COMPARISON OF LAND COVER CHANGES IN PROTECTED AND UNPROTECTED SITES ON THE OUTSKIRTS OF PRAGUE METROPOLIS (THE CZECH REPUBLIC), 1990–2006

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ABSTRACT

The Czech landscapes have been shaped by many driving forces such as sub/urbanisation, construction of transport and logistics infrastructure, afforestation or agriculture extensification. The outskirts of Prague belong to some of the most affected regions despite two protected landscape areas (PLA) spread out here, protecting unique nature in the national context. The key question is whether and how the land cover changes, their direction and magnitude, differ inside and outside of these two protected landscape areas and thus, whether legislative landscape and nature protection fulfils its role, preventing negative changes e.g. caused by urban sprawl. Therefore two groups of study sites were defined – inside and outside the PLAs – in order to test whether undergoing land cover changes differ. The CORINE land cover layers were used to quantify landscape structure and its change using landscape metrics and land cover changes during the time period of 1990–2006. Obtained data were analysed using methods of direct ordinations (redundancy analysis). The results showed that two groups of study sites differed in landscape structure and landscape composition in the year 1990, but trajectories and intensities of land cover changes since then have been very similar, however landscape structure unlike landscape composition have still remained different. It seems that socio-economic development influenced both groups in comparable ways and though, legislative landscape and nature protection doesn't restrict land cover changes even those caused by urban sprawl; however, further analyses are necessary.

Key words: landscape structure, CORINE land cover, protected landscape area, structure metric

1. Introduction

Land use and land cover changes have significant impact on the natural environment, including landscape functions (e.g. Hansen et al. 2004; Lambin et al. 2001; Stoate et al. 2001; Vitousek et al. 1997). They directly impact biotic diversity (Sala et al. 2000), contribute to local and regional climate change (Chase et al. 1999) by altering ecosystem services, and affect the ability of biological systems to support human needs (Vitousek et al. 1997). These changes also partly determine the vulnerability of places and people to climatic, economic or socio-political perturbations (Kasperson et al. 1995).

In recent decades, European cultural landscapes have been undergoing notable changes associated with intense and rapid social transitions (De Aranzabal et al. 2008; Nikodemus et al. 2005). This is especially valid in post-communist countries after political regime change (Kuemmerle et al. 2006), e.g. in the Czech Republic, the political and economical development has had a profound effect on land use management, subsequently resulting in widespread land cover changes (Václavík et al. 2009). Although population increase is stabilised in Europe (as the major driving force for landscape changes in course of centuries), expanding settlements and new infrastructure place even greater demands on the land consumption (EEA 2006). The improved mobility of modern society is connected with the intensive road construction and related infrastructure which leads to a greater fragmentation of open space (Walz 2008; Jaeger 2005). Generally, these European landscape changes have been caused by intensification of agriculture and increasing abandonment of marginal areas in rural landscapes or by the process of sub/urbanization in surroundings of cities (Haines-Young et al. 2003; Fry et al. 1997). Furthermore, the next important changes of land cover are expected particularly due to the recent shift in EU agricultural policy (Reger et al. 2007) and ongoing socio-economic changes in Eastern and Central Europe (Mander 2004).

According to the EEA Land Accounts for Europe 1990–2000 Report (EEA 2006) and Feranec et al. (2007, 2000), the recent landscape changes have resulted mainly from combinations of the following processes: (1) Growth of urban areas (suburbanization and urban sprawl). (2) Deforestation, but on the other hand (3) afforestation in other areas. (4) Intensification of agricultural production, i.e. growth of the extent of arable lands, vineyards, fruit and vegetable plantations; but also comparable intensive (5) extensification, i.e. decline of intensively exploited agricultural lands in favour of meadows, pastures or forests. Finally, (6) water reservoirs construction occurs in several European countries.

In last two decades, land cover changes in the Czech Republic have corresponded to the European trends. According to Romportl et al. (2010) the most important processes of land cover changes are: (1) extensification of

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agricultural production, (2) sub/urbanization, (3) intensification of agricultural production, (4) afforestation. However, some changes are more intensive due to the legacy of communist regime. The most affected landscapes are around large cities, along important highways and on main border crossings (Ouředníček et al. 2011).

Land cover changes lead to diversified modifications of landscape structure, an elementary landscape characteristic. All processes and transitions mentioned above change deeply traditional landscape structure distinguishing landscape character. Thus, regional landscape types, characterized by their specific landscape structure and character, are endangered by land cover transformation leading to unification and homogenization threatening landscape-based values such as biodiversity, cultural heritage and human appreciation (Dramstad et al. 2001). Therefore, landscape structure is widely recognized as a valuable quality of cultural heritage, which deserves legal protection, e.g. protected landscape areas and natural parks in the Czech Republic.

Comprehensive assessment of landscape change should therefore focus not only on land use/cover changes but also should evaluate the dynamics of landscape structure. A typical feature of landscape structure is a high diversity of change trajectories depending on the local conditions, regional context and external influences (Jongman 2002). Widely used approach of landscape structure assessment is quantification of specific patterns of patches (e.g. particular habitat), classes (e.g. particular type of land cover), or the whole landscape by using landscape metrics (McGarigal 2007). Three levels of evaluation are applied: (i) the patch level (characteristics of an individual patch), (ii) the class level (characteristics of one type of patches) and (iii) the landscape level (characteristics of all classes in the landscape and its pattern).

The study was aimed at the evaluation of the land cover transitions and quantification of landscape structure changes in the southwest outskirts of Prague. On the one hand, this region has been under high socioeconomic pressure due to its geographical location and it belongs among the most affected landscapes in the Czech Republic (Ouředníček et al. 2011). On the other hand, it contains areas of high natural values and two protected landscape areas (PLA) spread out here, protecting unique nature in the national context, where typical landscape character is one of the most important objects of protection. Thus landscape changes, their direction and magnitude, outside and inside PLAs should differ due to the legislative limitations of development in protected areas. The changes of land cover and landscape structure within municipalities are expected to be very low inside PLAs or qualitatively different in comparison with the model municipalities outside the PLAs. This topic may not yet have been studied, as we were unable to find published results. Therefore the objection of this study was to evaluate whether and how the landscape changes, their direction and magnitude, differ inside and outside protected landscape areas in the outskirts of Prague and whether legislative landscape and nature protection fulfils its role, preventing negative changes e.g. caused by urban sprawl.

2. Data and methods

The methodology consists of several basic steps: (1) the selection and the precise delimitation of the study sites; (2) the evaluation of landscape structure (GIS data processing, execution of structural metrics and their final selection for further analysis); (3) statistical analysis

2.1 Study area and study sites

The study area (Fig.1) is situated in the central part of the Czech Republic on the south-western outskirts of Prague Capital Area. It is characterised on the one hand by high socio-economic pressure, but on the other hand by its high natural values. Its proximity to Prague Capital Area as well as intersection by important highway D5, connecting Czechia with Germany, lead to strong pressure of residential and commercial suburbanisation. Two protected landscape areas (PLAs) are situated here: the Křivoklátsko PLA and Bohemian Karst PLA. Both protected landscape areas are considered unique and one of the most valuable protected areas in Czechia due to their specific landscape character and high biodiversity.

Study sites (i.e. municipalities and their close neighbourhood) fulfilling certain criteria were selected for the analyses. These criteria were defined in order to select municipalities potentially influenced by the same intensity of driving forces of sub/urbanisation and related processes. Criteria were: (i) Time accessibility: each study site was located in the same zone of time accessibility to Prague. The threshold interval was set from 10 to 20 minutes by car; it represents fast access to the metropolis for suburban inhabitants. It was based on the map of time accessibility published in Hrnčiarová et al. (2010). (ii) Distance from highway: all study sites lied in the same buffer zone of the D5 highway. The maximum distance was set to 10 km. (iii) Minimum distance among study sites to prevent overlapping of study sites. The distance was set to 1.2 km.

Differently from the first and the second criteria, the last one did not relate to geographical features but to exact spatial extent of study sites used for the analyses. To compare municipalities' landscape structure objectively, their spatial extent should differ neither in the extent nor in the shape. Therefore, a circular buffer zone around each municipality's point of gravity was applied for the precise delimitation of each study site. Regarding parameters of used spatial data (see below); the circular buffer zone was set to 5 sq. km. Thus, the distance among study sites (1.2 km) prevented overlapping (i.e. circular buffer zones).

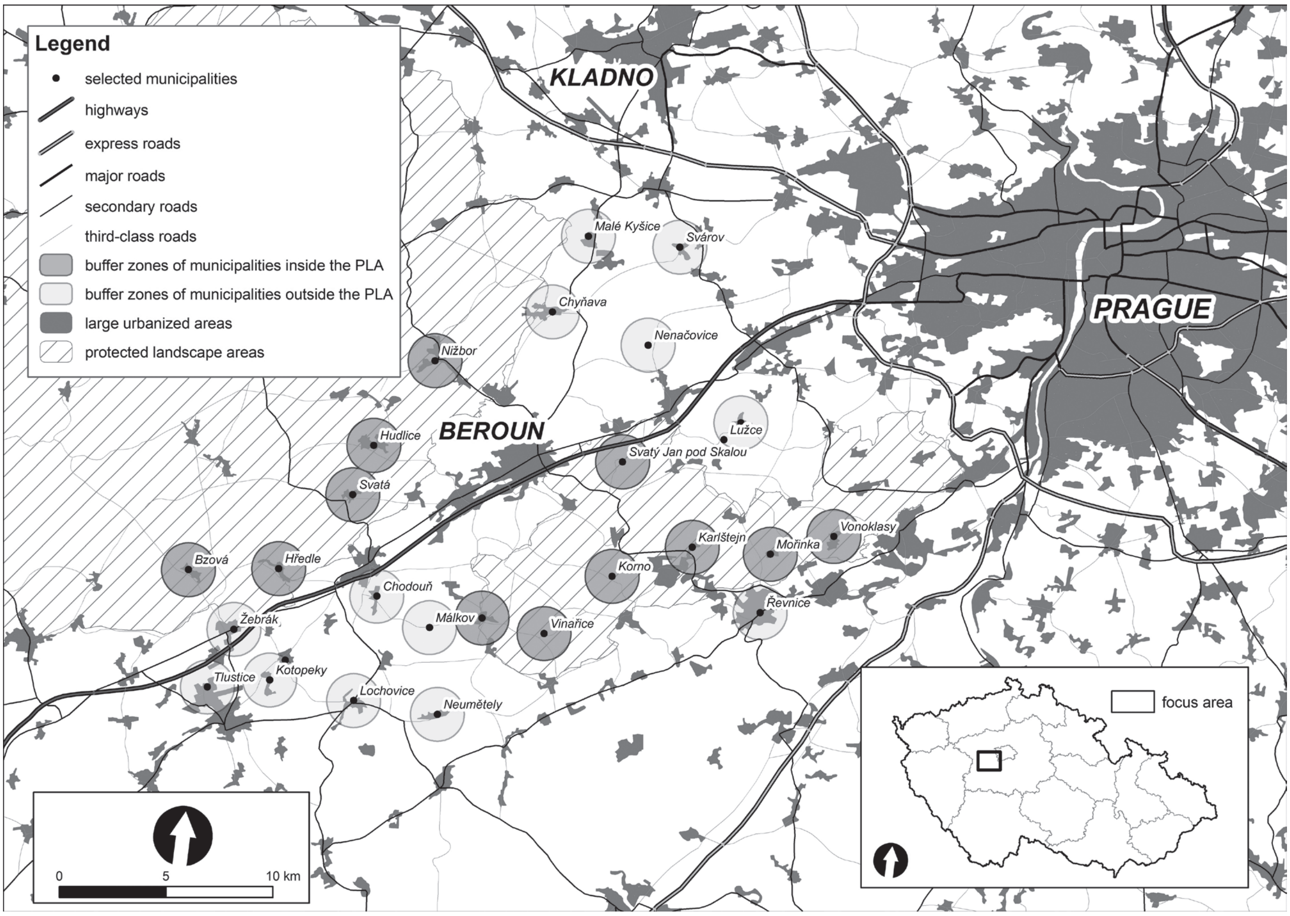

Fig. 1 Location of the study area within Czechia (in the lower right-hand corner) and its detail with study sites

2.2 Data

All spatial analyses were based on available vector layers of (i) municipalities, (ii) road systems, (iii) protected landscape areas and (iv) land cover. Whole topographic background was part of the Arc CR 500 database at a scale of 1 : 500,000. These layers were used for the delimitation of study sites (i.e. circular buffers) and for the division of study sites into two groups: (i) inside and (ii) outside of the PLAs. All analyses of land cover and landscape structure changes were based on CORINE land cover database (CENIA 2009) which is a vector data source of land cover in Europe; unique by its temporal and spatial extent as well as regular updates. The database captures land cover for the years 1990, 2000 and 2006. It was derived from LANDSAT images classified by common methodology (EEA 2007). The database was designed to be used at a scale of 1 : 100,000 with minimum mapping unit 25ha and the minimum width of linear elements 100m. Its nomenclature consists of 44 classes, organised hierarchically in three levels and representing the major land cover types across Europe (EEA 1994). The 33 classes recorded in Czechia are listed in App. 1.

Layers from reference years 1990 (CLC90) and 2006 (CLC06) were applied in this study.

All spatial analyses and pre-processing of GIS-layers listed above were performed using ArcGIS 9.2 (ESRI, 2009).

2.3 Analyses of landscape structure

The landscape structure at the landscape level was quantified by means of structure metrics of landscape composition and configuration computed using Patch Analyst 4.2.10 extension for ArcMap 9.2. (Ontario Ministry of Natural Resources 2009) and Fragstats 3.3. software (McGarigal et al. 2002). Metrics were analysed by regions, i.e. for each study site separately, from the CORINE land cover layer in the year 1990 (CLC90) and the year 2006 (CLC06).

Fragstats unlike the Patch Analyst works with raster data only and computes some more sophisticated metrics of landscape composition. The input CORINE land cover data were primary obtained in vector format, thus for data processing in Fragstats, both time horizons of CLC were converted to raster data format (grid) with the cell size of 10 m. This cell size was set and verified experimentally to eliminate artificial isolated cell classes occurring when converting vector data into raster of coarser resolution.

The fact that landscape metrics are derived from patch geometry or/and their spatial configuration has the further implication that many of the metrics are correlated and to some extent redundant by its information. The set of selected metrics should differ by the objection of the analysis. In this study the set of relevant metrics was defined according to correlations among metrics as well as based on review of published research. As some metrics showed non-normal distribution even after transformations, thus the Spearman's Rank correlation coefficients matrix computed in NCSS software package was used According to Abdullah (1990) in such a case replacing the observations by their ranks, the effect of the outliers is reduced.

2.4 Statistical analyses

The statistical program CANOCO for Windows 4.5 (ter Braak & Šmilauer 2002) and the NCSS (NCSS, 2007) software package were used for statistical evaluation of the datasets – land cover datasets and structure metrics datasets. Because both land cover classes and selected landscape metrics represent multivariate data (number of dependent variables), the multivariate statistical analysis was used. We used the redundancy analysis (RDA – constrained linear ordination method) where the ordination axes correspond to the direction of the greatest variability that can be explained by the independent variable. RDA is thus a multiple regression for all dependent variables simultaneously and describes variation between two multivariate data sets. Specifically, a matrix of predictor variables is used to quantify variation in a matrix of response variables. In RDA, the scores from a principal component analysis are regressed on a specified set of predictor variables with each iteration and the fitted values of the regression become new scores (Jongman et al. 1995) The PCA is thus constrained by the environmental or predictor variables.

Land cover data were logarithmically transformed unlike data of landscape structure. We used the redundancy analysis (RDA), with site position (inside/outside PLAs) as a categorical predictor to investigate how site position influences (i) land cover classes composition and (ii) landscape structure. The statistical significance of site position was tested, in both cases, using Monte Carlo permutation test. Both years (1990 and 2006) were tested separately.

The RDA analysis together with Monte Carlo permutation test were also used to assess the temporal change in land cover class composition and landscape structure, separately for study sites inside and outside PLAs in period 1990–2006, and to test the interaction between temporal change and site position. The null hypothesis for these two tests (temporal change with site position) were: (i) site position has no effect on the temporal changes in the land classes composition; (ii) site position has no effect on the temporal changes in the landscape structure.

The critical level of significance for all statistical tests was chosen as α = 0.05.

3. Results

3.1 Study municipalities

Twenty-five municipalities fulfilled defined criteria (see Fig. 1) and were included into analyses. For the purpose of hypotheses testing, they were divided in two groups – (i) study municipalities lying inside PLAs (protected landscape areas): 13 municipalities, and (ii) study municipalities lying outside PLAs: 12. Study municipalities are listed in App. 2.

3.2 Proportion of land cover classes

Study sites, inside and outside protected landscape areas, differed in land cover class composition only in the first time horizon (the year 1990). The RDA analysis (Fig. 2) showed significant result; however, the explained variability was rather low. The site position (position inside/outside PLA) accounted only for 8.1% of variability among municipalities (P = 0.044; F-ratio = 2.037). In the second time horizon (the year 2006), the test was not statistically significant; it revealed convergence of the proportions of land cover classes (see table 1 and table 2). For example there were no patches of "Industrial and commercial units" or "Road and rail networks and associated land" classified in the study sites inside the PLAs in 1990, whereas these classes occurred in this group in 2006.

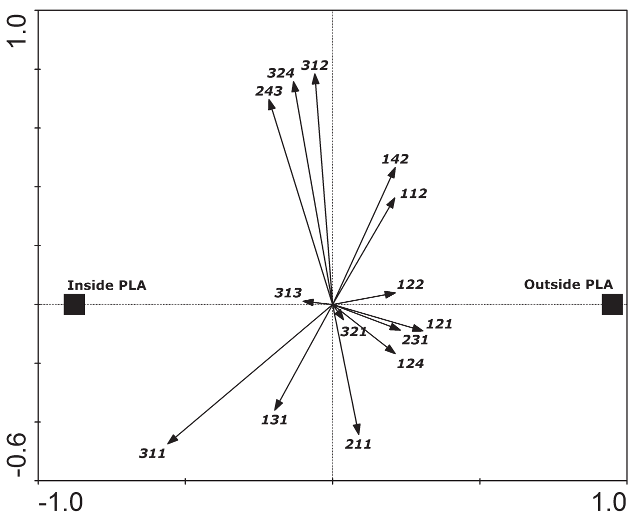

Fig. 2 RDA ordination of land cover classes and site position in the year 1990. The diagram shows the differences of land cover class composition between the municipalities inside and outside PLAs. (Codes explanation: 112 – Discontinuous urban fabric; 121 – Industrial and Commercial units; 122 – Road and rail networks and associated land; 124 – Airports; 131 – Mineral extraction sites; 142 – Sport and leisure facilities; 211 – Non-irrigated arable land; 231 – Pastures; 243 – Land principally occupied by agriculture, with significant areas of natural vegetation; 311 – Broad-leaved forests; 312 – Coniferous forests; 313 – Mixed forests; 321 – Natural grasslands; 324 – Transitional woodland-scrub)

Tab. 1 Land cover classes in the study sites in the year 1990. (For codes explanations see Fig. 2)

Land Cover Class	*Year 1990*	*112*	*121*	*122*	*124*	*131*	*142*	*211*	*231*	*243*	*311*	*312*	*313*	*321*	*324*
Inside PLA	*area (ha)*	422.3	0.0	0.0	0.0	6.2	0.0	2993.7	83.7	562.5	751.3	283.2	1318.3	15.0	63.1
	area (%)	6	0	0	0	0	0	46	1	9	12	4	20	0	1
	median	33.5	0.0	0.0	0.0	0.0	0.0	307.2	0.0	41.8	40.8	0.0	97.4	0.0	0.0
	mean	32.5	0.0	0.0	0.0	0.5	0.0	230.3	6.4	43.3	57.8	21.8	101.4	1.2	4.9
	std	26.5	0.0	0.0	0.0	1.6	0.0	115.2	16.8	30.3	59.4	44.3	84.1	4.0	7.8
Outside PLA	*area (ha)*	773.4	68.0	6.0	76.6	0.0	2.4	3534.5	124.3	364.6	56.9	195.8	682.9	26.1	87.9
	area (%)	13	1	0	1	0	0	59	2	6	1	3	11	0	1
	median	48.4	0.0	0.0	0.0	0.0	0.0	345.4	0.2	20.7	0.0	0.0	44.7	0.0	0.0
	mean	64.4	5.7	0.5	6.4	0.0	0.2	294.5	10.4	30.4	4.7	16.3	56.9	2.2	7.3
	std	75.3	12.7	1.7	21.2	0.0	0.6	140.4	18.3	37.9	10.5	35.2	49.7	7.2	20.4

Tab. 2 Land cover classes in the study sites in the year 2006. (For codes explanations see Fig. 2)

Land Cover Class	*Year 2006*	*112*	*121*	*122*	*124*	*131*	*142*	*211*	*231*	*243*	*311*	*312*	*313*	*321*	*324*
Inside PLA	*area (ha)*	432.6	4.4	11.9	0.0	6.2	16.2	2755.4	294.6	546.2	751.6	297.7	1328.0	15.0	39.6
	area (%)	7	0	0	0	0	0	42	5	8	12	5	20	0	1
	median	33.5	0.0	0.0	0.0	0.0	0.0	260.9	18.8	41.8	40.6	0.0	97.5	0.0	0.0
	mean	33.3	0.3	0.9	0.0	0.5	1.2	212.0	22.7	42.0	57.8	22.9	102.2	1.2	3.0
	std	27.8	1.2	3.2	0.0	1.6	4.3	101.7	22.2	29.0	59.4	44.2	83.4	4.0	7.5
Outside PLA	*area (ha)*	807.4	77.8	18.8	76.5	0.0	2.3	3314.6	288.0	364.3	56.8	236.0	702.5	26.2	28.0
	area (%)	13	1	0	1	0	0	55	5	6	1	4	12	0	0
	median	52.1	0.0	0.0	0.0	0.0	0.0	317.9	0.2	20.6	0.0	0.0	44.5	0.0	0.0
	mean	67.3	6.5	1.6	6.4	0.0	0.2	276.2	24.0	30.4	4.7	19.7	58.5	2.2	2.3
	std	79.6	14.5	3.8	21.1	0.0	0.6	141.2	53.0	37.9	10.5	45.6	53.1	7.2	5.2

Results of temporal change analysis also supported presumption of increasing similarities in land cover composition among study sites. The RDA analysis of temporal change of proportions of classes was statistically significant for both types of study sites (Fig. 3 and 4); however, no significant differences between the two types of sites were proved. These results showed that the proportions of land cover classes had changed; nevertheless, no significant differences in the direction of change between sites inside and outside PLA were recorded. The null hypothesis that site position has no effect on the temporal changes in the land classes composition could not be rejected.

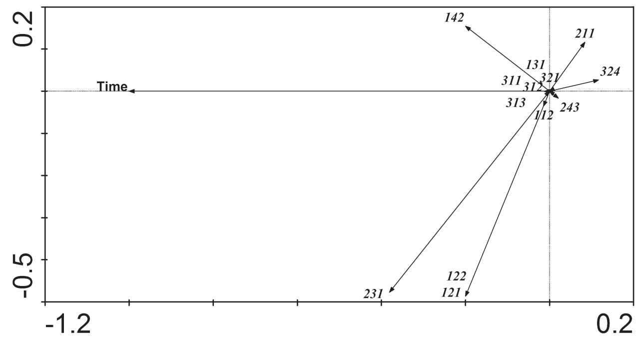

Fig. 3 Result of RDA ordination showing the change in land cover class composition for study sites inside PLAs in period 1990–2006. (P = 0.002, F = 6.320) (For codes explanations see Fig. 2)

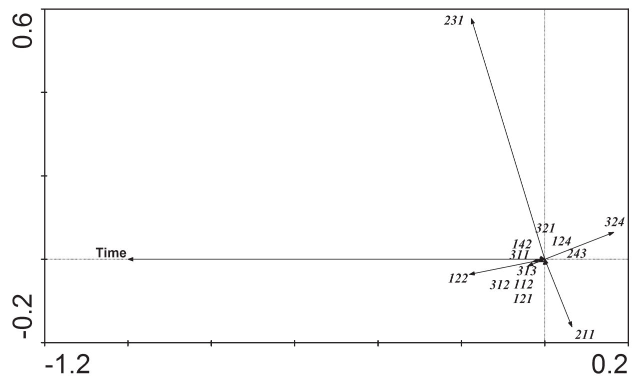

Fig. 4 Result of RDA ordination showing the change in land cover class composition for study sites outside PLAs in period 1990–2006. (P = 0.05, F = 1.358) (For codes explanations see Fig. 2)

Summary of land cover changes is given in table 3. The most extensive changes were detected in following land cover classes in both types of the study sites: (i) 211 – Non-irrigated arable land and (ii) 231 – Pastures. The proportion of arable land has decreased likewise in both groups of the study sites, on the other hand the extent of pastures has increased. The increase was a little higher in the study sites inside the PLAs. The third most extensive change was the increase of urban land cover categories (112 – Discontinuous urban fabric; 121 – Industrial and Commercial units; 122 – Road and rail networks

Tab. 3 Summary of land cover changes in the study sites (1990–2006)

Land Cover Class	*112*	*121*	*122*	*131*	*142*	*211*	*231*	*243*	*311*	*312*	*313*	*321*	*324*
Inside PLA – total change	10.25	4.42	11.86	0.03	16.24	−238.39	210.92	−16.27	0.27	14.43	9.72	−0.02	−23.46
Outside PLA – total change	34.06	9.76	12.85	0.00	0.00	−219.92	163.71	−0.30	−0.02	40.17	19.59	0.08	−59.89
Sum of total change	44.31	14.18	24.71	0.03	16.24	−458.30	374.63	−16.57	0.25	54.60	29.31	0.05	−83.35
Inside PLA – change per muni.	0.79	0.34	0.91	0.00	1.25	−18.34	16.22	−1.25	0.02	1.11	0.75	0.00	−1.80
Outside PLA – change per muni.	2.84	0.81	1.07	0.00	0.00	−18.33	13.64	−0.03	0.00	3.35	1.63	0.01	−4.99

and associated land; 124 – Airports; 131 – Mineral extraction sites; 142 – Sport and leisure facilities).

The increase of urban land cover classes was higher in the study sites outside the PLAs (4.7 ha/study site) than in the study sites inside the PLAs (3.3 ha/study site). Moreover, unprotected sites experienced intensive increase of impervious surfaces (categories 112, 122, 124).

From the summary table, it could be clearly seen, that the land cover category 324 (Transitional woodland shrub) also experienced extensive change, however it was only natural transition from this particular class into forest land cover classes (311, 312, 313) without any functional change.

3.3 Landscape structure

There were 20 metrics of landscape composition and landscape configuration computed (see App. 3) using the Patch Analyst 4.2 and Fragstats 3.3. The relationships among landscape metrics were assessed using matrix of Spearman's Rank correlation coefficients. As could be seen from the table (App. 3) there were many landscape metrics showing strong correlation, therefore out of the set of metrics we selected only uncorrelated or weakly correlated once. Metrics called "Number of patches" (NP) and "Total edge" (TE) remained in the selected set of metrics, despite their high correlations with others, as these metrics are considered to be core metrics (see Leitao et al. 2002).

The list of selected metrics is as follows: (i) metrics of landscape composition: NP – number of patch, NumC – number of classes, MPS – mean patch size, TE – total edge, MedPS – median patch size and (ii) metrics of landscape configuration: GY_MN – mean Radius of Gyration, MSI – Mean Shape Index, FR_MN – mean Fractal

Tab. 4 Spearman's Rank correlation coefficients of computed matrix for selected landscape metrics in the year 1990

Selected Landscape Metrics	*NP 90*	*TE90*	*MPS90*	*MedPS90*	*GY_MN90*	*MSI90*	*FR_MN90*	*NumC90*	*SHDI90*
NP 90	1.000	**0.912**	**–0.994**	0.038	**–0.712**	0.191	0.259	**0.556**	**0.884**
TE90	**0.912**	1.000	**–0.907**	0.230	**–0.448**	0.359	0.292	**0.653**	**0.916**
MPS90	**–0.994**	**–0.907**	1.000	–0.031	**0.700**	–0.201	–0.281	**–0.571**	**–0.885**
MedPS90	0.038	0.230	–0.031	1.000	0.205	0.017	–0.206	0.205	0.293
GY_MN90	**–0.712**	**–0.448**	**0.700**	0.205	1.000	0.175	–0.085	–0.246	**–0.442**
MSI90	0.191	0.359	–0.201	0.017	0.175	1.000	**0.860**	**0.537**	0.274
FR_MN90	0.259	0.292	–0.281	–0.206	–0.085	**0.860**	1.000	**0.490**	0.169
NumC90	**0.556**	**0.653**	**–0.571**	0.205	–0.246	**0.537**	**0.490**	1.000	**0.622**
SHDI90	**0.884**	**0.916**	**–0.885**	0.293	**–0.442**	0.274	0.169	**0.622**	1.000

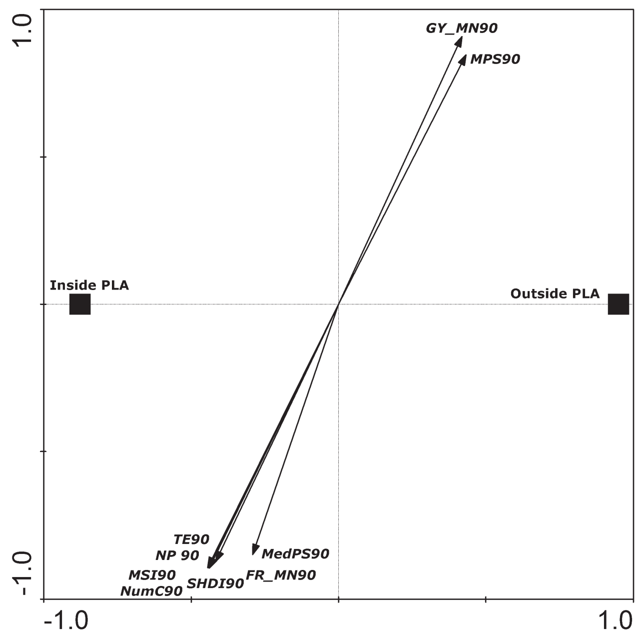

Fig. 5 RDA ordination of selected landscape metrics and site position in the year 1990. The diagram shows the differences of landscape metrics between the municipalities inside and outside PLAs

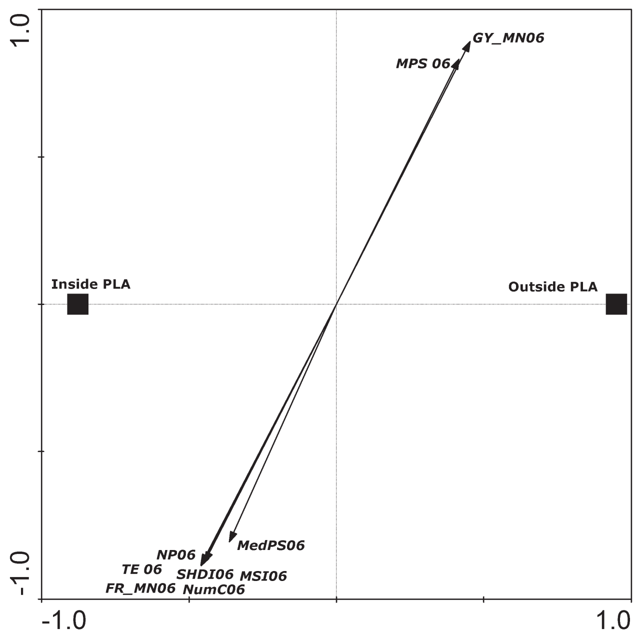

Fig. 6 RDA ordination of selected landscape metrics and site position in the year 2006. The diagram shows the differences of landscape metrics between the municipalities inside and outside PLAs

Index, SHDI – Shannon's diversity index. For description and further details about the metrics, visit e.g. Fragstats homepage (http://www.umass.edu/landeco/research/fragstats/documents/Metrics/Metrics%20TOC.htm).

3.4 Site position as a landscape structure predictor

The RDA analysis showed that the landscape structure in two groups of the study sites differed in both reference years. Site position (inside/outside PLAs) as a categorical predictor explained 17.6% ($P = 0.03$; F-ratio = 4.897) of variability in 1990, and 20.2% ($P = 0.012$; F-ratio = 5.830) of variability in 2006. Ordination diagrams (Fig. 5, Fig. 6) are revealing finer grain-size of landscape mosaic in the study sites inside the PLAs than in the study sites outside the PLAs in both reference years. This means that higher values of metrics like TE, NP, NumC, MSI, MedPS, FR_MN and SHDI were more likely to be related to the study sites inside PLAs, unlike higher value of metrics GY_MN, MPS were more likely to be related to the study sites outside the PLAs. Landscape inside PLAs tends to consist of higher number of land cover classes and also higher number of patches with higher sum of edge length. Metrics showing the patch shape complexity over total landscape (fractal dimension, shape index or radius of gyration) reveals more complex shapes to be associated with landscape inside PLAs.

3.5 Temporal change of landscape structure

Analysis of temporal changes also showed significant results meaning that landscape structure changed in both groups of sites during period 1990–2006. Temporal changes explained 17.8% ($P = 0.004$; F-ratio = 11.669) of variability in the study sites inside the PLAs and 11.1% ($P = 0.002$; F-ratio = 8.530) of variability in the study sites outside the PLAs. However, no significantly different directions of changes were identified between the two groups of the study sites. The null hypothesis that site position has no effect on the temporal changes in the landscape structure could not be rejected.

4. Discussion

The results of RDA analyses of changes of land cover classes' proportions suggested convergent development of two groups of the study sites during the monitored period (1990–2006). The statistically significant differences between two groups of the study sites decreased; in other words, ongoing processes were similar in both groups of the study sites. The major distinguished processes were (i) extensification of agriculture (i.e. decrease of the proportion of arable land and increase of pastures) that was slightly more intense in the study sites within the PLAs and (ii) sub/urbanisation which was on the contrary more intense in the study sites outside the PLAs. However, the intensity of the latter was highly influenced by a construction of a golf course in Karlštejn (a municipality inside PLAs). These major land cover transitions followed national (Romportl et al. 2010) or even international trends typical for post-communist Central European countries (Feranec et al. 2007; EEA 2006), Only the process of agricultural intensification typical in other parts of the Czech Republic was not detected in this study area. The dissimilar intensity (among two groups of the study sites) of transition of the class 324 – Transitional woodland shrubs was noticeable: more intensive forestry was apparent in the study sites outside the PLAs.

The RDA analyses of landscape structure changes showed certain differences between the two groups of study sites. Landscape mosaics in the study sites inside the PLAs were of finer grain-size than in the study sites outside the PLAs in the both reference years. The presumption of lower intensity of landscape structure changes in the forenamed group was not certified.

The obtained results can be summarized as follows. Although the study sites inside the PLAs retained theirs distinctions – finer grain-size of landscape mosaics than in the study sites outside the PLAs, the intensity and trajectories of changes were comparable in both evaluated groups. It seemed that the status of PLA had certain influence on the preservation of the uniqueness of protected areas but also that its landscape structure was subject to the same processes (residential and commercial construction etc.) like unprotected areas. Therefore, pressure of socio-economic development, which essentially reflects on the landscape qualities, did not avoid even to the most valuable, i.e. legislatively protected, areas in the region of interest. According to Jongman (2002), this was accordant with others European countries.

Nevertheless, the interpretation of obtained results should be considered in connection with the applied methodology. One factor is the used data of land cover. Due to the spatial parameters of the CORINE Land Cover layer (see above), the results were not to be used for an evaluation of the fine landscape microstructure. Thus, it is possible that number of little landscape elements, which also generated the landscape qualities, occurred in the study sites but they missed in the analyses. Despite this fact, this dataset provides unique source of information about land cover and landscape structure. Its exceptional advantages are large temporal and spatial extent and easy availability.

Another factor to be mentioned is the final set of metrics. Both, the metrics executed from vector layer and from raster layer were contained by reason of capturing whole complexity of landscape structure (see above). However, conversion to the raster as well as lattice grid structure, which leads in prolongation of patch edge length, can influence values of metrics (Bailey et al. 2007; McGarigal 2007) and; therefore, also comparability between metrics executed from vector and from raster. From the reason of distortion elimination, the vector layers were converted into the rasters with a small cell size, which avoided an origin of artificial patches, i.e. patches not presented in the original vectors. As the possible distortions by prolonged patch edges in raster were the same in all study sites, this factor did not influenced the interpretation of results.

Also, the selection of metrics to the final set should be mentioned. Although a large number of structure metrics was defined in literature, their predicative values are often overlapping. Thus, only several metrics were selected according to the small correlations among them in 1990. However, others were added on the base of rather subjective criteria (see above). For example Shannon index of diversity or Edge density which were noticed as an important for evaluation of scenery quality and structural diversity of landscape, i.e. of landscape character (Herbst et al. 2009). Of course preferences of another metrics could have influenced the results. However, according to Tavernia et al. (1990), it is not possible to make one universal set of metrics but it must be created for each particular study with usage of statistical methods.

Landscape structure changes are closely associated with the threats of landscape fragmentation and homogenisation. Both named processes bring not only higher pressure for organisms (protected and also unprotected) but also unfavourably impacts others landscape functions such as water retention, landscape character, etc. Landscape character, i.e. specific landscape structure, has been object of conservation in many European countries (Wascher 2005). In the Czech Republic, protected landscape areas serve the purpose of conservation of harmonic cultural landscape. But the presented study said that important changes of land cover and consequently of landscape structure occurred in the study sites inside the PLAs as well.

Unification of landscape inside and outside protected areas gradually increases. This transition may lead to the irreversible loss of valuable cultural and natural heritage. Of course, this assumption should be confirmed by studies in others protected areas because the exceptional state of Prague's outskirts could not be fully excluded. Such studies are mostly missing (e.g. Breuer et al 2010); however, a visual evaluation of maps from Atlas of spatial differentiation of the Czech Republic (Ouředníček et al. 2011) confirmed the assumption.

This study contributed also to the development and verification of landscape assessment method. Such research is still needed in the Czech Republic, e.g. according to Obršálová (2006) current practise still has insufficient possibilities of anthropogenic impact quantification in area.

Nevertheless, the presented study was focused only to one aspect of landscape features, to landscape structure. It indeed indicates the others landscape features as well but not wholly directly. Thus, a gap for further studies remained: for including more initial datasets, different analyses, etc. with the purpose of capturing the whole complexity of landscape.

5. Conclusion

The aim of the study was to compare the development of landscape structure and land cover in two groups of study sites with the same socio-economic potential but different conservation status since the change of the political regime in the Czech Republic. The obtained results showed that two groups of study sites differed in landscape structure and landscape composition in the year 1990, but trajectories and intensities of land cover changes since then have been very similar, however landscape structure unlike landscape composition have still remained different. The study sites inside PLAs still has finer grain-size of landscape mosaics. The convergent development of both groups was suggested but this assumption should be confirmed by an enlargement of the analyses to the more complex landscape evaluation.

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Appendix 1
Classes of CORINE land cover database recorded in the Czech Republic

1. Artificial surfaces
   - 1.1 Urban fabric
     - 1.1.1 Continuous urban fabric
     - 1.1.2 Discontinuous urban fabric
   - 1.2 Industrial, commercial and transport units
     - 1.2.1 Industrial or commercial units
     - 1.2.2 Road and rail networks and associated land
     - 1.2.3 Port areas
     - 1.2.4 Airports
   - 1.3 Mine, dump and constructions sites
     - 1.3.1 Mineral extraction sites
     - 1.3.2 Dump sites
     - 1.3.3 Construction sites
   - 1.4 Artificial, non-agricultural vegetated areas
     - 1.4.1 Green urban areas
     - 1.4.2 Sport and leisure facilities
2. Agricultural areas
   - 2.1 Arable land
     - 2.1.1 Non-irrigated arable land
   - 2.2 Permanent crops
     - 2.2.1 Vineyards
     - 2.2.2 Fruit trees and berry plantations
   - 2.3 Pastures
     - 2.3.1 Pastures
   - 2.4 Heterogeneous agricultural areas
     - 2.4.1 Annual crops associated with permanent crops
     - 2.4.2 Complex cultivation patterns
     - 2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation
3. Forest and semi-natural areas
   - 3.1 Forests
     - 3.1.1 Broad-leaved forests
     - 3.1.2 Coniferous forests
     - 3.1.3 Mixed forests
   - 3.2 Scrub and/or herbaceous vegetation associations
     - 3.2.1 Natural grasslands
     - 3.2.2 Moors and heathland
     - 3.2.4 Transitional woodland-scrub
   - 3.3 Open spaces with little or no vegetation
     - 3.3.2 Bare rocks
     - 3.3.3 Sparsely vegetated areas
4. Wetlands
   - 4.1 Inland wetlands
     - 4.1.1 Inland marshes
     - 4.1.2 Peat bogs
5. Water bodies
   - 5.1 Inland waters
     - 5.1.1 Water courses
     - 5.1.2 Water bodies

Appendix 2
List of evaluated municipalities, i.e. study sites

Municipalities inside the PLAs	*Municipalities outside the PLAs*
Bzová	Chodouň
Hředle	Chyňava
Hudlice	Kotopeky
Karlštejn	Lochovice
Korno	Malé Kyšice
Mořinka	Málkov
Nižbor	Nenačovice
Suchomasty	Neumětely
Svatá	Řevnice
Svatý Jan pod Skalou	Svárov
Vinařice	Tlustice
Vonoklasy	Vysoký Újezd
Žebrák	

Appendix 3
Spearman's Rank correlation coefficients of computed matrix in 1990

Computed Landscape Metrics	*NP 90*	*LPI90*	*TE90*	*MPS90*	*MedPS90*	*GY_MN90*	*MSI90*	*FR_MN90*	*PA_MN90*	*CI_MN90*	*CO_MN90*	*CONTA90*	*IJI90*	*DIVIS90*	*NumC90*	*SHDI90*	*SIDI90*	*SHEI90*	*SIEI90*	*AI90*
NP 90	1.000	**–0.827**	**0.912**	**–0.994**	0.038	**–0.712**	0.191	0.259	**0.406**	**0.494**	**–0.419**	**–0.773**	0.379	**0.84**	**0.556**	**0.884**	**0.903**	**0.766**	**0.863**	**–0.895**
LPI90	**–0.827**	1.000	**–0.887**	**0.816**	–0.378	0.362	–0.112	0.027	–0.062	–0.289	0.065	**0.782**	**–0.532**	**–0.99**	**–0.503**	**–0.898**	**–0.879**	**–0.790**	**–0.842**	**0.832**
TE90	**0.912**	**–0.887**	1.000	**–0.907**	0.230	**–0.448**	0.359	0.292	0.173	**0.498**	–0.183	**–0.713**	0.350	**0.90**	**0.653**	**0.916**	**0.864**	**0.715**	**0.790**	**–0.981**
MPS90	**–0.994**	**0.816**	**–0.907**	1.000	–0.031	**0.700**	–0.201	–0.281	**–0.408**	**–0.520**	**0.424**	**0.767**	–0.359	**–0.83**	**–0.571**	**–0.885**	**–0.907**	**–0.760**	**–0.859**	**0.891**
MedPS90	0.038	–0.378	0.230	–0.031	1.000	0.205	0.017	–0.206	**–0.525**	–0.075	**0.529**	–0.259	0.389	0.38	0.205	0.293	0.205	0.275	0.229	–0.152
GY_MN90	**–0.712**	0.362	**–0.448**	**0.700**	0.205	1.000	0.175	–0.085	**–0.622**	–0.109	**0.648**	**0.508**	–0.205	–0.37	–0.246	**–0.442**	**–0.535**	**–0.483**	**–0.590**	**0.434**
MSI90	0.191	–0.112	0.359	–0.201	0.017	0.175	1.000	**0.860**	0.045	**0.648**	–0.009	0.074	–0.159	0.10	**0.537**	0.274	0.139	–0.065	–0.006	–0.375
FR_MN90	0.259	0.027	0.292	–0.281	–0.206	–0.085	**0.860**	1.000	0.328	**0.772**	–0.303	0.127	–0.315	–0.02	**0.490**	0.169	0.082	–0.133	–0.058	–0.327
PA_MN90	**0.406**	–0.062	0.173	**–0.408**	**–0.525**	**–0.622**	0.045	0.328	1.000	0.205	**–0.995**	–0.168	–0.121	0.06	0.085	0.076	0.228	0.135	0.265	–0.226
CI_MN90	**0.494**	–0.289	**0.498**	**–0.520**	–0.075	–0.109	**0.648**	**0.772**	0.205	1.000	–0.198	–0.213	0.005	0.31	**0.427**	**0.433**	0.343	0.209	0.220	**–0.512**
CO_MN90	**–0.419**	0.065	–0.183	**0.424**	**0.529**	**0.648**	–0.009	–0.303	**–0.995**	–0.198	1.000	0.185	0.102	–0.07	–0.075	–0.078	–0.233	–0.151	–0.282	0.237
CONTA90	**–0.773**	**0.782**	**–0.713**	**0.767**	–0.259	**0.508**	0.074	0.127	–0.168	–0.213	0.185	1.000	**–0.731**	**–0.80**	–0.092	**–0.799**	**–0.878**	**–0.997**	**–0.965**	**0.713**
IJI90	0.379	**–0.532**	0.350	–0.359	0.389	–0.205	–0.159	–0.315	–0.121	0.005	0.102	**–0.731**	1.000	**0.56**	–0.216	0.395	**0.454**	**0.726**	**0.640**	–0.321
DIVIS90	**0.841**	**–0.993**	**0.903**	**–0.829**	0.379	–0.375	0.103	–0.021	0.065	0.311	–0.072	**–0.796**	**0.565**	1.00	**0.481**	**0.887**	**0.868**	**0.801**	**0.844**	**–0.858**
NumC90	**0.556**	**–0.503**	**0.653**	**–0.571**	0.205	–0.246	**0.537**	**0.490**	0.085	**0.427**	–0.075	–0.092	–0.216	**0.48**	1.000	**0.622**	**0.487**	0.112	0.276	**–0.570**
SHDI90	**0.884**	**–0.898**	**0.916**	**–0.885**	0.293	**–0.442**	0.274	0.169	0.076	**0.433**	–0.078	**–0.799**	0.395	**0.89**	**0.622**	1.000	**0.958**	**0.814**	**0.869**	**–0.865**
SIDI90	**0.903**	**–0.879**	**0.864**	**–0.907**	0.205	**–0.535**	0.139	0.082	0.228	0.343	–0.233	**–0.878**	**0.454**	**0.87**	**0.487**	**0.958**	1.000	**0.887**	**0.948**	**–0.832**
SHEI90	**0.766**	**–0.790**	**0.715**	**–0.760**	0.275	**–0.483**	–0.065	–0.133	0.135	0.209	–0.151	**–0.997**	**0.726**	**0.80**	0.112	**0.814**	**0.887**	1.000	**0.963**	**–0.709**
SIEI90	**0.863**	**–0.842**	**0.790**	**–0.859**	0.229	**–0.590**	–0.006	–0.058	0.265	0.220	–0.282	**–0.965**	**0.640**	**0.84**	0.276	**0.869**	**0.948**	**0.963**	1.000	**–0.774**
AI90	**–0.895**	**0.832**	**–0.981**	**0.891**	–0.152	**0.434**	–0.375	–0.327	–0.226	**–0.512**	0.237	**0.713**	–0.321	**–0.86**	**–0.570**	**–0.865**	**–0.832**	**–0.709**	**–0.774**	1.000

NP – number of patches, LPI – largest patch index, TE – total edge, MPS – mean patch size, MedPS – median patch size, GY_MN – mean radius of gyration, MSI – mean shape index, FR_MN – mean fractal index, PA_MN – mean perimeter-area ratio , CI_MN – mean related circumscribing circle, CO_MN – Contiguity Index Distribution, CONTA – contagion, IJI – Interspersion & Juxtaposition Index, DIVIS – Landscape division index, MESH – Effective Mesh Size, SPLIT – Splitting Index, NumC – number of classes, SHDI – Shannon's diversity index, SIDI – Simpson's Diversity Index, SHEI – Shannon's Evenness Index, MSIDI – Modified Simpson's Diversity Index, SIEI – Simpson's Evenness Index , MSIEI – Modified Simpson's Evenness Index, AI – Aggregation Index

RÉSUMÉ

Srovnání změn v krajině uvnitř a vně chráněných území v zázemí Prahy mezi lety 1990 a 2006

V České republice dochází v posledních dvou dekádách v důsledku hlubokých společenských a politických změn k významným změnám krajinného pokryvu a jeho struktury (Romportl et al. 2010). Na většině území Evropy dochází k homogenizaci krajiny a zániku regionálních krajinných typů (Jongman 2002). Specifické formy využívání krajiny a krajinný ráz přitom patří mezi základní kulturní hodnoty, které si zaslouží legislativní ochranu. V České republice jsou k tomuto účelu zřízeny kategorie přírodních parků a chráněných krajinných oblastí. Otázkou ovšem zůstává, zda statut těchto chráněných území zajišťuje dostatečnou ochranu specifické skladby krajinného pokryvu a jeho struktury. Mezi potenciálně nejohroženější oblasti patří bezesporu území v zázemí velkých měst atraktivních pro rezidenční i komerční výstavbu. Tento efekt ještě více zvyšuje existence dálnic a dalších důležitých dopravních tras. V předložené studii jsme se proto zaměřili na srovnání změn krajinného pokryvu a jeho struktury ve vybraných 25 obcích v zázemí Prahy v zóně obdobné časové dostupnosti a vzdálenosti k dálnici D5. Třináct z těchto obcí leží na území CHKO Český kras, resp. CHKO Křivoklátsko, zbylých dvanáct pak mimo chráněná území. Cílem analýzy bylo ověření hypotézy, že v chráněných území by nemělo docházet k významným změnám krajinného pokryvu a jeho struktury, které by vedly ke snížení hodnot krajinného rázu. Výsledky však ukázaly, že v obou typech modelových lokalit dochází ke krajinným změnám podobné intenzity. Ačkoli se výchozí charakter krajinného pokryvu a jeho struktury v obou typech krajiny liší, dochází postupně ke konvergentnímu vývoji, jinými slovy ke smazávání rozdílů mezi krajinou na území CHKO a krajinou nechráněnou. Z toho vyplývá, že status chráněných krajinných oblastí pravděpodobně nepředstavuje dostatečnou úroveň ochrany krajiny v exponovaných územích České republiky.

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