LAND USE CHANGES' RELATION TO GEORELIEF AND DISTANCE IN THE EAST CARPATHIANS BIOSPHERE RESERVE

BRANISLAV OLAH[1], MARTIN BOLTIŽIAR[2], FRANTIŠEK PETROVIČ[2]

[1] Department of Applied Ecology, Faculty of Ecology and Environmental Sciences in Banská Štiavnica, Technical University of Zvolen, Kolpašská 9/B, 969 01 Banská Štiavnica, The Slovak Republic, e-mail: olah@fee.tuzvo.sk
[2] Institute of Landscape Ecology of the Slovak Academy of Sciences, Akademická 2, 949 01 Nitra, The Slovak Republic, e-mail: martin.boltiziar@savba.sk, frantisek.petrovic@savba.sk

Abstract

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The paper deals with land use changes occurred in the East Carpathians Biosphere Reserve between 1949, 1987 and 2003. This area was characteristic with a significant change in landscape organisation caused by a drinking water reservoir construction what led to an emigration of local inhabitants (7 villages) and following abandonment of the western part. Using aerial photographs land use changes and their intensity were assessed. Georelief (altitude, inclination and aspect) and distance from the settlements as main natural and socio-economical driving factors affecting the land use of the areas were evaluated using affinity and relative frequency calculus. The study resulted into an identification of land use development break point leading to the recent overgrowing trends.

Key words: land use changes, affinity, Poloniny National Park, GIS

Introduction

European rural landscape (mainly in mountain and marginal areas) faces continual decrease of land use intensity, what leads to secondary succession overgrowing and a loss of cultural landscape (García-Ruiz et al., 1996; Kristensen, 1999; Lipský et al., 1999; Pärtel et al., 1999). This phenomenon could be considered positive, as a return of natural ecosystems and thus an increase of local ecological stability. On the other hand it might be viewed as negative since it causes a loss of specific ecosystems and landscape character. This process is mostly caused by changes in human society, being them change of local inhabitants' preferences, ways of living, or whole social and economical situation.

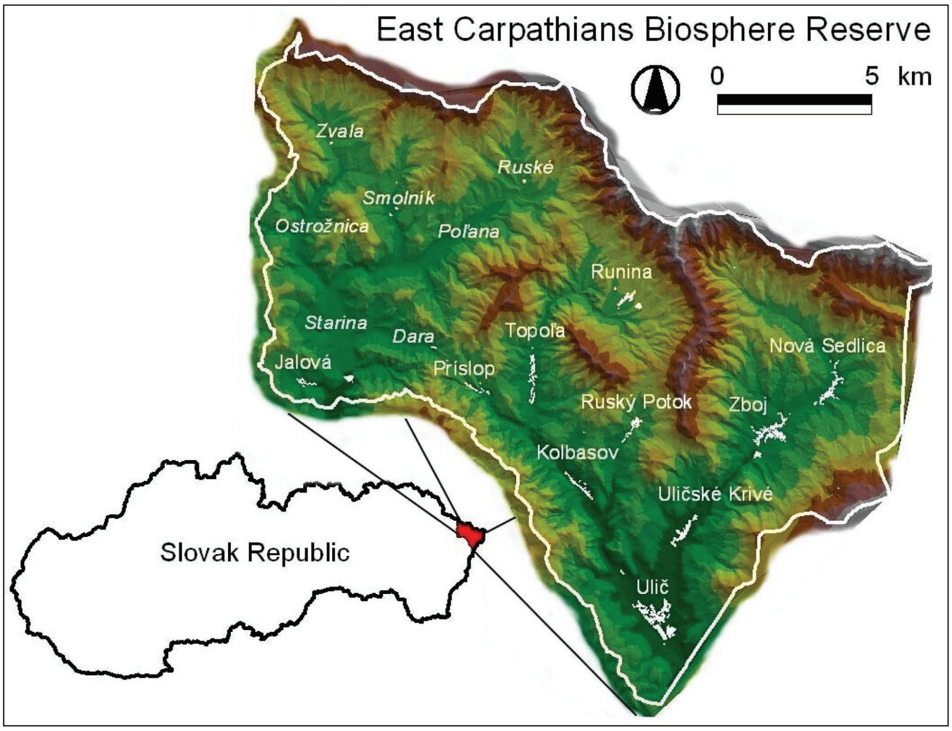

Fig. 1. Study area.

One of the main goals of biosphere reserves (within the UNESCO programme Man and Biosphere) is to study natural and socio-economical processes and their application in sustainable landscape management (Midriak, 2002). Since land use integrates both natural and socio-economical conditions (Žigrai, 2001) a study of its changes therefore not only helps us to understand this phenomenon and its causes but also provides us with information useful in management activities.

The study area of the East Carpatian Biosphere Reserve lies in the very east corner of the Slovak Republic at the border with Poland and Ukraine (Fig. 1). The area belongs to the Bukovské vrchy Mts built by flysch rocks, the altitude raises from 200 to 1200 m above the sea level and the total area is 34 210 ha. Mainly moderately cool mountain climate at greater altitudes changes into moderately warm and very humid in the valleys. Mean annual temperatures are 4 to 8 °C and total rainfall varies with altitude from 800 to 1200 mm. Dystric cambisols prevail to eutric cambisols and planosols, potential natural vegetation was formed mainly by submontane beech woods and beech and fir woods with forb-rich undergrowth.

The local natural condition along with the marginal localisation affected the urbanisation (mostly small villages) and the land use (prevailing agriculture and forestry) of the area. In the late 1980-ties the area experienced a very significant change in a land organisation for its west part was abandoned due to the construction of a drinking water reservoir. Since then the two parts of the biosphere reserve have been developing differently. In the following chapters we focused on the land use changes and their relation to basic characteristics of georelief (as natural factors) and distance from the settlements (as a socio-economical factor).

Methods

The methods consisted of following steps:

1. identification of land use in 1949, 1987 and 2003. Parts of current development in the field of geoinformation technology are remote sensing and geographic information systems (GIS), which belong to the most progressive alternatives of mapping of land use and its changes in different scales – from global to local level (Feranec et al., 1997). Its particular manifestation are mapping and multitemporal analysis applied in works of different scales and orientation (Feranec, Oťaheľ, 2001; Feranec et al., 1997; Oťaheľ et al., 2003, e.g.). Preparatory stage included obtaining and study of aerial photos as well as preliminary recognoscation of terrain. Large-scale land use thematic maps of the study area were produced in PC software ArcView GIS 3.1 and their procession included following operations:
   - preparation of historical aerial photos from 1949 and 1987 and its orthorectification in software ERDAS IMAGINE 8.4 by module Orthobase
   - identification of individual land use forms by means of analogue (visual) interpretation of aerial ortophotos (8 land use forms: forest, shrub, ext. grassland, grassland, field, settlement, substrate, water)
   - digitising of spatial data by method *"on screen"* – creation of land use thematic maps (1:5000) from 1949, 1987 and 2003
   - creation of flexible database, in which are saved all relevant information and which will enable to realise all further needed operations
   - evaluation of land use changes by overlay method and comparing of vector thematic maps from individual time periods and subsequent statistic processing
   - creation of land use changes database (1949–2003) and its statistic analysis
   - cartographic figuration of information layers in analogue output form – thematic maps of land use forms from 1949, 1987 and 2003,
2. occurrence of land use forms within the settlement distance zones with step 1 km (as percent portion of the whole zone),
3. assessment of affinity (a relation between land use forms and georelief characteristics) using formula

$$A = f_i . f_j . 100\%,$$

$$A = p_{ij} . (\Sigma p_i)^{-1} . p_{ij} . (\Sigma p_j)^{-1} . 100\%,$$

where A – affinity in %
f_i – relative frequency of occurrence in row (within georelief characteristics)
f_j – relative frequency of occurrence in column (within land use form)
p_{ij} – area of i-row and j-column
Σp_i – area sum in i-row
Σp_j – area sum in j-column.

The overlay of land use forms and georelief resulted in a contingency table with land use forms in columns and georelief characteristics in rows. Each georelief layer and land use form had a separate contingency table. Due to various areas of the layer polygons we used the sum of their areas instead of a simple count in the table.

This formula is based on an assumption that a frequency of a certain land use form within a certain georelief characteristics is indicative of a relationship between these factors,

4. intensity of land use change was calculated as a simple adding of land use intensity coefficients changes using formula

$$I_R = I_1 + I_2 + ... + I_n,$$

where I_R – relative intensity of land use change
I_1 – relative change between the 1st and the 2nd time horizons
I_n – relative change between the last but one and the last time horizons.

The land use forms were given coefficients of land use intensity (forests – 1, shrub, water, ext. grassland – 2, grassland – 3, field – 4, settlement, substrate – 5). Overlaid in GIS and using formula of the relative intensity of land use change the areas which undergone highest changes in land use were identified. The polygons with negative intensity of land use change represent the areas with land use extensification, on the other hand polygons with positive intensity represent the areas with intensification of land use. Polygons with the unchanged land use were marked as "no change",

5. occurrence of land use change intensity areas within the settlement distance zones with step 1 km (as per cent portion of the whole zone), and within the slope inclination, aspect and altitude zones.

Results and discussion

Land use changes between 1949–2003

In 1949 the traditional rural land use of the East Carpathians BR is characteristic with narrow blocks of fields and grasslands around 17 villages situated in the valleys bottoms along the local streams (Fig. 2). Although the majority of the area was covered with forests (65.1%), fields (13.1%), shrubs (10.6%) and grasslands (7.9%) were almost equally represented. Extensive grasslands (overgrowing with the secondary succession) covered 3.1%, which is the largest area of this category in the studied time horizons.

The year 1987 was very significant for the future trend of land use since it represents the time when 7 villages in the northwest (Fig. 1) were evacuated and the buildings removed due to the Starina drinking water reservoir construction. The dominant land use was forest (77.0%), the area of grassland increased to 13.3%, the area of fields decreased to 2.2% and shrubs to 3.9%. The most dramatic changes occurred in the northwest in the reservoir catchment's area. The vanishing fields (2.2%) and settlements were substituted by grasslands (13.3%) and uncovered substrate (0.9%) on the places of former houses and the reservoir construction area. The matrix of land use transformation is in the Table 1. The forests gained area mostly from former shrubs, grasslands and fields. Generally this time horizon was strongly affected by the administrative changes resulting from the reservoir construction. This caused also the relative high occurrence of new land use form – substrate. The remaining eastern 10 villages have undergone lesser land use changes.

The land use in 2003 resulted from the 2 main phenomena. The first was the continuing new administrative organisation and the second was the democratic revolution in 1989 connected with the following economical recession strongly affecting especially these

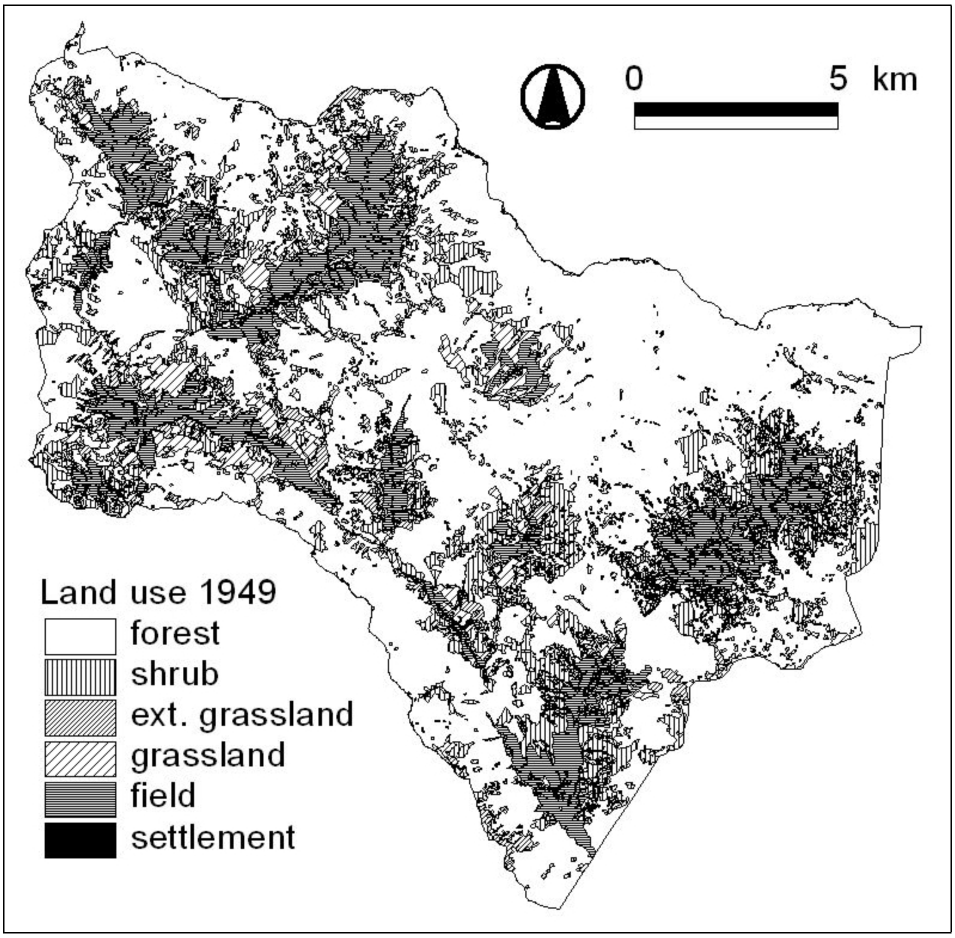

Fig. 2. Land use in 1949.

T a b l e 1. Transformation matrix of land use between 1949 and 1987

	LU 1987								
LU 1949	forest	shrub	ext. grassland	grassland	field	settlement	substrate	water	[%]
Forest	**20846.2**	**716.1**	107.2	456.5	41.9	5.0	87.9	0.3	65.1
Shrub	2718.5	304.5	182.6	401.7	4.5	0.0	10.3		10.6
Ext.grassland	649.4	78.7	63.8	254.8	3.5	0.1	3.5		3.1
Grassland	1278.0	99.7	179.8	1014.6	59.0	1.1	65.3	0.2	7.9
Field	841.9	133.1	**248.8**	**2400.2**	**640.8**	**93.7**	**135.9**		13.1
Settlement	3.4	3.1	2.0	6.5	12.4	39.0	15.0		0.2
[%]	77.0	3.9	2.3	13.3	2.2	0.4	0.9	0.0	100.0

T a b l e 2. Transformation matrix of land use between 1987 and 2003

LU 1987	LU 2003							
	forest	shrub	ext. grassland	grassland	field	settlement	water	[%]
Forest	**26026.6**	84.9	45.2	150.3	25.1	1.8	3.6	77.0
Shrub	1218.0	38.0	31.6	26.0		0.1	21.5	3.9
Ext. grassland	543.6	28.7	92.3	98.2	21.3	0.1		2.3
Grassland	1290.5	**123.0**	**440.8**	**2510.3**	125.3	1.7	42.7	13.3
Field	87.4		22.0	90.9	**548.4**	13.3		2.2
Settlement	2.5		2.2	2.3	10.9	**121.0**		0.4
Substrate	65.1	7.0	20.3	33.1		5.4	**187.1**	0.9
Water				0.1			0.3	0.0
[%]	85.5	0.8	1.9	8.5	2.1	0.4	0.7	100.0

marginal areas. Again the dominant land use was forest (85.5%). The second in coverage was grassland (8.5%). The area of fields was 2.1%. Other land use forms covered only minimal area. The majority of land use forms in 1987 remain unchanged, with exception of former grasslands which turned into new forest, shrubs and extensive grasslands. This fact points out the problem of overgrowing as a result of extensification of land use. In a relatively stable landscape (from a land use point of view) the highest values in the matrix would lie on a diagonal line. The shift downwards from the diagonal indicates extensification of land use. Between 1949 and 1987 this shift applied mostly to fields and grasslands, in the later transformation horizon (1987–2003) it applied to grasslands.

There are 2957 inhabitants (in year 2001) living in the area. The population density is very low under the mean value in Slovakia. The range is from 4 people on km^2 (village Runina) to 37 people on km^2 in village Ulič. Within the settlement structure, small villages with less than 500 inhabitants dominate. The only exception is the village Ulič with 1078 inhabitants which is the service centre of the Uličská valley.

The present time is characteristic as a period of updating and arrangement of land ownership. The part of the land was restituted to the former landowners and the private silvicultural companies were founded.

Distance from settlements (as centres of economic activities) is considered to be very important phenomenon affecting land use distribution. The analyses of the basic land use forms (forest and field) within the settlement distance zones are presented at Fig. 6. In 1949 the maximal distance from the settlements (villages) in the study area was 7 km. Within the 1 km distance zone the prevailing land use form was field with more than 40% of the zone coverage, with distance its area rapidly decreased. The trend of grasslands and shrubs decreased more slowly and it reached to 5–6 km. Forest was dominant already at the 2 km distance and continuously increased.

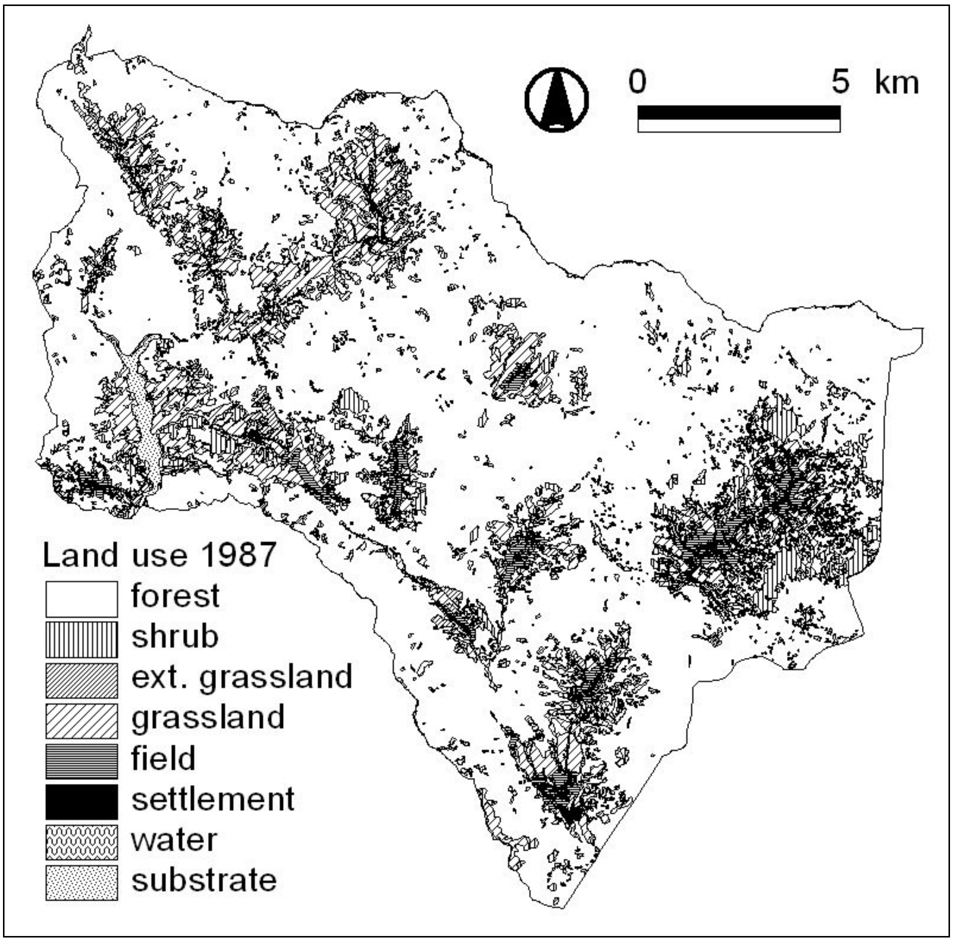

Fig. 3. Land use in 1987.

In 1987 the situation changed dramatically. The maximal distance increased to 14 km (due to the settlement abandonment) and already within the 1 km distance zone forest became dominant (with approx. 50% of coverage). The second was grassland (25%) followed with fields (16%). Extensive grasslands occurred more significantly in the 1 km, 6 km and 14 km distance (a decrease of the forest curve).

In 2003 the land use forms distribution remained almost unchained with the exception of relatively high grassland and extensive grasslands occurrence. The extensive grasslands increased between 6 to 8 km distances while the grasslands even reached the forest coverage at the 14 km distance (a decrease of the forest curve). The drift of extensively used grasslands again indicates the overgrowing thread to this cultural landscape.

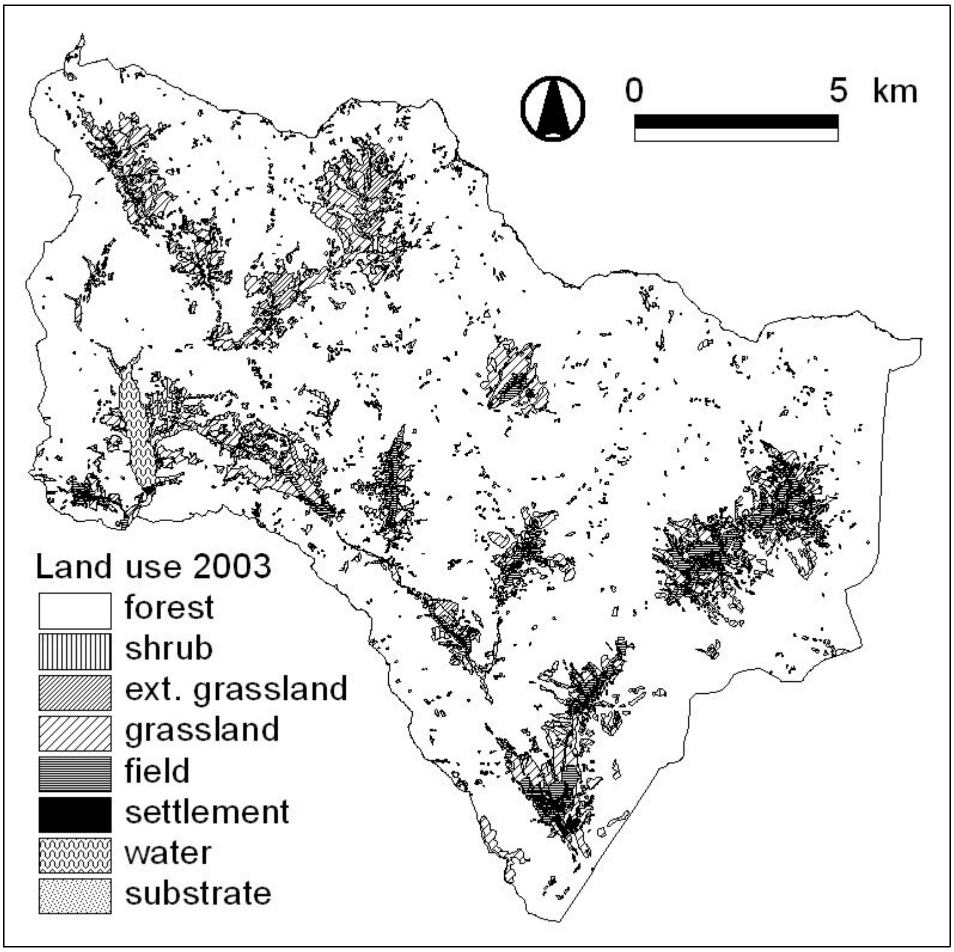

Fig. 4. Land use in 2003.

Affinity of land use forms indicates their dependence on natural conditions (in our case georelief characteristics). The results of the calculus are the most informative and reliable when applied to continuously utilised landscapes (without social or economical interruptions). The Fig. 7 shows the affinity of basic land use forms to the slope inclination during the studied period. In 1949 the affinity of fields slightly decreases with increasing inclination. On the other hand, the affinity of forests increases with the steeper slopes. The affinity of settlements (built-up areas) decreases and the grassland affinity is higher on slopes from 4–13 degrees. The extensive grassland affinity is relatively high on the steepest slopes. This situation could be described as ideal, almost exactly responding to general assumptions.

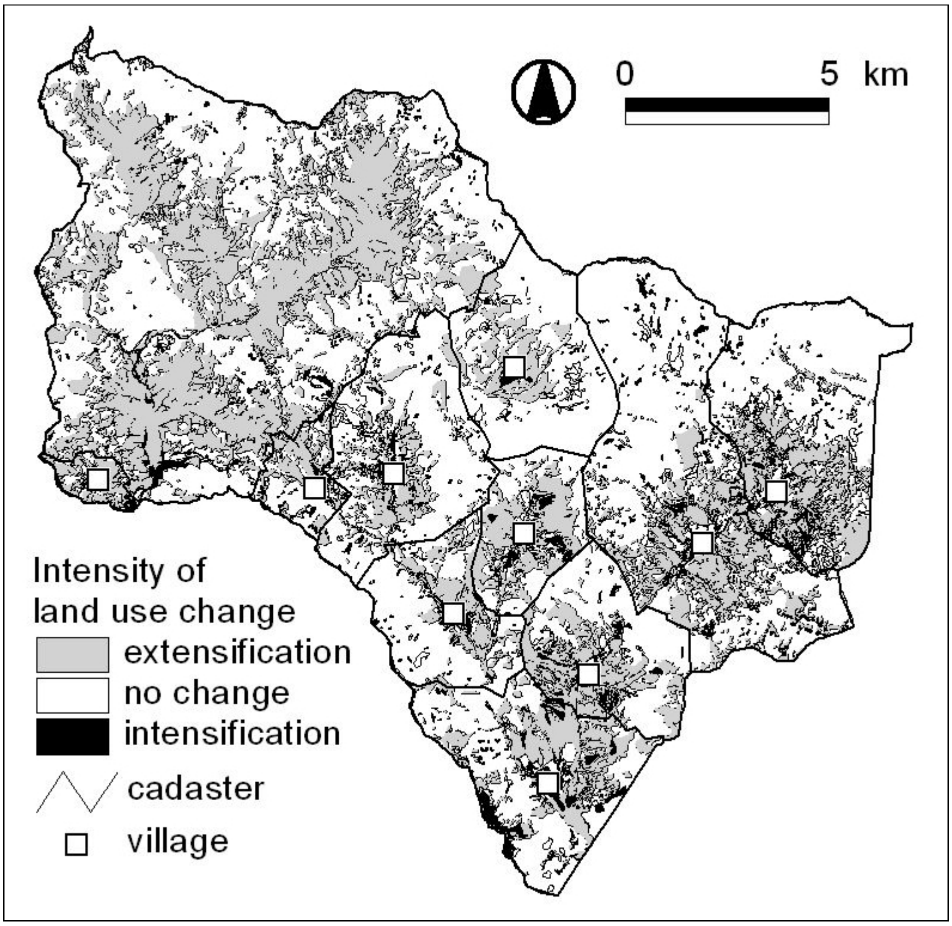

Fig. 5. Relative intensity of land use change between 1949–2003.

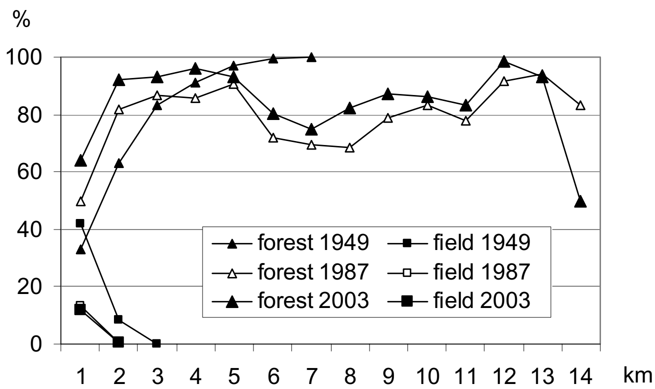

Fig. 6. Basic land use forms within the settlement distance zones between 1949–2003.

In 1987 and later in 2003 due to the local changes (the abandonment and reservoir construction) the affinity curves changed mainly on the lowest inclinations. The former highest field and settlement affinity declined and was substituted firstly (in 1987) by uncovered substrate (construction area) and partly by the grassland affinity, and lately (in 2003) by water (reservoir). The affinities to steeper inclination remained practically unchanged.

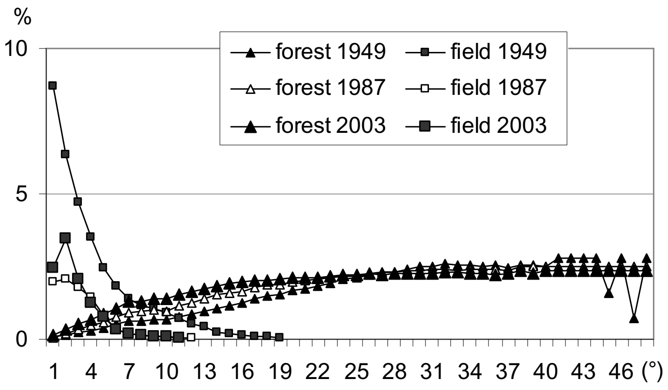

Fig. 7. Affinity (%) of basic land use forms to the slope inclination zones (°) between 1949–2003.

Similar to previous is the affinity of land use to altitude. Along with distance and inclination, altitude affects climate and an accessibility of the certain area and thus its use. The Fig. 8 presents how the affinity of land use to altitude changed during the study period. In 1949 the affinity of fields was the highest on the lowest areas and declined with altitude. The affinity of forest increased with altitude. The affinity of grasslands was minimal on the lower altitudes, it raised only at the altitude 1200 m a. s. l. (famous local meadows called *poloniny*).

In 1987 and later in 2003 still the highest affinity to the lowest parts belong to fields, but its value decreased from 33% to 12%. On the other hand, the affinities of grasslands and settlements rose from former 1–2% to 7–9%, grasslands due to their localisation in the catchment's area, settlements due to their expansion in the remaining 10 villages. The trend of affinities in the higher parts remained unchanged.

The analysis of land use and its affinity to aspect did not resulted into any significant trends due to the almost equal aspect representation in the area. However, the highest affinities reached forests (approx. 10%) to NE, E and SE aspects, grasslands and fields (approx. 3%) to SW, W, NW aspects.

Intensity of land use change

Since the major problems of the East Carpathians Biosphere Reserve are considered to be land abandonment and overgrowing, we analysed the occurrence of areas with different land use change intensity (during the years 1949–1987–2003). Fig. 8 presents the localisation of areas which have experienced: a) increase in land use intensity (intensification), b) no change in land use, and c) decrease in land use intensity (extensification). It is evident that the intensively used areas lie in the south-east part of the BR (around the recent villages), the exten-

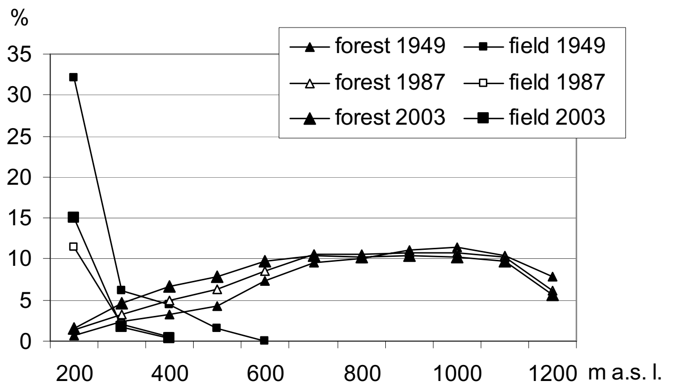

Fig. 8. Affinity (%) of basic land use forms to the elevation zones (m above the sea level) between 1949–2003.

sively used areas in the north-west part (in the catchment marked as a large and newly established joined cadaster) and the large areas of forests on the hill ranges remained unchanged.

Analysing the occurrence of the polygons with different land use change intensity within the distance, inclination, altitude and aspect zones (Figs 9–12) we might conclude that unchanged areas prevail at the distance from 2 to 5 km and 8 to 14 km. At the 1 km (next to the existing 10 villages) and 6 to 7 km (abandoned villages) distance the extensification areas equal or even prevail. The intensification areas occurred only within the first 2 km.

According to the aspect zones the unchanged areas slightly prevailed on the NE, E and SE aspects, while the extensification polygons on the S, SW, W, NW and N aspects. The intensification areas' occurrence within the aspect was of minimal significance.

The occurrence of different land use change intensity areas within the altitude categories implies that on the lowest parts the extensification and unchanged areas are equal, but with the altitude the former declines and the later increases. The intensification polygons decline from the highest occurrence on the 200 m a.s.l., but increases on the very high altitudes (new small grasslands).

The similar is the situation of land use change intensity within the inclination. On the areas with the inclination from 1 to 3 ° prevails the extensification (the catchment), from the 4° the unchanged areas are dominant. On the highest inclinations both this intensity categories are equal (relatively high percentage was caused by minimal absolute area of the inclination category). The intensification areas decline with inclination.

Conclusion

The changing approach of a man to the landscape appears in different forms of land use, which changes the composition of landscape elements. In a simplified way, the structure of individual elements can represent the specific quality of environment and state of biodiversity. The landscape changes could be identified by means interpretations and analyses of historical maps and aerial or satellite images from different time periods. The next step is to find causes of these changes and to identify the relevant pressures on landscape and other connections between the human activities and nature. The analyses showed how significant could the socio-economical changes (evacuation of local inhabitants, disposal of settlements and construction of a large water reservoir along with entrance and land use limitations) be in landscape-ecological relations. On the other hand land use of the area, its changes and distribution is strongly affected by the local natural conditions. Although the main driving force were socio-economical a new land use is always adapting to the natural conditions.

The knowledge about the significance of these changes linked to the protection of biodiversity, nature and environment are important from a perspective of possible changes in future. Variants of future landscape development can be outlined, considering both real (more probable) and extreme situations in the landscape. This can help to approach the sustainable development of the region.

Translated by the authors

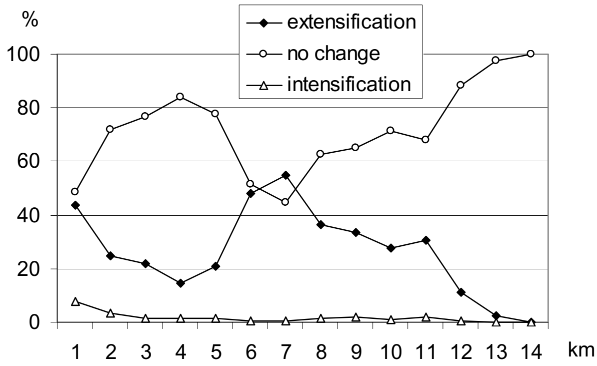

Fig. 9. Relative intensity of land use change within the settlement distance zones.

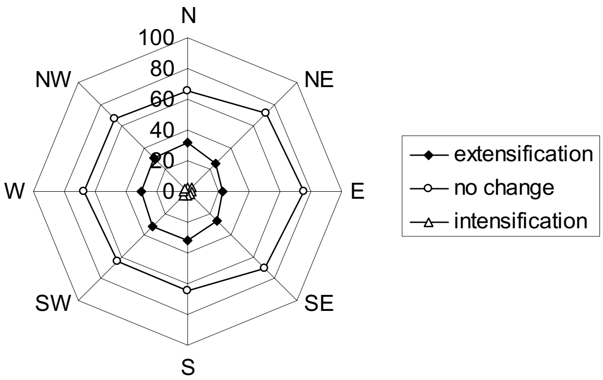

Fig. 10. Relative intensity of land use change within the aspect.

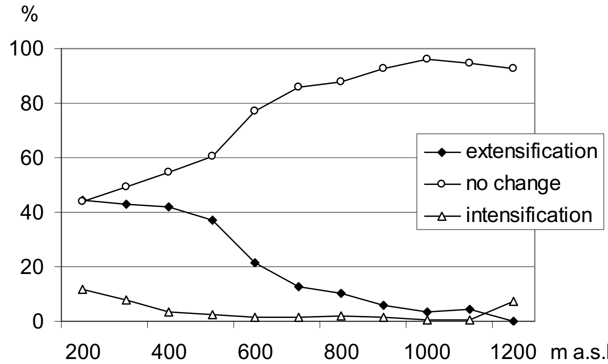

Fig. 11. Relative intensity of land use change within the elevation (m above the sea level).

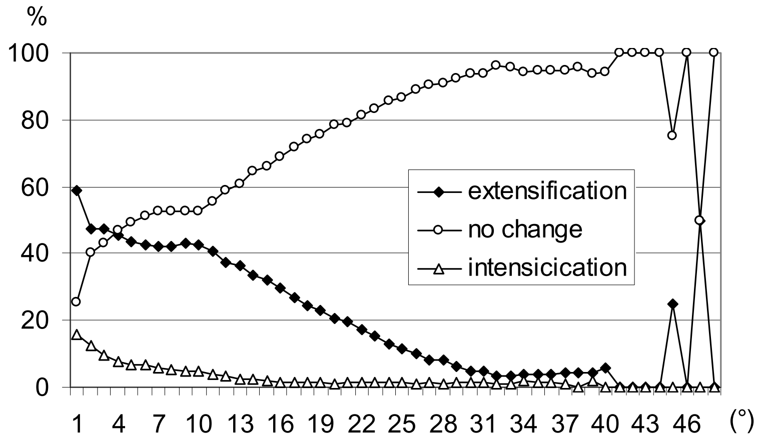

Fig. 12. Relative intensity of land use change within the slope inclination (°).

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Olah B., Boltižiar M., Petrovič F.: **Vzťah zmien využitia krajiny ku georeliéfu a vzdialenosti v Biosférickej rezervácii Východné Karpaty.**

Príspevok sa zaoberá zmenami využitia krajiny v Biosférickej rezervácii Východné Karpaty v rokoch 1949, 1987 a 2003. Toto územie bolo charakteristické významnou zmenou v organizácii využívania krajiny spôsobenou výstavbou vodárenskej nádrže, čo viedlo k vysťahovaniu miestnych obyvateľov (7 obcí) a následnému spustnutiu západnej polovice biosférickej rezervácie. Zmeny využitia krajiny a ich intenzita boli vyhodnotené na základe leteckých snímok. Georeliéf (hypsometria, sklonitosť a expozícia) a vzdialenosť od sídiel ako jedny z hlavných prírodných ako aj socio-ekonomických faktorov ovplyvňujúcich využitie krajiny boli analyzované na základe výpočtu afinity a relatívnej frekvencie. Štúdia vyústila do identifikácie zlomového bodu vo vývoji využitia krajiny vedúceho k súčasným trendom zarastania krajiny.