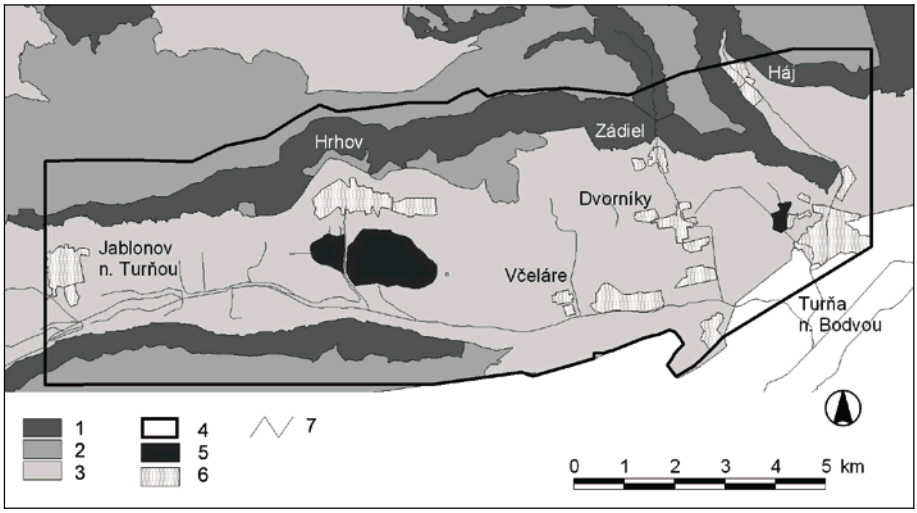

Fig. 10. The study area of the Slovak Karst Biosphere Reserve (1 – core area, 2 – buffer zone, 3 – transition zone, 4 – study area, 5 – water, 6 – settlements, 7 – streams).

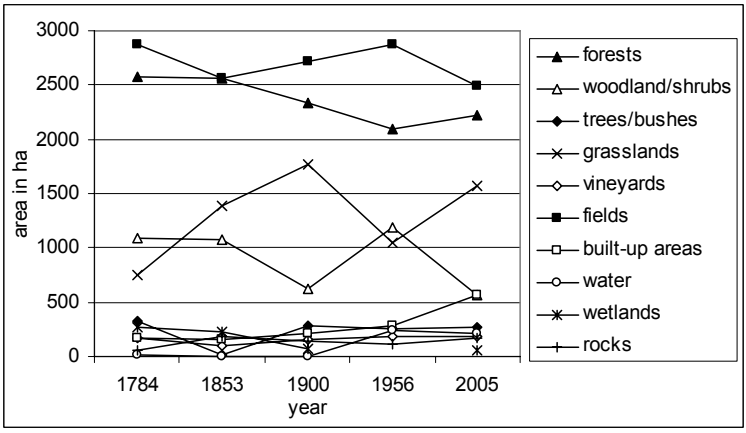

Fig. 11. Land use changes in the Slovak Karst BR (1784–2005).

The southern part of the core area is almost whole covered with stable land use as well as the surrounding buffer zone. The situation on the northern part is quite different. Only a part of the core area is unchanged, the rest has been changed at least once (forests-shrubs-grasslands). Very similar is the situation within the buffer zone. The analysis of absolute land use changes intensity (Fig. 13) shows that the most significant changes occurred on the geomorphologi-

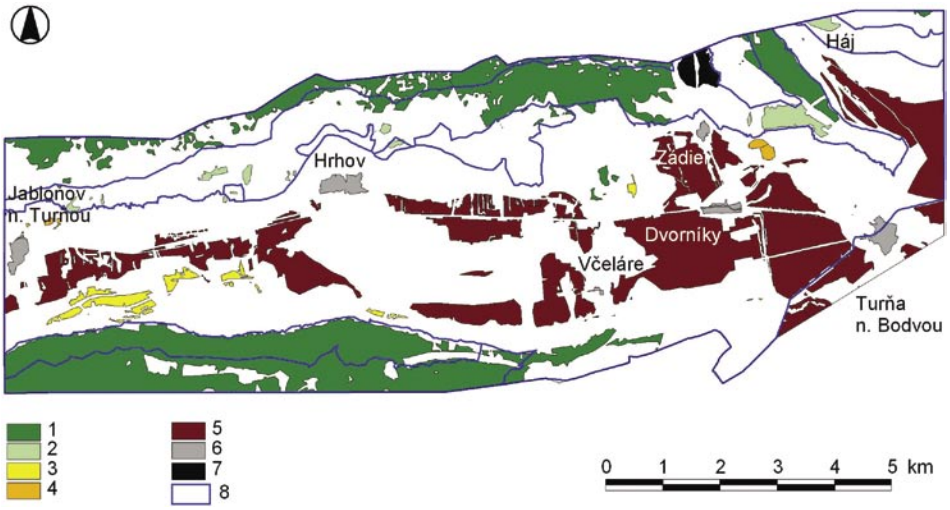

Fig. 12. The areas with stable land use in the Slovak Karst BR in years 1784–2005 (1 – forest, 2 – shrub, 3 – grassland, 4 – vineyard, 5 – field, 6 – settlements, 7 – rocks, 8 – BR zones).

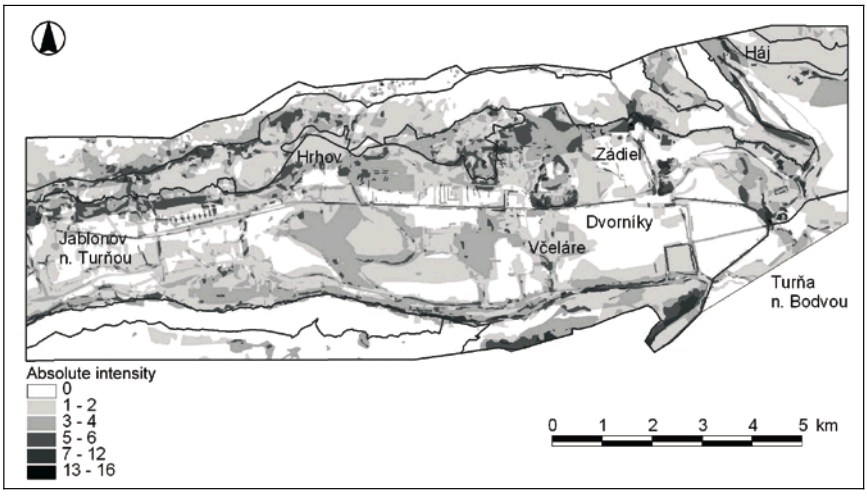

Fig. 13. Absolute intensity of land use change in the Slovak Karst BR (1784–2005).

cal thresholds (basin bottom-slopes-plateaus). Their occurrence very closely follows the borders of the BR zones, in fact justifying their correct design. The core areas experienced less changes, the buffer zones more but they appeared mostly between forests and shrubs. The transition zone lying on the basin bottom has been changed thus to more intensive as well as to less intensive land use forms. The changed areas lie along the streams, around settlements and at the very bottom where the former wetlands were turned to water dams or drainaged to fields.

Generally the intensification of land use prevails to the extensification on the whole territory. The lower parts (up to 400 m a. s. l.) are the most dynamic areas. In this landscape type the very significant land use factors are slope inclination and aspect due to karst character of the rock bed and climate conditions. The slopes with north aspect are covered with unchanged forest while the slopes with south aspect have turned to a mixture of xerotherm forests, shrubs and small grasslands.

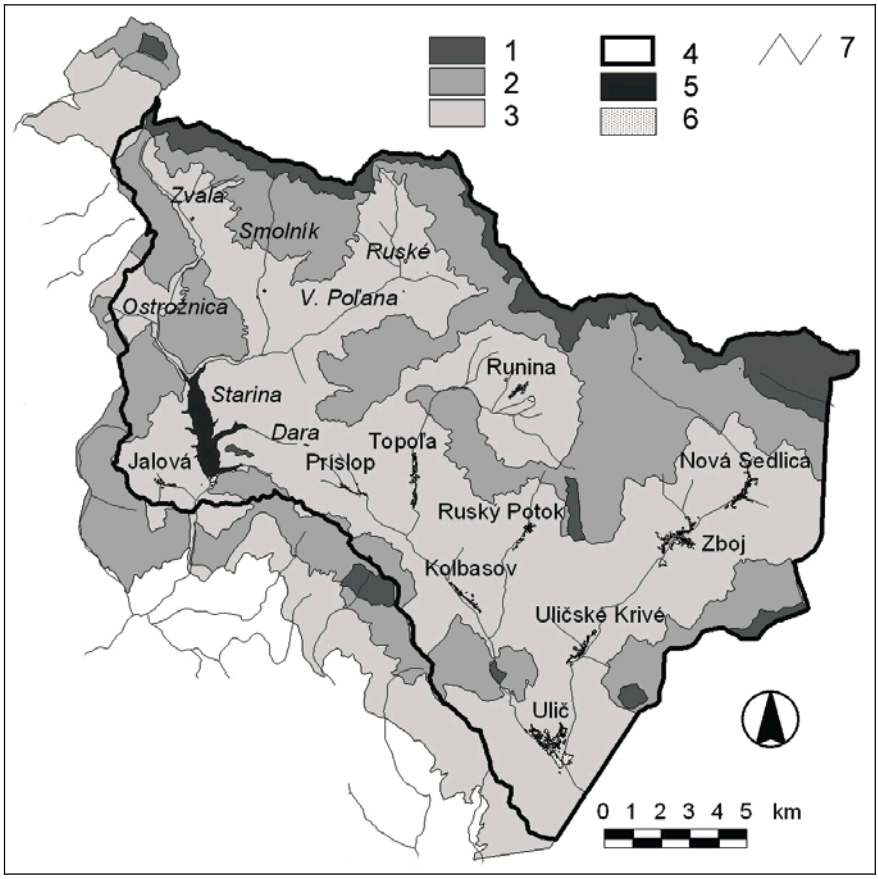

Fig. 14. The study area of the East Carpathians Biosphere Reserve (1 – core area, 2 – buffer zone, 3 – transition zone, 4 – study area, 5 – water, 6 – settlements, 7 – streams).

In the East Carpathians BR the study area covers 83% of the whole BR (the basins of the Starina, Uličský and Zbojský potok streams). The total area is 34 220 ha and the elevation range rises from 232 to 1180 m a. s. l. The overview of the land use changes in the East Carpathians BR is presented in Fig 15. The most significant change was in forests which area decreased till 1900 and since then increases continuously. Other categories oscillated around the same area.

The unchanged land use areas (Fig. 16) covered 35% (12 025 ha) of the BR study area. 99% of it belongs to forests, the rest to other categories. The core area along the Slovakia-Poland border is almost unchanged. The separate core areas consist of changed areas but oriented towards less intense land use forms. In the buffer zone there prevail stable forest complexes. The changes of land use occurred along the buffer/transition zone border however they are also extensification areas. The largest changed areas lie within the transition zone. Its whole western part is changed due to the forced emigration of local inhabitants and the following land abandonment since the Starina water reservoir construction in 1987. Therefore the changes follow a direction toward less intensive forms (fields-grassland-shrubs-forests). In the eastern part where settlements have been preserved the land use changes occurred mostly around the villages. The closest areas turned to new built-up ones or remain fields, the remote parts underwent extensification towards shrubs and forests (more in Olah et al., 2006).

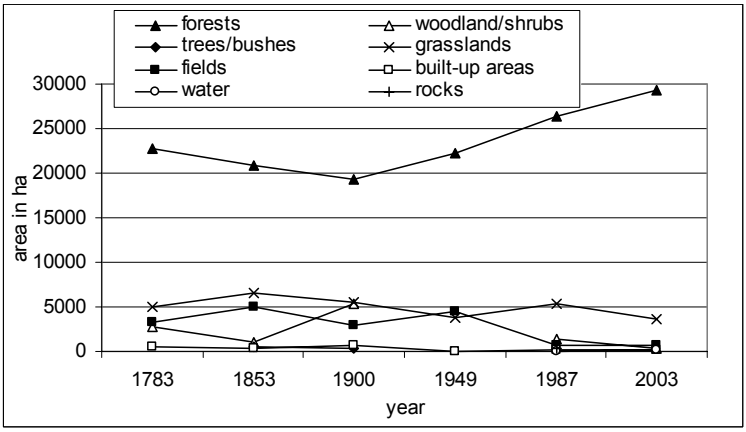

Fig. 15. Land use changes in the East Carpathians BR (1783–2003).

As in other BRs also in the East Carpathians the most important natural factors of the land use changes were altitude, slope inclination, less important was aspect. However, the majority of changes were directly caused by the socio-economic factor – the construction of the water reservoir and marginal location of the whole area within the Slovak Republic connected with an economic regression of the last decades. Thanks to these factors the territory belongs among the best-preserved nature parts of Slovakia.

Coefficient of ecological stability

For a comparison of the 4 Slovak biosphere reserves (study areas) the coefficient of ecological stability (Fig. 18) was applied. This coefficient takes into account coverage of land use categories and could be therefore used to

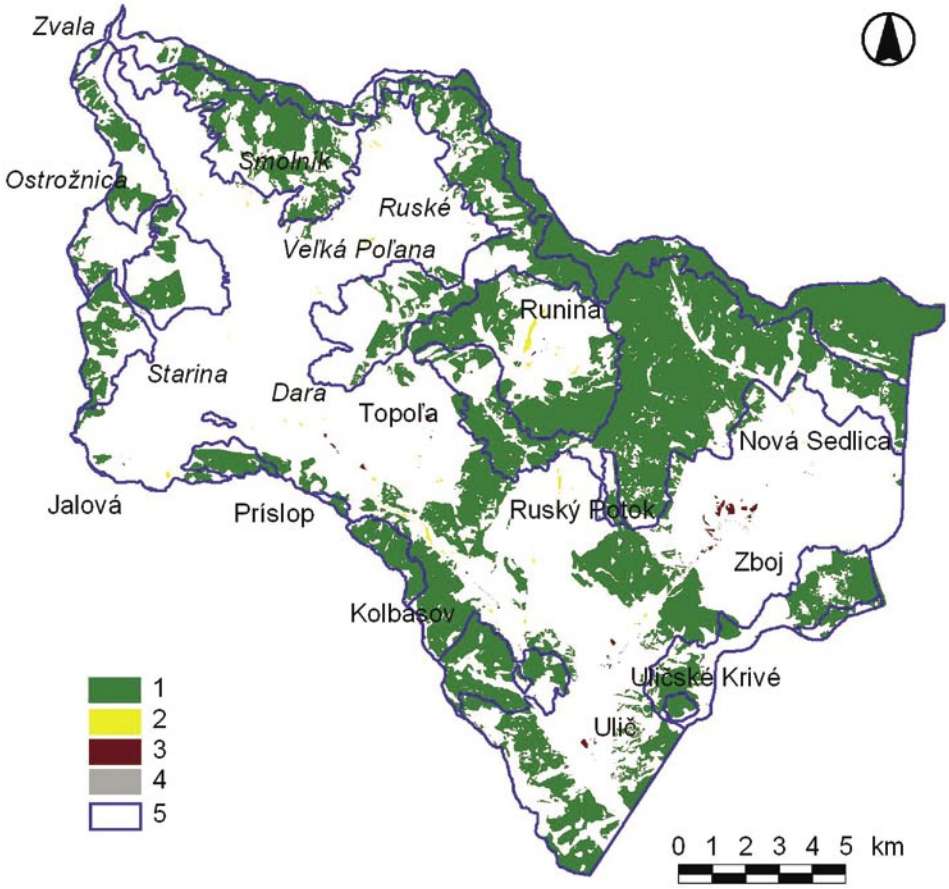

Fig. 16. The areas with stable land use in the East Carpathians BR in years 1783–2003 (1 – forest, 2 – grassland, 3 – field, 4 – settlements, 5 – BR zones).

compare otherwise different areas. The courses of the Tatry BR and the Slovak Karst BR coefficients are almost identical (they oscillate around partly stabilised and stabilised landscape). The landscape of the East Carpathians BR was stabilised till 1900, since 1987 it is highly stabilised. The Poľana BR landscape stability was always high. Even though the calculus of the coefficient depends on the selection of a representative area in each BR the results describe a certain quality of landscape and its development in time.

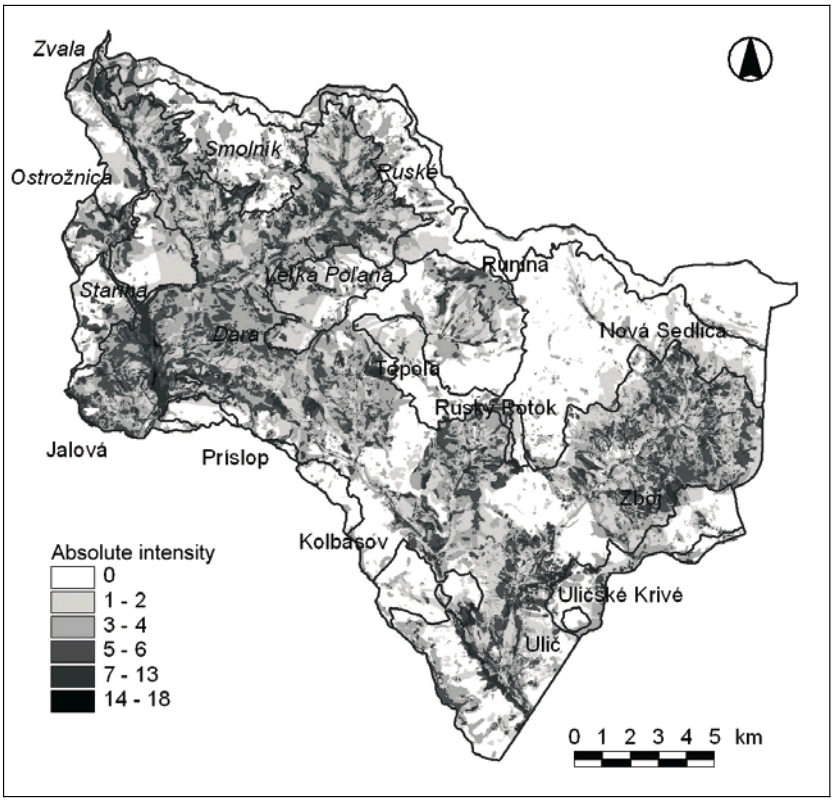

Fig. 17. Absolute intensity of land use change in the East Carpathians BR (1783–2003).

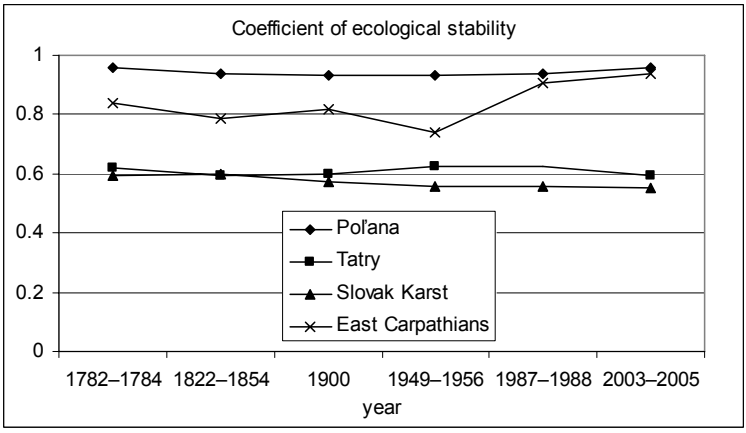

Fig. 18. Coefficients of ecological stability in the study areas.

Conclusion

The Poľana BR is a highly stabilised natural landscape because of the more intensive land use forms lie outside its border. The area is covered by forests with grasslands enclaves (with secondary succession overgrowing due to the remote location and low economic profitability of use in the last 50 years, Gallayová, 2007).

The study area of the Tatry BR is characterised by highly stabilised basin bottom (with fields and settlements and rapidly developing towns) and really unchanged high mountain landscape. The main changes occurred on the transition of basin to mountains and since 1900 in the continuously growing tourism centres. As very significant land use factors can be considered periodical wind calamities (the oldest identified calamity areas from historical maps were before years 1772 and 1822, in following years again reforested).

The Slovak Karst BR (Turnianska kotlina basin) study area was also very stabilised during the last 221 years. The fertile basin bottom was ameliorated (wetlands turned to fields or water reservoirs), the plateaus and north slopes remained covered with forests, south xerothermic slopes covered with secondary shrubs and grasslands.

The land use development of the East Carpathians BR has been significantly affected by 2 phenomena. The first was the remote and marginal position of the whole territory what led to the creation of small villages and agricultural (cattle pasture) and forestry use of the landscape. The second was the removal of 7 villages due to the water reservoir construction in 1987 what led to land abandonment of the whole catchment's area and rapid secondary overgrowing.

The presented results could be summarised into the following main points:

- the most stable land use was bound to low situated parts with low inclination on one hand (fields and settlements on basin and valleys bottoms) and to higher parts with steeper slopes and N aspect (high mountain vegetation, forests, shrubs, locally secondary grasslands) on the other hand. The majority of changes occurred between these 2 localisations.
- intensification of land use prevailed also on lower situated areas and extensification on higher and remote locations. The exceptions were recorded only in the territories where the land use was affected by new socio-economic phenomena as tourism centres development in the Tatry BR and the water reservoir construction in the East Carpathians BR.
- the declared zones of all Slovak biosphere reserves fulfil their basic requirements from the land use stability point of view. The core areas represent the most stable territories without any significant land use changes. The transition zones consist of relatively unstable land use areas (with more intensive use). The buffer zones are somewhere in the middle. This pattern is altered only in the Tatry BR and the Slovak Karst BR due to historical (deforestation and pasturing in forests) and present factors (wind calamities and tourism development).

Translated by the authors

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