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LAND COVER CHANGES IN SLOVAKIA 1990-2006 RELATED TO THE DISTANCE FROM INDUSTRIAL AREAS AND ECONOMIC DEVELOPMENT

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Land cover changes in Slovakia 1990-2006 related to the distance from industrial areas and economic development

Changes of land cover in Slovakia around the industrialized patches were determined. We have used the available Corine Land Cover (CLC) maps from 1990 and 2006 in vector format converted to grid form with cell size of 5 × 5 m and the third level of CLC legend coding. To examine land cover changes in the closest vicinity of industrial patches two adjacent buffers with a width of 1 km around the extracted industrial patches were constructed. Changes in the area of landscape features were evaluated as the area percentage for each land cover class. We have calculated selected landscape indices of land cover for both time horizons using FRAGSTATS 3.3. Fourteen types of land cover changes were defined to analyse trends in the three landscape segments. Evaluation of the trends was carried out using the raster calculator module by the addition of raster layers of different periods. Comparison of the structure of land cover and changes in the close surroundings of industrial areas with those in remote landscape more than 10 km from these areas proved that the strongest trends in these areas are both, the extensification and intensification of agriculture and the afforestation. On the other hand, in remote landscape there is a predominance of afforestation over the intensification and extensification of agriculture. Trends of industrialization and urbanization have been declining in relation to the increasing distance from the industrial patches.

Key words: land-cover changes, industrialization, Slovakia, landscape indices, buffer, Corine Land Cover

INTRODUCTION

The impact of industrial production on the Slovak landscape is obvious and significant even from simple examination of the landscape with the naked eye. It appears as alternation of different types of landscape (land cover), with the largest contrasts occurring in territories of rural and industrial landscape confrontations, focal areas of towns and industrial parks, and between the past and present landscapes. This article aims to assess changes that occurred over 16 years in these contact territories. The answer to the question of whether the increase in national industrial production consequently increased the industrialization in territories located in close proximity to existing industrial areas will be sought. Industrialization is closely related to the decrease of natural landscape features in large parts of the landscape and to heavy degradation of the natural

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environment as well. The density and spatial distribution of the current industrialized areas and whether and how changes in these values reflect changes in the land cover of areas located at least 10 km from the nearest industrial site will be analysed.

Effects of land cover (LC) changes contribute to global change and *vice versa*. Monitoring changes in land cover/land use is considered to be an essential step to identify drivers of change (Bürgi et al. 2004, Muchová et al. 2010, Havlíček et al. 2012, Mojses and Boltižiar 2012, Skokanová et al. 2012 and Tarasovičová et al. 2013). The following studies are based in some of the international projects and programmes devoted to LC changes: MURBANDY/ MOLAND project (Lavalle et al. 2001), BIOPRESS (Gerard et al. 2010), Global Land Project (GLP 2005), Land Use and Cover Change Programme (Lambin et al. 1999). In Slovakia, LC changes were evaluated within the international project BIOPRESS and many other works including Feranec et al. (2002), Feranec and Oťaheľ (2009), Feranec et al. (2010), Feranec and Soukup (2013). Changes of LC influence a number of landscape ecological phenomena including hydric potential of landscape as mentioned by Lepeška (2010 and 2013). Historical LC research was applied in the works of Hronček (2008 and 2011). Rural/urban contact areas and transition gradients between the urban and the rural landscape have recently become the subject of intense research. Hahs and McDonnell (2006) and further McDonnell and Hahs (2008) identified 17 common urbanization criteria, which were successfully tested in several model areas (du Toit and Cilliers 2011). The increase in urbanization is the direct cause of population decline of several species of animals including avifauna (Biamonte et al. 2011).

MATERIALS AND METHODS

Available Corine Land Cover data CLC 1990 and CLC 2006 (acquired from the EEA website) in vector format were used and transformed into a grid with cell size of 20×20 m. The third level of CLC legend coding was used. The methodology of CLC layer creation can be found in many works including Feranec et al. (2002 and 2004). The extraction of cells, which belonged to CLC class "*3, 121; Artificial surfaces; Industrial, commercial and transport units; Industrial or commercial units*" was carried out using the ArcGIS 9.3 environment. Consequently, the nearest neighbour index based on an average Euclidean distance of adjacent elements was calculated, using the module Spatial Statistical Tool – Analysing Patterns – Average Nearest Neighbour. Examination of LC changes in the close vicinity of industrial patches had been carried out in 2 adjacent buffers with a width of 1 km around extracted industrial patches. The second buffer was created around the previous at 1-2 km distance from the industrial patches. Two 1 km wide buffers have been used to examine and detect possible effects of industry on the LC structure in the close surroundings of industrial patches, because they usually represent areas of city (urban) boundaries and buffer zones, as well as contact areas of urban and rural types of LC. The width of 1 km was used because of the map scale issues (representing the whole of Slovakia on a single map) in order to capture a significant area of the landscape capable of representing the quality and quantity of LC changes. Changes in the area of land cover classes were evaluated as the percentage area of each.

Selected landscape indices of LC for both time horizons were calculated using the FRAGSTATS 3.3 (McGarigal and Marks 1995). Values of indices were affected by the nature of data format of the CLC raster layers in the sense of spatial resolution (20×20 m grid). Comparing the changes of landscape index values it was possible to determine trends in LC changes in terms of landscape configuration and composition, which took place in the surveyed landscape cutouts during the chosen time period. The Spatial Analyst Tools – Distance – Euclidean Distance module in ArcGIS 9.3 were used in the study of areas located at least 10 kilometres from the nearest industrial patch, creating a graphical representation of distances between industrialized areas. Territories more than 10 km from industrial areas were extracted using the previous layer by the Spatial Analyst Tools Module – Extract – Extract Attributes. The same analysis was performed (percentage changes and evaluation using landscape indices produced by FRAGSTATS 3.3).

The following trends of LC changes based on the methodology of Oťaheľ et al. (2004), Cebecauerová (2007), Feranec et al. (2010), Feranec and Soukup (2013), were defined in three landscape segments: no change (1), extensification of urbanization (2), intensification of urbanization (3), de-industrialization (4), industrialization (5), de-urbanization (6), urbanization (7), deforestation (8), afforestation (9), extensification of agriculture (10), intensification of agriculture (11), land drying (12), land water-logging (13), flooding (14) other changes (15). Evaluation of these trends was carried out using the raster calculator module by adding the raster layers representing buffers around industrial patches in each year.

The following FRAGSTATS 3.3 landscape indices were used for the evaluation of spatial properties of the selected LC cut-outs (at the landscape-level metrics): area/boundary (total edge TE, edge density ED, largest patch index LPI, area-weighted mean patch area of distribution AREA_AM, area-weighted mean radius of gyration GYRATE_AM), and three indices of landscape diversity (patch richness density PRD, Shannon's diversity index SHDI, modified Shannon's evenness index SHEI).

One standard economic variable was chosen as an economic indicator of the industrial development of Slovakia – industrial production measured in million Euro b.c.

RESULTS

The economic development of Slovakia is described in rough outline in Tab. 1. According to data from the Statistical Office of the Slovak Republic, the industrial production in Slovakia was continuously increasing from 1995 until 2006 when it first declined (data before 1995 are not available for the Slovak Republic).

The values of the average Euclidean distance in Tab. 2 indicate an increase of distances between the industrialized and urbanized areas between the years 1990 and 2006, which means that their density of spatial distribution diminished within the landscape structure of Slovakia during the surveyed period. This result may be a proof of recent de-urbanization and de-industrialization in some parts of Slovakia, which followed after the year 1989.

Tab. 1. Values of Slovakia's industrial production 1995-2006 (data for the previous years are not accessible at the Statistical Office)

Industrial production (mil. EUR b.c.)											
1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
4 330.23	4 690.71	4 739.60	5 300.22	5 146.60	6 625.64	7 478.36	7 255.56	8 260.07	9 401.41	10 223.63	11 563.03

Tab. 2. Average Nearest Neighbour values computed in ArcGIS 9.3 (represent average distances from one urban /industrial patch to another)

Average Nearest Neighbour Summary				
	Urban 1990	Urban 2006	Industr. 1990	Industr. 2006
Observed Mean Distance	1 417.645610	1 881.001149	3 467.688088	3 871.278449
Expected Mean Distance	2 129.688174	2 431.925671	6 141.549432	6 623.811394
Nearest Neighbor Ratio	0.66565	0.773462	0.564628	0.584449

The first buffer

For the first buffer in the vicinity of industrial zones up to a distance of 1 km (Tab. 3) significant changes were observed in the proportional representation of LC class 211 non-irrigated arable land showing a decline of 2.79%. The second largest reduction in extent occurred in class 243 *Land principally occupied by agriculture with significant areas of natural vegetation*, extent of which decreased by 1.03%.

Only small percentage changes ranging from –0.30% to –0.01% were found in other diminishing LC classes. Overall, the reduction of spatial extent occurred in 15 out of 26 identified classes. The most significant increase occurred in class 242 *Complex cultivation patterns*, which expanded by 1.14%. The second highest rise was observed in class 112 – *Discontinuous urban fabric*, which increased by 0.91%. The third most enlarged class was 311 *Broad-leaved forest*, which grew by 0.70% during this period. The fourth class with the largest increase was 324 *Transitional woodland-shrub*, which expanded by 0.51%. The most significant landscape classes for the first buffer in 2006 were represented by: 211 *Non-irrigated arable land* – 49.01 %, 112 *Discontinuous urban fabric* – 18.27%, 311 *Deciduous forests* – 7.24%, 313 *Mixed forests* – 3.03%, 231 *Pasture* – 2.97%. Overall, increases were observed mainly in classes that included natural landscape elements (242, 312, 324) and class 112, which in turn represented an increase of urbanization in the landscape. Diminishing of LC patches with agricultural land use in the first buffer could be interpreted as a result of the influence of industry and also of the changed socio-economic situation after the year 1989, both possibly having a synergic effect upon the landscape surrounding the industrialized patches. The increase of urbanization in the surroundings of industrial patches is a more or less common process (more building activity usually occurs around such attractor patches).

Tab. 3. Comparison of the extent of LC classes between 1990 and 2006 in buffers

Land/cover class	buff90ind	buff06ind	Comparison 1	buff90ind2	buff06ind2	Com parison 2
Continuous urban fabric	0.30	0.20	-0.10	0.10	0.07	-0.03
Discontinuous urban fabric	17.36	18.27	0.91	7.97	8.22	0.24
Industrial or commercial units	0.99	1.03	0.04	6.14	6.67	0.53
Road and rail networks and associated land	0.34	0.43	0.09	0.05	0.13	0.08
Port areas	0.10	0.05	-0.04	0.01	0.00	0.00
Airports	0.21	0.18	-0.03	0.22	0.21	-0.01
Mineral extraction sites	0.18	0.12	-0.06	0.13	0.13	0.00
Dump sites	0.27	0.34	0.07	0.09	0.07	-0.02
Construction sites	0.46	0.17	-0.30	0.42	0.05	-0.37
Green urban areas	0.22	0.13	-0.80	0.07	0.10	0.03
Sport and leisure facilities	0.25	0.25	-0.01	0.28	0.33	0.04
Non-irrigated arable land	51.40	49.01	-2.39	50.27	48.46	-1.80
Vineyards	1.05	0.96	-0.09	1.11	0.86	-0.25
Fruit trees and berry plantations	0.39	0.30	-0.09	0.48	0.39	-0.09
Pastures	3.01	2.97	-0.04	4.22	4.14	-0.08
Complex cultivation patterns	1.07	2.21	1.14	0.75	1.97	1.22
Land principally occupied by agriculture, with significant areas of natural vegetation	7.69	6.66	-1.03	7.31	5.92	-1.39
Broad-leaved forest	6.54	7.24	0.70	10.41	11.11	0.70
Coniferous forest	2.43	2.71	0.28	3.82	3.87	0.05
Mixed forest	2.78	3.03	0.25	3.40	3.90	0.50
Natural grasslands	0.24	0.21	-0.03	0.27	0.13	-0.14
Transitional woodland-shrub	1.32	1.82	0.51	1.40	2.22	0.82
Sparsely vegetated areas	0.06	0.06	-0.01	0.04	0.03	-0.01
Inland marshes	0.26	0.13	-0.14	0.25	0.11	-0.14
Water courses	0.58	0.66	0.08	0.38	0.35	-0.03
Water bodies	0.52	0.89	0.37	0.40	0.57	0.17

The most significant changes occurred in class *Non-irrigated arable land*, which diminished at a rate of 2.39% in the case of the first buffer and 1.80% in case of the second. Another significant loss was seen in the class *Land principally occupied by agriculture, with significant areas of natural vegetation*. The class showing the biggest increase was *Complex cultivation patterns*. These changes may represent a trend of extensification of agriculture in the close vicinity of industrial patches due to worsening of natural conditions for intensive agricultural activities, or it can also be seen as a consequence of the common trend of agricultural extensification occurring after 1989. It is obvious that LC changes during 16 years are within a small range 0-2.39%, thus the landscape was not changing very rapidly.

The second buffer

In the case of the second buffer starting at a distance of 1 km and extending up to 2 km from industrial patches (Tab. 3), some changes in the extent of landscape classes similar to the previous area were observed. The greatest loss was found in land cover class 211 *Non-irrigated arable land* – a decrease of 1.80%. The second class with an observed significant loss of extent was 243 – *Land principally occupied by agriculture* with significant areas of natural vegetation, which decreased by 1.39%. The third most significant change was the reduction of extent of the category 133 *Construction sites by* 0.37%. A decreasing trend was evident in 13 out of 26 land cover classes. An increase of extent is most apparent in the case of category 242 *Production areas*, which increased by 1.12%. The second most significant change was seen in the category 324 *Transitional woodland-shrub*, which increased by 0.82% compared to 1990.

In the second buffer in 2006, the most significant landscape classes were represented by: 211 *Non-irrigated arable land* – 48.46%, 311 *Deciduous forests* – 11.11%, 112 *Discontinuous urban fabric* – 8.22%, 243 *Agricultural land with a significant proportion of natural vegetation* – 5.92%, 231 *Pasture* – 4.14%.

Graphic comparison of LC changes in two buffers is shown in Fig. 1. LC changes occurring in the second buffer were quite similar to the first, but a significant increase was present in class *Transitional woodland-shrub*, probably induced by the ongoing processes of extensification of agricultural land use and processes of landscape abandonment. The areal extent of class *Production sites* indicates a slight increase in industrial land use also in the case of the more distant buffer, which can be explained by new factories (such as the PSA near Trnava) usually not being built very close to the neighbouring town.

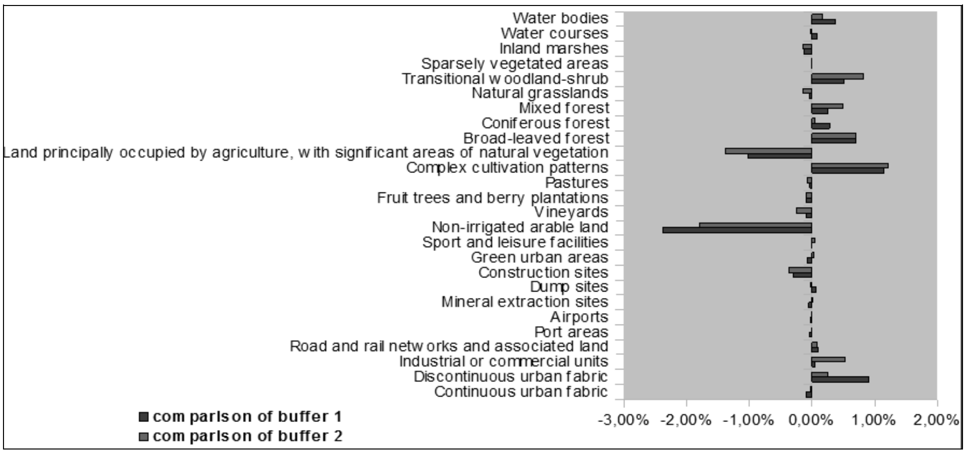

Fig. 1. Percentage changes of LC classes in 2 adjacent buffers around industrial patches (representing changes such as agricultural extensification, abandonment of agricultural land use and reforestation, and increase of urban patches)

Proportional comparison of areas of LC classes in the buffers at different time horizons gives us a first indication of the trends of changes in the landscape. On the other hand, comparing the relative size of LC classes between the first and second buffer reveals differences in composition of land cover in different areas and at different distances from industrialized areas.

Trends of land cover changes

Evaluation of LC changes demonstrated relatively small changes in both LC buffers and remote areas. This also applies to Slovakia's LC as a whole. For the first and second buffer around the industrial areas, as well as for the rest of the examined areas, more than 90% of the area did not change during 16 years. The strongest trend in the first buffers had been the intensification of agriculture in contrast to the second buffer where the extensification of agriculture was stronger. In remote landscape more than 10 km away from industrialized areas afforestation was proven to be the strongest trend (Fig. 2); afforestation was

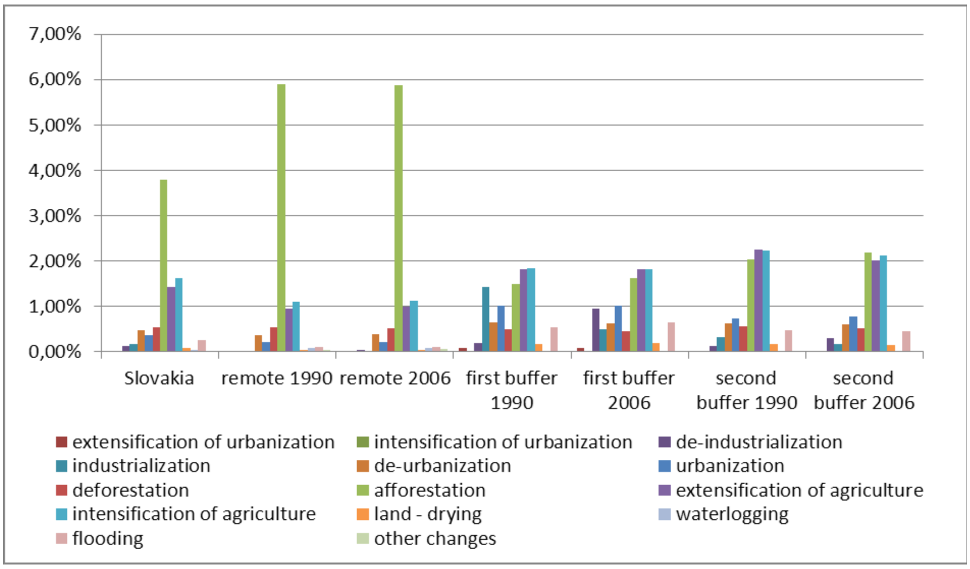

Fig. 2. Trends of land cover changes in the selected areas of Slovak landscape

also strongest in the case of the whole LC. The second most significant trend in the first buffer was extensification of agriculture. In the case of the second buffer, the whole LC and remote areas, it was intensification of agriculture. The third most important trend in the first buffer and the second buffer was afforestation. In the territories more than 10 km away from the industrialized areas, as well as in case of the whole LC, the 3rd strongest trend was extensification of agriculture. Slight differences in trends of LC changes can be observed by comparing buffers created for different time layers (buffers created around industrial patches in 1990 compared to 2006). These results reflect the fact that between the years 1990 and 2006 some of the patches ceased to exist while new industrial sites emerged in different spots (thus having a different surrounding LC). The precise percentage representation can be found in Tab 4. Graphic representations of LC change trends in 5 selected areas are given in Figs. 3-8.

Changes for the whole LC of Slovakia were included for the possibility of comparison between the buffers and remote areas. From the obtained data we can say that the remote areas do have more similar trajectories to the whole LC, while values of trends for the buffers differ significantly by not reflecting the overall strong trend of afforestation of the landscape. Values for the remote landscape and buffers slightly vary according to the year in which the layer had been created.

Tab. 4. Trends of LC changes in proportional form

Change	Slovakia	Remote 1990	Remote 2006	First buffer 1990	First buffer 2006	Second buffer 1990	Second buffer 2006
Without change	91.10	90.62	90.57	90.19	90.23	90.42	90.66
Extensification of urbanization	0.01	0.00	0.00	0.09	0.09	0.01	0.02
Intensification of urbanization	0.00	0.00	0.00	0.00	0.01	0.01	0.01
De-industrialization	0.14	0.01	0.03	0.20	0.96	0.13	0.30
Industrialization	0.16	0.02	0.02	1.44	0.49	0.32	0.17
De-urbanization	0.47	0.38	0.40	0.66	0.63	0.62	0.62
Urbanization	0.36	0.21	0.21	1.03	1.01	0.74	0.79
Deforestation	0.54	0.55	0.52	0.50	0.46	0.56	0.53
Afforestation	3.78	5.89	5.87	1.49	1.62	2.03	2.18
Extensification of agriculture	1.44	0.94	0.99	1.82	1.83	2.26	2.01
Intensification of agriculture	1.62	1.10	1.12	1.85	1.83	2.23	2.11
Land - drying	0.09	0.04	0.04	0.18	0.19	0.17	0.15
Waterlogging	0.03	0.09	0.09	0.01	0.01	0.01	0.01
Flooding	0.25	0.10	0.10	0.54	0.64	0.47	0.45
Other changes	0.02	0.05	0.06	0.00	0.01	0.02	0.01

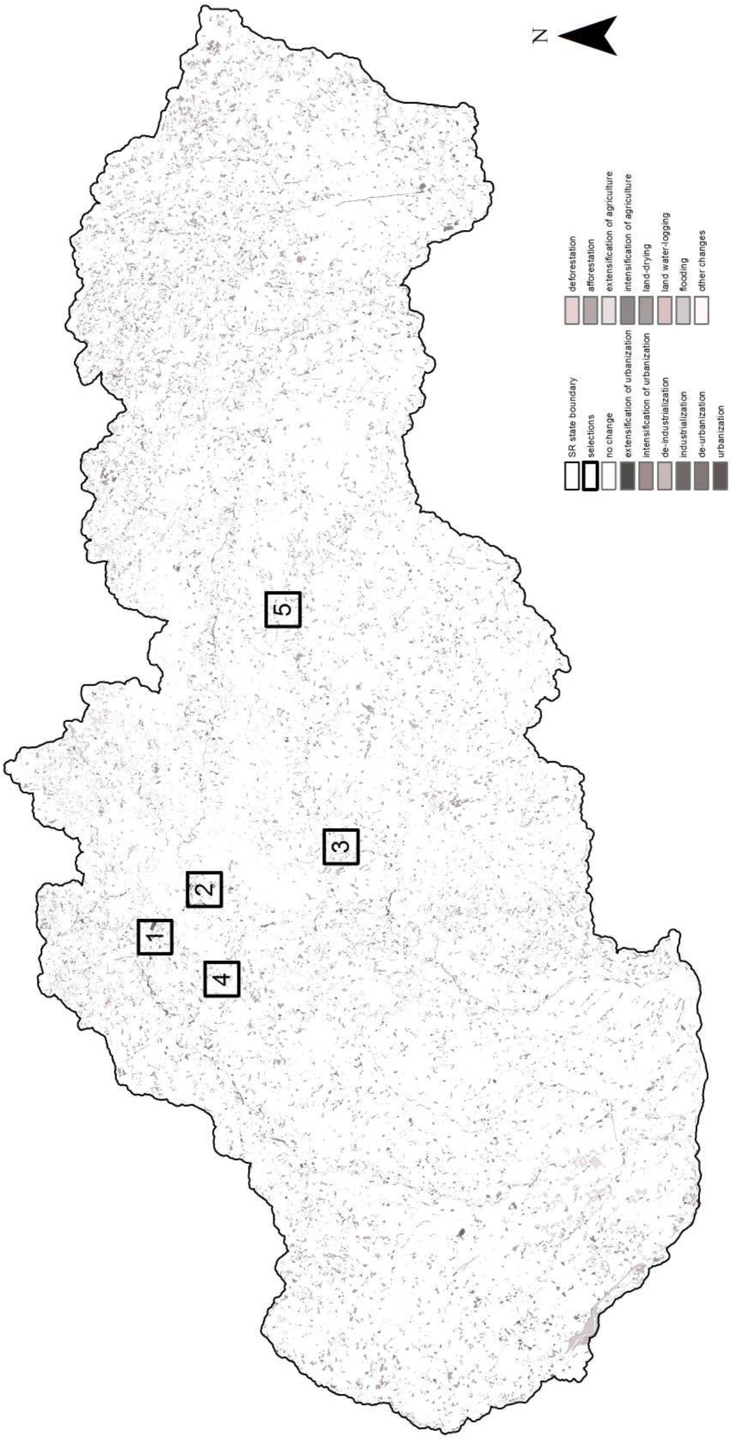

Fig. 3. Location of selected areas of LC made in 10 x 10 km square cut-outs

Square 1 represents LC near Žilina, the centre of square 2 is located near Martin and square 3 depicts LC around Banská Bystrica. Square 4 represents LC of a part of the Malá Fatra Mts., square 5 is located over the Slovenský raj NP.

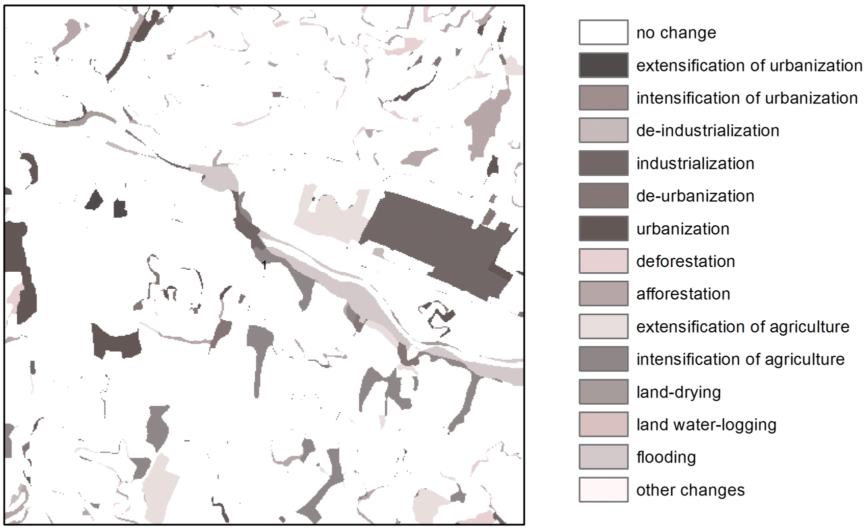

Fig. 4. Trends of LC changes near Žilina represent a LC cut-out of all changes in the LC of Slovakia

A significant trend of industrialization can be seen in the middle right part of the image occurring as a result of the KIA motors plant construction in 2004-2006.

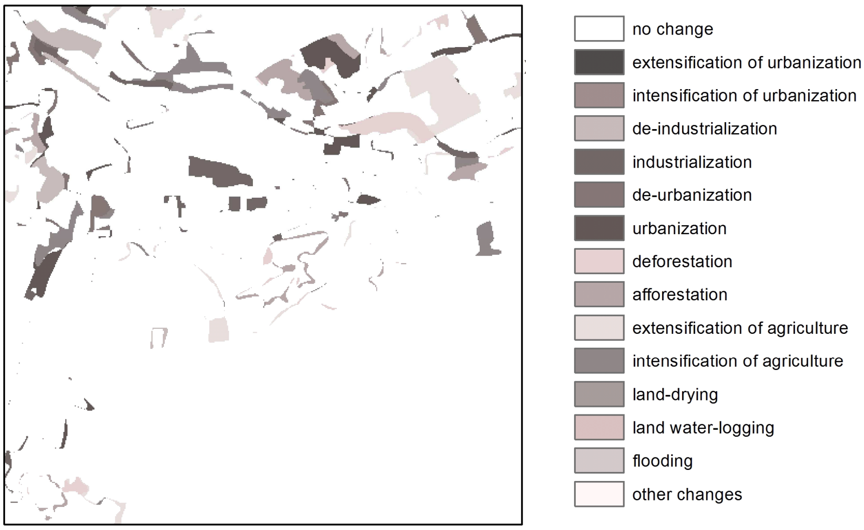

Fig. 5. Trends of LC changes in the buffer created around industrial patches near Martin according to 1990s LC

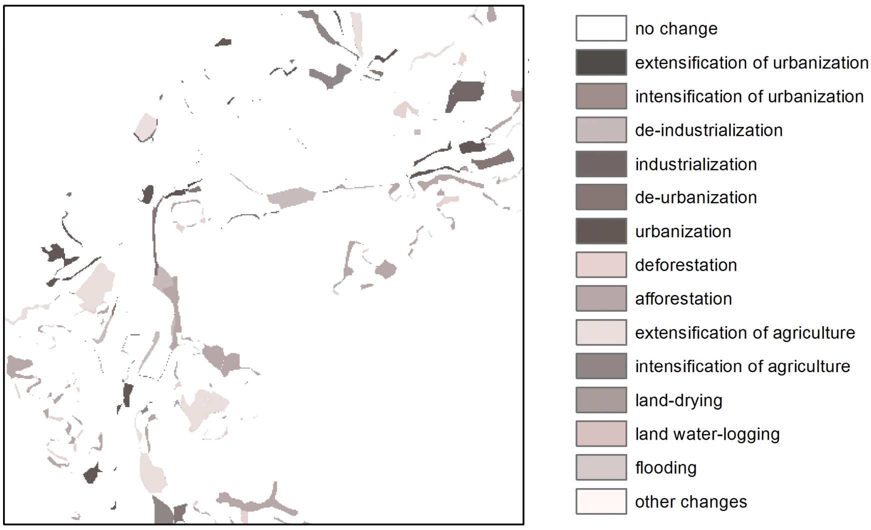

Fig. 6. Trends of LC changes in the buffer near Banská Bystrica according to the 2006 LC

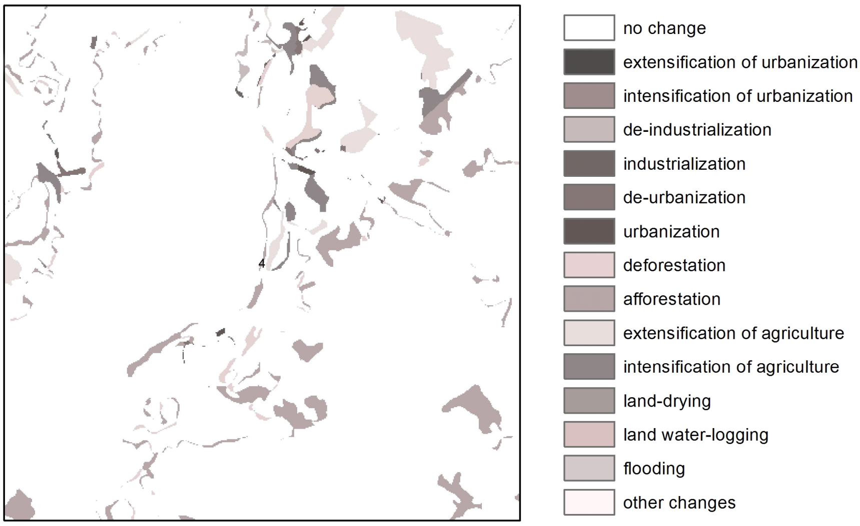

Fig. 7. Trends of LC changes in remote area in the Malá Fatra Mts. (more than 10 km away from industrial patches)

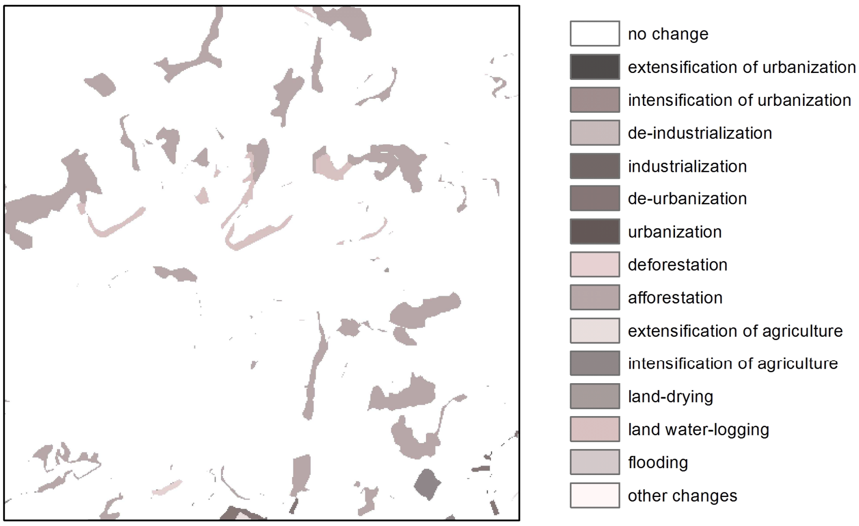

Fig. 8. Trends of LC changes, which occurred in remote area of the Slovenský raj NP (more than 10 km away from industrial patches)

Evaluation of land cover changes using landscape indices (Tab. 5)

Changes in values of the TE and ED indices show a reduction of the length of borders indicating that the length of ecotones was diminishing in the landscape along with the structural diversity and complexity of the land cover. The LPI index increase demonstrates the presence of the trend towards a more homogenous landscape when comparing the first two buffers, but it still maintains relatively small values, thus indicating that landscape holds fragmented small patches (in the case of the first buffer).

The area-weighted mean patch area of distribution (AREA_AM) increased in the second buffer and remote areas more than 10 km away from industrialized areas showing a significant level of fragmentation observed in the remote areas. The decrease of AREA_AM index was only observed in the first buffer showing that landscape patches got larger in the industrial surroundings. In the case of increasing values of the GYRATE_AM, index results indicate the growing fragmentation and complexity of patch shapes in the studied LC.

The values of indices describing landscape diversity within buffers around industrialized patches and the remote landscape vary considerably. While in the case of the first buffer an increase in the patch richness density index of 0.0004 can be observed, this value was only about 0.0002 for the 2nd buffer and 0 in the remote landscape. Differences in land cover structure relating to the distance from the industrialized patches became even more obvious looking at the values of SHDI and SHEI diversity indices, which only slightly changed in the case of the remote landscape compared to the values obtained in the two buffers located close to industrialized areas.

Tab. 5. Comparison of landscape indices

	TA	LPI	TE	ED	AREA_AM	GYRATE_AM	PRD	SHDI	SHEI
first 1990	251 528.32	0.6674	5 530 520	21.9877	342.5574	812.5772	0.0103	1.7328	0.5319
first 2006	243 843.64	0.7671	6 003 780	24.6214	340.5531	813.8736	0.0107	1.8149	0.5570
second 1990	377 881.44	1.3271	9 092 520	24.0618	502.5947	1 111.2150	0.0069	1.7188	0.5275
second 2006	367 372.32	1.2011	8 524 140	23.2030	521.7521	1 124.9030	0.0068	1.7687	0.5495
remote 1990	1 094 938.50	2.9805	32 555 620	29.7328	5 289.2605	2 932.9920	0.0024	2.0819	0.6390
remote 2006	1 087 862.80	3.4210	30 567 080	28.0983	5 594.2028	3 189.9777	0.0024	2.0864	0.6400

TA – total area, LPI – land shape index, TE – total edge, ED – edge density, AREA_AM – area-weight mean patch size, GYRATE_AM – area-weight mean radius of gyration, PRD – patch richness density, SHDI – Shannon's diversity Index, SHEI – Shannon's Evenness Index

Results show than the land cover characteristics differ greatly according to proximity to industrial patches. The values of most indices in the remote areas are higher compared to values in two adjacent buffers, also showing bigger amplitude of change. The difference between the 1st and the 2nd buffers is clearly shown, indicating that land cover changes occurring at greater distance from the industrial patches might be induced by different drivers of change, and that distance from industry is potentially an important factor of land cover dynamics.

DISCUSSION

Studies of LC changes have shown that not all causes of changes at all levels of organization are equally important (Geist and Lambin 2004). In Slovakia, LC changes captured by the Corine Land Cover were evaluated within the European project BIOPRESS on 8 transects in the years 1950-1990 and 1990-2000 (Gerard et al. 2006). Most transects have captured both urbanized and more natural landscapes in varying proportions. The evaluation carried out using the first CLC legend level in most cases pointed out the growth of artificial surfaces. According to Feranec et al. (2000), who evaluated changes in the LC of Slovakia in the period 1970-1990, the trend of deforestation (25.9%), decrease (23.5%) and increase (34.3%) of intensively farmed agricultural areas were proved as the most significant. Feranec and Oťaheľ (2009) evaluated LC changes in Slovakia in the 1990-2000 and 2000-2006 periods. Their research showed trends of LC changes similar to our results, although they considered changes in the whole area of the Slovak Republic. According to data from the MURBANDY/Moland project (Lavalle et al. 2001), the phenomenon of increasing urban sprawl around Bratislava between 1950 and 1990 was the fourth most significant in Europe (with 202.6%), with 18.6% of the studied area experiencing the loss of natural or agricultural land use. However, such a dramatic view is not present in our examined landscape cut-outs. LC changes and their trends identified by Blažík et al. (2011) represent similar results in decrease of agricultural areas and the increasing trend of urbanization (although their research took place in slightly different locations). The trend of urbanization within 2 km from industrial areas was the 4th strongest (it should also be mentioned that the trends of LC changes for areas around Bratislava are a logical result of a spatially unequal development of the Slovak economy). In the case of territories more than 10 km away from the industrialized patches, the trend of de-urbanization was more significant than urbanization processes. These statements however do not pay any attention to the fact that over 90% of the investigated area represented no changes of land cover, and trends of land cover changes in the given land cover classes ranged from 0.01 to 2.55%, which can be considered relatively low. The largest increase in extensification and intensification of agriculture and afforestation can be observed in the first two buffers around industrialized areas. Given that agricultural land was the dominant LC component located in close proximity to industrial areas and the second most dominant class was the forest class, these trends seem to be logical. Afforestation of landscape proved to be the most significant trend within territories at least 10 km away from the industrialized areas and in the overall LC of Slovakia. Evaluation of LC changes using landscape indices showed an increase of landscape diversity in the first two buffers, decrease in territories more than 10 km away from industrialized areas, reduction of the ecotone length in landscape (in remote territories), and increase of shape regularity of landscape patches located nearest to the industrialized areas, while the land cover of the second buffer and the remote landscape showed changes in the opposite direction (fragmentation).

CONCLUSIONS

When we combine the processes identified in LC with the trend of decreasing spatial density of industrialized areas in Slovakia, it can be argued that the upward trend in industrial production is not directly related to the changes that occurred in the examined landscape. Comparing the structure of LC and changes in the close surroundings of industrial areas and in the remote landscape more than 10 km away from these areas proved that the strongest trends were both the extensification and intensification of agriculture and afforestation. On the other hand, there is a predominance of afforestation over intensification and extensification of agriculture in a remote landscape proving that the process of landscape abandonment took place in these areas. The trend of urbanization declined with increasing distance from industrial areas and values of landscape indices indicate that the LC of the first buffer is quite different from the second buffer and from the land cover of the remote areas as well, thus showing that landscape closely surrounding industrial areas is on a different trajectory of LC changes.

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ZMENY KRAJINNEJ POKRÝVKY SLOVENSKA MEDZI ROKMI 1990-2006 VO VZŤAHU K VZDIALENOSTI OD PRIEMYSELNÝCH PLÔCH A K EKONOMICKÉMU ROZVOJU

V príspevku hodnotíme zmeny krajinnej pokrývky, ku ktorým došlo počas 16 rokov na kontaktných územiach priemyselných plôch a okolitej krajinnej pokrývky. Pokúsili sme sa odpovedať na otázku, či zvýšenie priemyselnej činnosti (vyjadrené pomocou údajov o priemyselnej výrobe na Slovensku) spôsobuje nárast vybraných ukazovateľov industrializácie a urbanizácie v územiach, ktoré sa nachádzajú v tesnej blízkosti existujúcich priemyselných oblastí. Industrializácia úzko súvisí s poklesom prírodných krajinných prvkov na veľkých plochách krajiny a s degradáciou prírodného prostredia. Analyzovali sme hustotu a rozmiestnenie existujúcich priemyselných plôch a zisťovali, či a ako sa zmeny týchto hodnôt odrážali na zmenách v krajinnej pokrývke plôch vo vzdialenosti viac ako 10 km od najbližšieho priemyselného areálu.

V metodickom postupe sme použili mapy krajinnej pokrývky Európy Corine Land Cover (CLC) z rokov 1990 a 2006 vo vektorovom formáte, ktoré boli následne konvertované na rastrovú formu s veľkosťou bunky 5×5 metrov a tretiu úroveň CLC kódovania. Extrakcia buniek, ktoré patrili do CLC triedy „3, 121, umelé povrchy, priemyselné, obchodné a prepravné jednotky, priemyselné alebo komerčné jednotky“ bola vykonaná v prostredí ArcGIS 9.3. Následne sme vypočítali index najbližšieho suseda založený na priemernej euklidovskej vzdialenosti susedných prvkov. Zmeny krajinnej pokrývky v najbližšom okolí priemyselných plôch sme analyzovali na dvoch pásoch so šírkou 1 km umiestnených koncentricky okolo priemyselných plôch. Zmeny krajinnej pokrývky boli hodnotené ako pomerné zmeny v rámci jednotlivých kategórií krajinnej pokrývky. Porovnanie zmien hodnôt krajinných indexov sme využili na určenie zmien krajinnej pokrývky z hľadiska usporiadania a konfigurácie. Trendy zmien krajinnej pokrývky boli skúmané na základe metodiky Cebecauerová (2007) a Oťaheľ et al. (2004) nasledovne: žiadna zmena, extenzifikácia urbanizácie, intenzifikácia urbanizácie, deindustrializácia, industrializácia, deurbanizácia, urbanizácia, odlesňovanie, zalesnenie, extenzifikácia poľnohospodárstva, intenzifikácia poľnohospodárstva, vysušenie, zamokrenie, zatopenie, ostatné zmeny. Vybrané indexy krajinnej pokrývky pre oba časové horizonty boli vypočítané s použitím FRAGSTATS 3.3 (McGarigal a Marks 1995). Pre hodnotenie priestorových vlastností vybraných výrezov krajinnej pokrývky sme použili tieto krajinné indexy (na úrovni krajinnej metriky): index celkových hraníc, index hustoty hraníc, index najväčšej plôšky, vážený priemer indexu distribúcie plôšok, vážený priemer indexu polomeru gyrácie a tri indexy diverzity krajinnej pokrývky. Jedna ekonomická premenná bola vybraná ako ukazovateľ priemyselného vývoja v krajine – priemyselná produkcia v mil. eur ročne.

Štúdium zmien krajinnej pokrývky ukázalo, že nie všetky príčiny zmien na všetkých úrovniach organizácie sú rovnako dôležité (Geist a Lambin, 2004). Podľa údajov z projektov MURBANDY/MOLAND (Lavalle et al. 2001) bol fenomén nárastu mestskej zástavby okolo Bratislavy medzi r. 1950-1990 štvrtým najvýznamnejším v Európe (s 202,6 %), keď na 18,6 % skúmanej oblasti došlo k strate prírodného charakteru alebo poľnohospodárskeho využitia pôdy. Naše výsledky neposkytujú taký dramatický pohľad v rámci skúmaných oblastí. Trend urbanizácie vo vzdialenosti 2 km od priemyselnej zóny bol až štvrtým najdôležitejším trendom. V prípade území vzdialených viac ako 10 km od priemyselných plôch bol trend deurbanizácie výraznejší ako trend urbanizačných procesov. Naše údaje ukazujú, že na viac ako 90 % rozlohy sledovaných oblastí nenastali zmeny krajinnej pokrývky a trendy zmien krajinnej pokrývky v rámci daných kategórií boli v rozmedzí od 0,01 do 5,89 %, čo sú relatívne nízke hodnoty. V prvých dvoch pásoch okolo priemyselných oblastí môžeme pozorovať najväčší nárast extenzifikácie a intenzifikácie poľnohospodárstva a zalesňovania územia. Vzhľadom na to, že poľnohospodárska pôda bola dominantnou zložkou krajinnej pokrývky nachádzajúcej sa v tesnej blízkosti priemyselných plôch, pričom druhou v poradí bola kategória lesných porastov, zdajú sa byť hodnoty týchto trendov logické. V oblastiach vzdialených viac ako 10 km od priemyselných plôch sa najvýznamnejšie ukázal trend zalesňovania krajiny. Trendy industrializácie a urbanizácie sa najvýraznejšie prejavili v prípade prvého pásu v okolí industrializovaných plôch. Hodnotenie zmien krajinnej pokrývky s využitím krajinných indexov preukázalo nárast krajinnej diverzity v prvých dvoch pásoch a jej pokles v oblastiach vzdialených viac ako 10 km od priemyselných oblastí, kde sa silne prejavil aj trend zmenšovania dĺžky ekotonov v krajine, nárast pravidelnosti tvaru plôšok bol signifikantný v najtesnejšej blízkosti priemyselných plôch, zatiaľ čo v krajinnej pokrývke druhého pásu a oblastí vzdialených viac ako 10 km od industriálnych plôch nastali zmeny v opačnom smere (fragmentácia).

Vychádzajúc zo vzťahu identifikovaných zmien v krajinnej pokrývke k trendu znižovania priestorovej hustoty priemyselných oblastí na Slovensku môžeme povedať, že vzostupný trend v priemyselnej produkcii krajiny priamo nesúvisí so zmenami, ku ktorým došlo v nami skúmaných oblastiach. Porovnanie štruktúry krajinnej pokrývky a zmien v blízkom okolí priemyselných plôch a v oblastiach vzdialených viac než 10 km od industrializovaných plôch ukázalo, že najvýznamnejšími trendmi v oboch prípadoch boli extenzifikácia a intenzifikácia poľnohospodárstva a zalesňovanie. Na druhej strane, vo vzdialenej krajine prevládol trend zalesňovania nad intenzifikáciou a extenzifikáciou poľnohospodárstva, čo potvrdzuje prítomnosť fenoménu upúšťania od poľnohospodárskeho využitia krajiny. Trendy industrializácie a urbanizácie klesajú s rastúcou vzdialenosťou od priemyselných oblastí a zo zistených hodnôt krajinných indexov a ich rozdielov vyplýva, že krajinná pokrývka prvého pásu sa značne líši a podlieha zmenám rýchlejšie ako krajinná pokrývka druhého pásu a oblastí vzdialených viac ako 10 km od priemyselných plôch. Krajina v tesnej blízkosti priemyselných plôch vykazuje odlišnú trajektóriu zmien krajinnej pokrývky a mení sa dynamickejšie ako ostatné skúmané oblasti.