SPATIO-TEMPORAL TRENDS OF LANDSCAPE DEVELOPMENT IN SOUTHWEST PART OF SLOVAKIA: ANALYSIS OF MAJOR LANDSCAPE CHANGE TYPES

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Abstract

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Landscape changes identified from multitemporal land cover databases allow the detection of the changes of individual landscape elements with high spatio-temporal precision. The similarity of the causal relations as well the characteristic states of landscape before and after change allowed us to group individual land cover changes into the landscape change types representing more complex processes in the landscape. In the paper, 13 landscape change types were proposed for the analysis of major developmental trends in the study area during the last 50 years. The described landscape change types derived from land cover databases of four time horizons, allowed us to identify and understand some of the spatial and temporal trends of landscape development related to main social and economic changes, which happened during the second half of the 20th century. Results show that during the last 50 years, the 63.9% of the study area changed. The most significant processes forming the contemporary landscape structure were urbanization, industrialization, intensification and extensification of agriculture and loss of agricultural land. The influence of these processes on the landscape development was changing during the analysed time periods.

Key words: CORINE Land Cover, land cover change, landscape change types

Introduction

The understanding and regulation of environmental changes is a great challenge for whole society. The study of landscape helps to set indicators and strategic plans for monitoring and modelling of these changes (Lambin et al., 2003; Verburg, Veldkamp, 2005). The driving forces behind contemporary changes are above all in the demographic evolution, technological innovations, general globalisation processes and easy access to fossil energy

(Gulinck et al., 2001). The decrease of soil in favour artificial surfaces, transformation of soil and water systems, development of intensive agricultural production areas in contrast with abandoned areas and loss of the traditional landscape character – these are some of the often-mentioned consequences of landscape changes.

The complex co-ordination of landscape development processes requires environmental information appropriate for global comparisons and approaches of landscape assessment applicable at different levels of detail. The analysis of visual and cultural characteristics as an observable manifestation of landscape system structures is in Europe connected to evaluation of CORINE Land Cover (CLC) databases. Along with other information sources, the land cover database constitutes an important input for various landscape evaluations (EEA, 2001; Siedentop, Meinel, 2004).

The analysis of multitemporal land cover databases derived from remote sensing data is an effective approach to understanding of landscape changes (Turner, 1990; Ihse, 1995; Feranec et al., 1997). This approach allows to analyse and interpret spatial (area) changes of landscape elements, to identify changes of their spatial structure (by spatial metrics techniques, Antrop, Van Eetvelde, 2000) and subsequently to deduct the landscape changes, which are not directly detectable from remote sensing data such as species diversity loss or decay of cultural heritage (Gulinck et al., 2001; Kolejka, 2001).

Some types of landscape elements changes have been attracting attention of researchers for a long time because of their evident influence on the overall landscape system functioning (deforestation, changes of agricultural land utilisation, enlargement of settlements – urbanization, etc.). This paper presents the approach to identification of 13 selected landscape change types through processing of land cover databases. The identification and analysis of landscape change types within the spatial context of whole study area helps to understand the main development trends and transformations of landscape elements situated in the centre of social interest. The definition of landscape change types is a purpose-based selection of land cover changes and their grouping into types, indicating more complex processes in the landscape. The land cover change analysis based solely on the contingency tables (constructed from the CLC classes) usually does not allow to understand wider context of landscape processes, therefore the identification of common features of partial changes may help us to detect specific trends of landscape development.

Methodology

Study area

The study area (131.57 km^2, Fig. 1) is situated in the SW part of Slovakia mainly in the southern part of Borská nížina lowland and partly in the adjacent part of Malé Karpaty Mts. The NW part of Bratislava (city wards Lamač and Dúbravka) is situated in the southern part of the study area. The central part with city wards Devínska Nová Ves and Záhorská Bystrica (rural settlements annexed to Bratislava in 1972) and the northern part with the town Stupava form the suburban zone of Bratislava. Forests are forming three complexes – forests of Devínske Karpaty, Pezinské Karpaty and the lowland forest extending at the NW from Stupava.

Fig. 1. Location of the study area.

Morava river, the largest watercourse in study area, represents west border of the area.

Land cover changes

The analysis of land cover changes was based on the multitemporal databases representing the state of land cover in four time horizons. These databases were derived by the computer aided visual interpretation of aerial images from years 1954, 1979, 1992 and 2003 (Cebecauerová, Cebecauer, 2004, 2005) using the modified CLC nomenclature designed for scale 1:50 000 (Feranec, Oťaheľ, 1999). This nomenclature, following the principles of the CORINE land cover nomenclature for scale 1:100 000 (EC, 1993; Feranec, Oťaheľ, 2001), was extended with the aim to respects national particularities and scale differences. It comprises four hierarchic levels, on the first level it is divided into 5 classes and on the fourth level into 77 classes, from which 36 were identified in the study area. The process of database generation is described in more detail in Cebecauerová (2004).

The first step in the analysis of landscape changes was the integration of the four databases by overlay and the identification of changed areas – creation of the change databases 1954–1979, 1979–1992 and 1992–2003. By the comparison of land cover states in the individual time were identified:

– selected characteristics (extent, number of areas) for change analysis,
– contingency tables allowing us to study mutual changes among classes of land cover for three periods (1954–1979, 1979–1992, 1992–2003),
– maps of land cover changes allowing the identification of spatial distribution of land cover changes horizons were derived.

T a b l e 1. Conversion table of land cover changes into landscape change types.

Land cover classes 1954 (1979, 1992) \ Land cover classes 1979 (1992, 2003)	112	121	122	131	132	133	141	142	211	221	222	231	242	311	312	313	324	411	511	512
112	-	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
121	o	-	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
122	o	o	-	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
131	R	R	R	-	o	o	R	R	R	o	o	R	R	R	R	R	R	o	o	o
132	R	R	R	x	-	o	R	R	R	o	o	R	R	R	R	R	R	o	o	o
133	u	t	t	x	o	-	u	u	R	o	o	R	R	R	R	R	R	o	o	o
141	o	o	o	x	o	o	-	o	o	o	o	o	o	o	o	o	o	o	o	o
142	o	o	o	x	o	o	o	-	o	o	o	o	o	o	o	o	o	o	o	o
211	u L	t L	t L	x L	t L	t L	u L	u L	-	i	i	e	e	a L	a L	a L	a L	w L	d L	L
221	u L	t L	t L	x L	t L	t L	u L	u L	e	-	o	e	o	a L	a L	a L	a L	w L	d L	L
222	u L	t L	t L	x L	t L	t L	u L	u L	e	o	-	e	o	a L	a L	a L	a L	w L	d L	L
231	u L	t L	t L	x L	t L	t L	u L	u L	i	i	i	-	i	a L	a L	a L	a L	w L	d L	L
242	u L	t L	t L	x L	t L	t L	u L	u L	i	i	i	e	-	a L	a L	a L	a L	w L	d L	L
311	u D	t D	t D	x D	t D	t D	u D	u D	i D	i D	i D	i D	i D	-	o	o	D	w D	d D	D
312	u D	t D	t D	x D	t D	t D	u D	u D	i D	i D	i D	i D	i D	o	-	o	D	w D	d D	D
313	u D	t D	t D	x D	t D	t D	u D	u D	i D	i D	i D	i D	i D	o	o	-	D	w D	d D	D
324	u D	t D	t D	x D	t D	t D	u D	u D	i D	i D	i D	i D	i D	a	a	a	-	w D	d D	D
411	u	t	t	x	t	t	u	u	i E	E	E	i E	E	a E	a E	a E	a E	-	o	o
511	u	t	t	x	t	t	u	u	o	o	o	o	o	a	a	a	a	o	-	o
512	u	t	t	x	t	t	u	u	o	o	o	o	o	a	a	a	a	o	o	-

Landscape change types

u	Urbanization
t	Industrialization and technicization
x	Enlargement or exhaustion of natural resources
i	Intensification of agriculture
e	Extensification of agriculture
a	Afforestation and reforestation
w	Waterlogging
d	Drainage
R	Reconstruction, reclamation
L	Loss of agricultural land
D	Deforestation
E	Extinction of swamps
o	Other changes (unclassified changes)
-	Not changed area
	Areas with two landscape change types

Land cover classes

1st level		2nd level		3rd level	
1	Artificial surfaces	11	Urban fabric	112	Discontinuous urban fabric
		12	Industrial, commercial and transport units	121	Industrial or commercial units
				122	Road and rail networks and associated land
		13	Mine, dump and construction sites	131	Mineral extraction sites
				132	Dump sites
				133	Construction sites
		14	Artificial, non agricultural vegetated areas	141	Green urban areas
				142	Sport and leisure facilities
2	Agricultural areas	21	Arable land	211	Non-irrigated arable land
		22	Permanent crops	221	Vineyards
				222	Fruit trees and berry plantations
		23	Pastures	231	Pastures
		24	Heterogeneous agricultural areas	242	Complex cultivation patterns
3	Forest and semi-natural areas	31	Forests	311	Broad-leaved forests
				312	Coniferous forests
				313	Mixed forests
		32	Scrub and/or herbaceous vegetation associations	324	Transitional woodland-scrub
4	Wetlands	41	Inland wetlands	411	Inlands marshes
5	Water bodies	51	Inland waters	511	Water courses
				512	Water bodies

Identification and evaluation of landscape change types

The classes of land cover change databases 1954–1979, 1979–1992 and 1992–2003 were reclassified into 13 types of landscape changes according to the reclassification table (Table 1). The construction of reclassification table for conversion of land cover changes to landscape change types was based on the methodical principles of Feranec et al. (2000, 2002) who derived landscape change types by association of land cover changes at the second hierarchic level of CLC nomenclature to specific landscape processes or specific states of landscape after changes. For the purpose of this work the reclassification table was constructed for land cover changes at the third hierarchic level of CLC nomenclature (Table 1). This approach allowed us to evaluate landscape changes in more details and highlight some processes related to information content of the third hierarchic level of CLC nomenclature. The table assigns each combination of CLC 1954–1979, CLC 1979–1992 and CLC 1992–2003 change to the corresponding landscape change type. Number of combinations of land cover changes (1296 combinations) was simplified by reclassification to the database of 13 landscape change types for each of the three studied time periods (1954–1979, 1979–1992, 1992–2003). The area extent of individual types was identified and compared to the extent of the whole study area and that of changed area in each of the studied periods. The spatial distribution of landscape change types is presented on Fig. 4. In majority of proposed landscape change types the land cover changes were realised at the first hierarchic level of CLC nomenclature. The exception was the analysis of processes in the agricultural landscape and forests, where along with the enlargement of the areas by the change of main classes, the changes within classes of agricultural landscape or forest landscape were considered.

The process of land cover change encompasses two sub-processes: old class extinction and new class emergence. These two processes were distinguished and treated separately in the course of landscape change types identification and evaluation (cells with two codes in the Table 1). For example, the change of forest into a housing estate may be considered as the process of deforestation and at the same time as the process of urbanization. In this case the both processes are taking place at the same location. By taking into consideration this fact the landscape change types are divided into types indicating processes of extinction: *urbanization, industrialization and technicization, enlargement or exhaustion of natural resources, intensification and extensification of agriculture, afforestation, waterlogging, drainage***,** and processes of emergence: *reconstruction* and *reclamation, loss of agricultural land, deforestation, extinction of swamps* (Fig. 4a, b, c).

Characteristics of type of landscape changes (based on information which is attributed to CLC database)

Urbanization (u) – this process includes enlargement of residential areas in towns and settlements; it represents the changes of agricultural, forest and semi-natural areas, wetlands and water bodies (classes 2xx, 3xx, 4xx a 5xx) into urbanized areas with residential houses, and buildings designated for education, health care, recreation and sport (classes 11x and 14x).

Industrialization and technicization (t) – it represents changes of agricultural, forest and semi-natural areas, wetlands and water bodies (classes 2xx, 3xx, 4xx a 5xx) into classes: constructions and facilities for industrial and agricultural production and all means of transport and classes of construction and dump sites.

Enlargement or exhaustion of natural resources (x) – contains the changes of all classes into the mineral extraction sites (131).

Intensification of agriculture (i) – is defined as the process of increase of the resources and labour share applied on the unit of area (Ivanička, 1983); this process encompasses the changes of classes 3xx and 4xx into class 2xx (representing increase of class 2xx) and specific changes of the agricultural land utilisation fulfilling criteria of intensification (the following changes were assigned to this type: changes of pastures and complex cultivation patterns into arable land, vineyards or fruit trees and berry plantations; change of pastures into complex cultivation patterns; changes of arable land into vineyards and fruit trees and berry plantations).

Extensification of agriculture (e) – reverse process to intensification; it represents changes of vineyards, fruit tree and berry plantations into arable land or pastures; changes of arable land into pastures or complex cultivation patterns; changes of complex cultivation patterns into pastures. The process of extensification is related only to the inner changes within agricultural landscape, the changes of arable land into other classes at the first hierarchic level (2xx 1xx, 3xx, 4xx, 5xx) are classified as other processes. The land cover changes belonging to landscape change types of intensification and extensification of agriculture unambiguously indicate the assignment of new areas to the one of the classes of agriculture land (2xx). Although these processes in

some cases reflect the internal transformations of class 2xx evaluated from the aspect of utilization intensity, we incorporate them into the processes indicating the emergence of classes. By this approach we accept the conventional attitude to the evaluation of changes of the agricultural land utilization.

Afforestation (reforestation) (a) – natural or man-induced changes of areas after felling into forests or emergence of forest on the new areas; this process is represented by changes of arable land, wetlands and water bodies into forests or transitional woodland-scrub; change of transitional woodland-scrub into forests.

Waterlogging (w) – enlargement of inland marshes situated in the agricultural, forest and semi-natural landscape; in the study area this process is triggered by natural factors – the increased level of water during floods in the inundation part of alluvial plains.

Drainage (d) – the process of surplus water draining from the landscape by the network of artificial drainage channels constructed in the agricultural and forest and semi-natural landscape.

Reconstruction and reclamation (R) – improvement of undesirable landscape conditions and revitalisation of environment; it represents changes of mineral extraction sites and dump sites into other artificial surfaces or agricultural, forest and semi-natural areas; changes of construction sites into agricultural, forest and semi-natural areas.

Loss of agricultural land (L) – denotes substantial change of land resources utilisation, these changes are characterized by the loss of land used for agricultural production; it represents all changes of agriculture areas (2xx) into other classes on the first hierarchic level of CLC nomenclature (1xx, 3xx, 4xx, 5xx)

Deforestation (D) – is characterized by the change of forest and transitional woodland-scrub areas by anthropogenic activities (clear-cuts, devastation) and natural disasters into other classes. The result of this process is the permanent loss of forest and semi-natural areas or temporal change of forests into transitional woodland-scrubs.

Extinction of swamps (E) – change of inland marshes into classes of agricultural, forest and semi-natural areas.

Other changes (o) – unclassified changes (waste depositions, etc.).

Results

Land cover changes

The intensive landscape dynamics induced above all by human pressure was the characteristic feature of the study area in recent 50 years. The most significant changes identified were the increase of artificial surfaces from 5% in the year 1954 to 14% of the study area in the year 2003 and decrease of the agricultural surfaces by 12% to final 57% in the year 2003. Especially during the first period (1954–1979), the growth of the Bratislava city wards was noticeable, above all by the construction of new residential areas (housing estates), industrial facilities with associated transport and technical infrastructure. In the succeeding periods the growth of artificial surfaces continued, however with lower intensity.

The extent of the agricultural areas was decreasing in the course of all studied periods as a result of increase of artificial surfaces and moderate change of forest and semi-natural areas, however the most intensive decrease was during the first period (1954–1979). The vast changes taking place within the agriculture areas significantly changed the impression of landscape. The collectivisation and modernisation of agricultural production induced extensive changes especially during the first period, the mosaic of small plots of arable land and pastures cultivated by individual farmers was replaced by large plots of arable land cultivated by co-operative and state farms and the extent of pastures considerably

decreased. Only in the last period (1992–2003), the reverse processes appeared, the extent of arable land decreased and area of pastures increased. This trend is the result of political and economic transformations that started in 1989 and actual influence of the European agricultural policy – the trend of intensive agricultural cultivation only on the most productive areas (Bastian, Steinhard, 2002; Lipský, Kvapil, 2000).

The overall extent of forests and semi-natural areas was during all periods slightly increasing, positively influencing the ecological quality of the whole territory. The spatial structure of large forest complexes is one of the most stable landscape elements, the changes of forests took place predominantly on the transition to the agricultural areas with gradual transformation of pastures into forests. Within the agricultural landscape, the increase of forest and semi-natural areas was connected above all with the growth of riparian vegetation along the drainage channels.

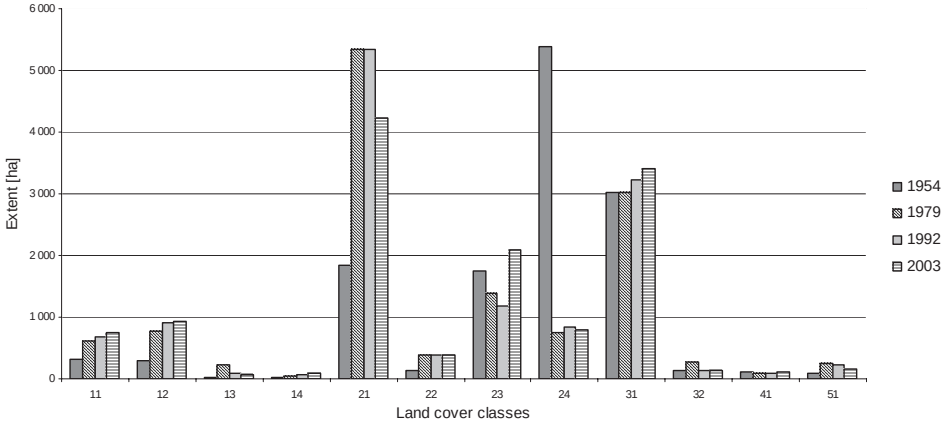

Fig. 2. Extent of land cover classes in the years 1954, 1979, 1992 a 2003 (2nd hierarchic level). Explanation of land cover classes is presented in Table 1.

T a b l e 2. The chosen characteristics of land cover classes (first and second hierarchic level).

Land cover class	1954		1979		1992		2003		Change (1979-1954)		Change (1992-79)		Change (2003-1992)	
	[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]	[ha]	[%]
11	319.38	2.43	617.90	4.70	671.87	5.11	751.52	5.71	298.51	2.27	53.97	0.41	79.66	0.61
12	300.18	2.28	763.33	5.80	917.13	6.97	926.79	7.04	463.15	3.52	153.80	1.17	9.66	0.07
13	25.49	0.19	231.27	1.76	100.71	0.77	68.51	0.52	205.78	1.56	-130.55	-0.99	-32.20	-0.24
14	19.91	0.15	51.82	0.39	62.91	0.48	90.78	0.69	31.91	0.24	11.09	0.08	27.87	0.21
1	**664.97**	**5.05**	**1664.32**	**12.65**	**1752.62**	**13.32**	**1837.60**	**13.97**	**999.35**	**7.60**	**88.30**	**0.67**	**84.99**	**0.65**
21	1845.95	14.03	5334.30	40.54	5352.07	40.68	4233.74	32.18	3488.35	26.51	17.77	0.14	-1118.34	-8.50
22	144.11	1.10	378.07	2.87	386.34	2.94	376.57	2.86	233.97	1.78	8.27	0.06	-9.77	-0.07
23	1747.95	13.28	1390.17	10.57	1172.97	8.91	2091.65	15.90	-357.77	-2.72	-217.20	-1.65	918.68	6.98
24	5389.82	40.96	752.83	5.72	831.97	6.32	799.17	6.07	-4636.99	-35.24	79.14	0.60	-32.80	-0.25
2	**9127.83**	**69.37**	**7855.38**	**59.70**	**7743.35**	**58.85**	**7501.12**	**57.01**	**-1272.46**	**-9.67**	**-112.03**	**-0.85**	**-242.23**	**-1.84**
31	3014.82	22.91	3015.84	22.92	3223.37	24.50	3412.04	25.93	1.02	0.01	207.53	1.58	188.68	1.43
32	143.48	1.09	275.37	2.09	131.69	1.00	144.27	1.10	131.88	1.00	-143.67	-1.09	12.58	0.10
3	**3158.30**	**24.00**	**3291.20**	**25.01**	**3355.06**	**25.50**	**3556.32**	**27.03**	**132.90**	**1.01**	**63.86**	**0.49**	**201.25**	**1.53**
4 (41)	**108.74**	**0.83**	**101.59**	**0.77**	**87.41**	**0.66**	**110.51**	**0.84**	**-7.15**	**-0.05**	**-14.18**	**-0.11**	**23.10**	**0.18**
5 (51)	**97.70**	**0.74**	**245.07**	**1.86**	**219.10**	**1.67**	**151.99**	**1.16**	**147.36**	**1.12**	**-25.96**	**-0.20**	**-67.12**	**-0.51**

Landscape change types

The **urbanization** was most intensive during the first period (1954–1979) and took place at almost 3% of the total study area due to an extensive construction of housing estates and residential areas. During the second and third periods this process was connected with the growth of residential areas and associated urban greenery. In Stupava, Marianka, Záhorská Bystrica and Devínska Nová Ves the growth of residential areas was situated in adjacency to the existing built-up area. The construction of new building complexes in the city wards Dúbravka and Lamač was situated on the slopes of Pezinské Karpaty and Devínske Karpaty Mts in direction to Lamačská brána – where almost a continuous new urban zone was formed. During the last period the urbanization slightly increased and the new suburban residential zones were established in Marianka and Záhorská Bystrica.

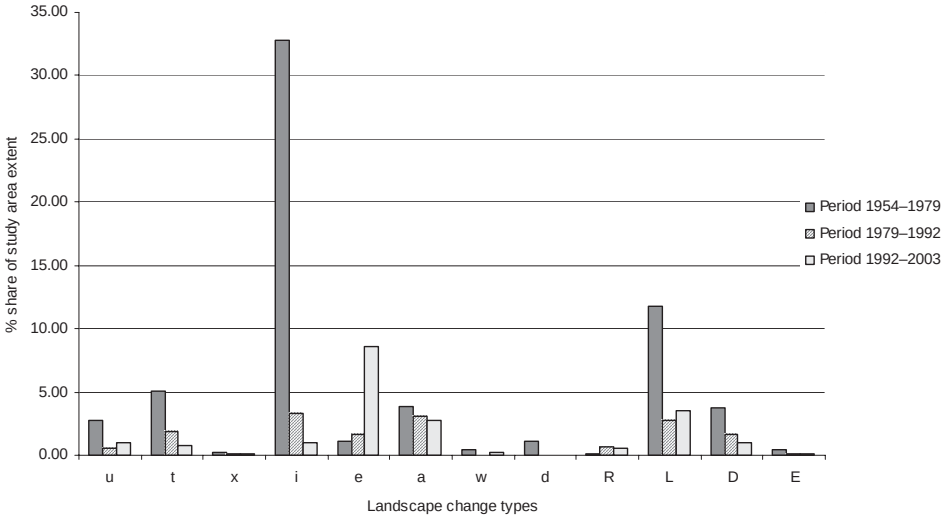

Fig. 3. Comparison of landscape change types (1954–1979, 1979–1992, 1992–2003). Explanation of codes of landscape change types is presented in Table 3.

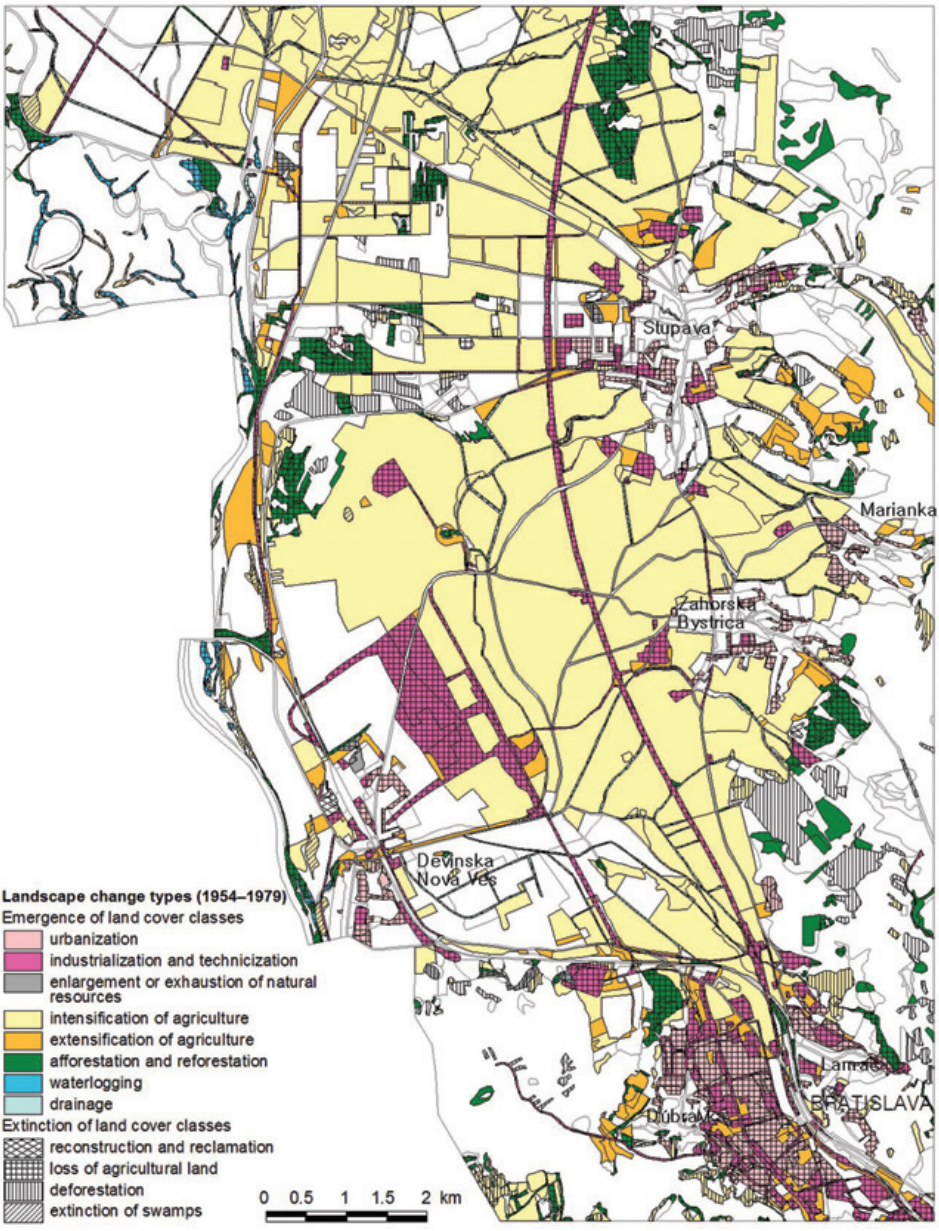

Fig. 4a. Spatial composition of landscape change types (1954–1979).

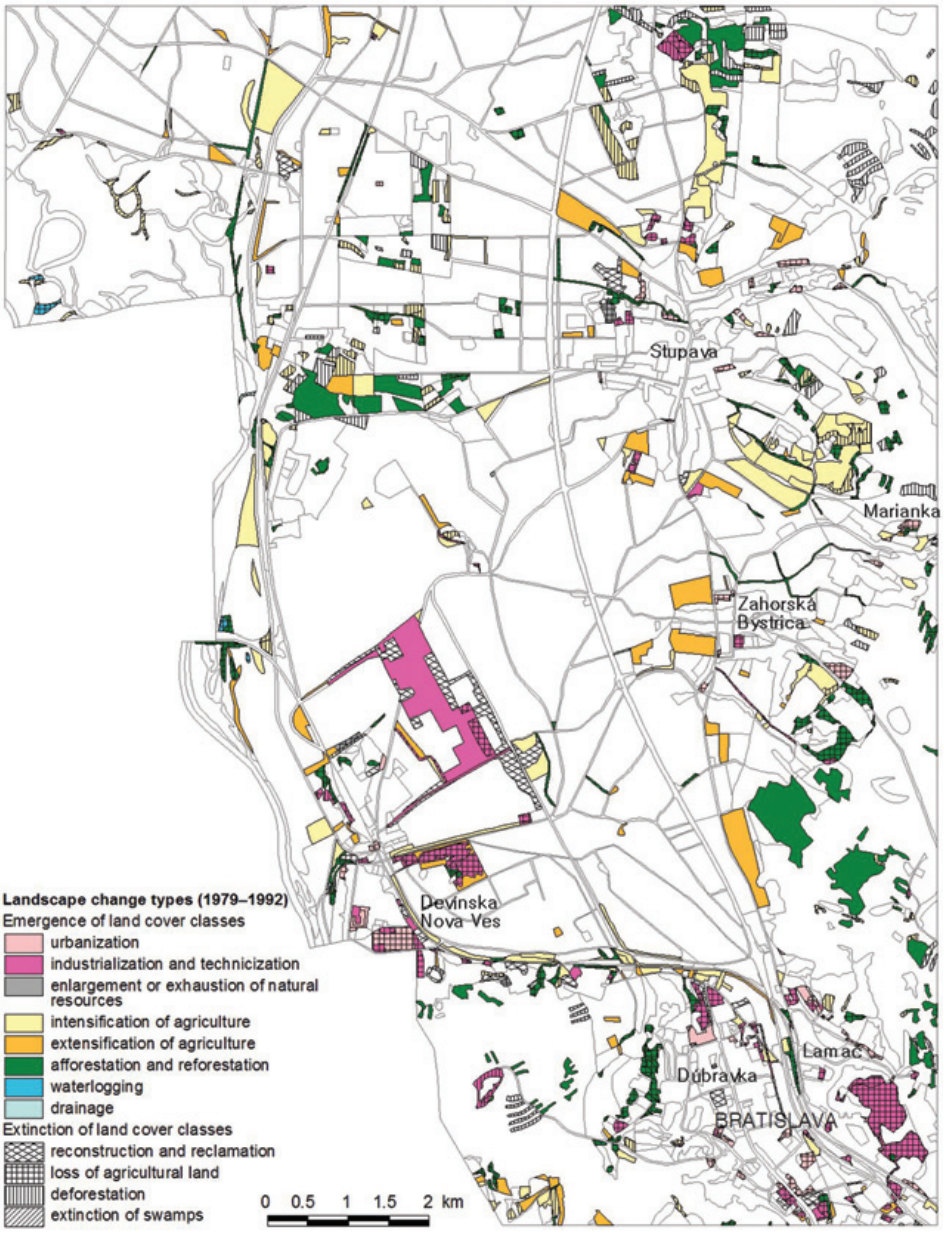

Fig. 4b. Spatial composition of landscape change types (1979–1992).

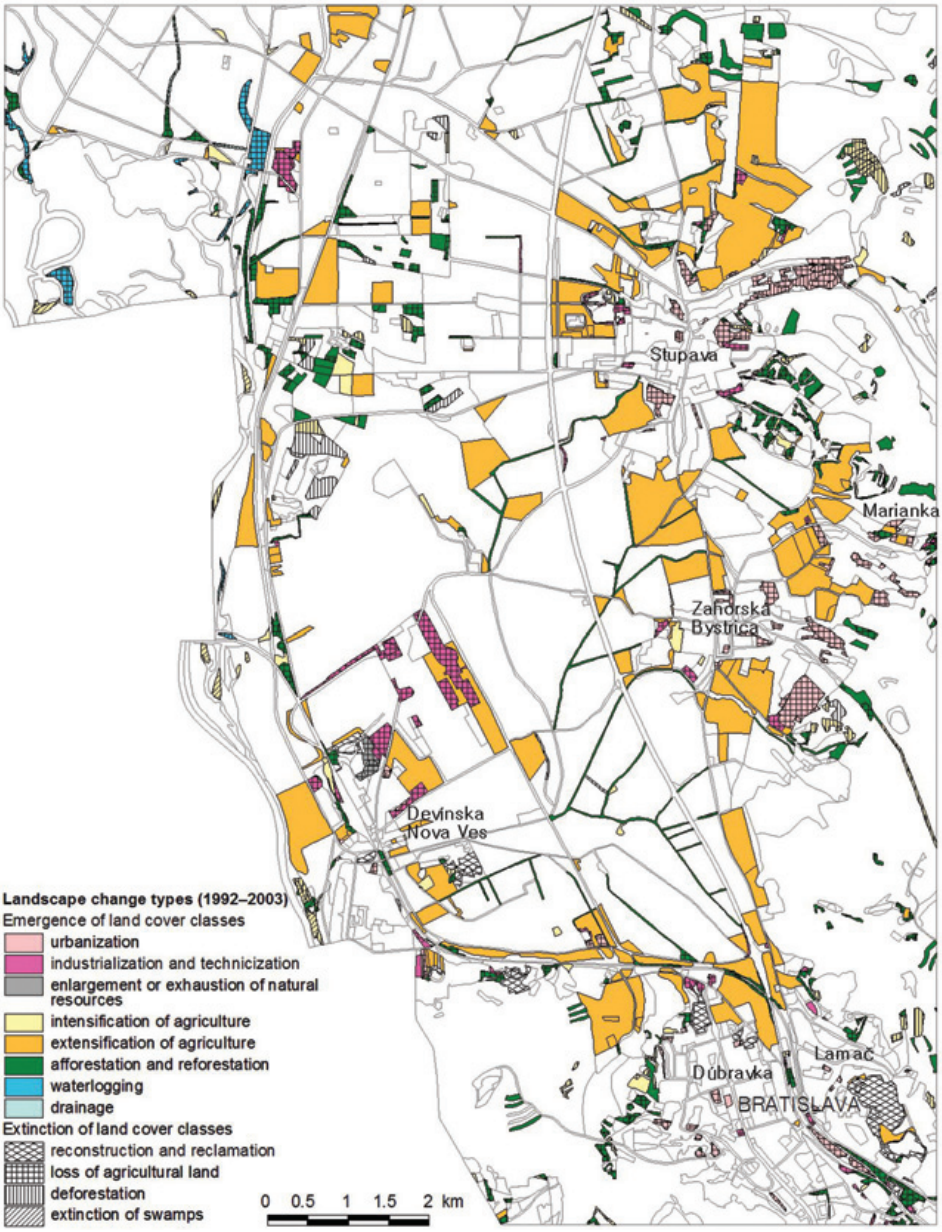

Fig. 4c. Spatial composition of landscape change types (1992–2003).

	Landscape change type	Period 1954–1979			Period 1979–1992			Period 1992–2003		
		[ha]	[%]*	[%]**	[ha]	[%]*	[%]**	[ha]	[%]*	[%]**
u	Urbanization	357.27	2.72	4.90	66.37	0.50	3.15	134.38	1.02	5.40
t	Industrialization and technicization	672.06	5.11	9.21	246.51	1.87	11.68	102.18	0.78	4.11
x	Exlargement or exhaustion of natural resources	24.26	0.18	0.33	8.03	0.06	0.38	7.37	0.06	0.30
i	Intensification of agriculture	4 308.30	**32.74**	59.07	441.25	**3.35**	20.91	133.80	1.02	5.38
e	Extensification of agriculture	146.79	1.12	2.01	219.15	1.67	10.39	1 126.26	**8.56**	45.27
a	Afforestation and reforestation	503.42	3.83	6.90	402.86	**3.06**	19.09	367.70	2.79	14.78
w	Waterlogging	57.24	0.44	0.78	5.18	0.04	0.25	35.64	0.27	1.43
d	Drainage	141.54	1.08	1.94	2.37	0.02	0.11	3.67	0.03	0.15
R	Reconstruction, reclamation	11.51	0.09	0.16	92.99	0.71	4.41	70.14	0.53	2.82
L	Loss of agricultural land	1 551.68	**11.79**	21.28	358.23	2.72	16.98	459.25	**3.49**	18.46
D	Deforestation	490.80	3.73	6.73	223.53	1.70	10.59	137.34	1.04	5.52
E	Extinction of swamps	57.76	0.44	0.79	19.37	0.15	0.92	16.66	0.13	0.67
o	Other changes	449.69	3.42	6.17	522.79	3.97	24.78	460.66	3.50	18.52
Changes associated with landscape change types		6 843.54	52.01	93.83	1 587.32	12.06	75.22	2 027.35	15.41	81.48
Changed area total		7 293.23	55.43	100.00	2 110.11	16.04	100.00	2 488.00	18.91	100.00
Not changed area total		5 864.32	44.57		11 047.44	83.96		10 669.55	81.09	
Extent of total territory		13 157.55	100.00		13 157.56	100.00		13 157.55	100.00	

Notes:
[%]* – share of total study area extent
[%]** – share of changed area extent

T a b l e 3. Landscape change types.

The processes of **industrialization and technicization** were very intensive in all studied periods and the development of industrial facilities and their infrastructure had roughly similar spatial localisation as changes caused by urbanization. During the first period the medium-sized industrial and agricultural production facilities were constructed in close environs of towns (Stupava) and settlements (Záhorská Bystrica). On the contrary the large industrial complexes were constructed further away from settlements to reduce the potential negative influence of this technical element on landscape and inhabitants. An important factor of localisation for industrial facilities is the transport infrastructure of the international importance – motorway Bratislava – Brno – Praha. The small industrial and commercial facilities, areas of public services and infrastructure functionally connected to city were built in Bratislava. In the Lamač ward the construction of the spacious hospital complex was started and interrupted before finishing, leaving in the landscape some large partially built objects. The new areas resulting from processes of **reconstruction and reclamation** are closely related to the industry, transport and construction areas.

The process of **enlargement or exhaustion of natural resources** took place on the small areas near the quarries and opencast mines between Dúbravka and Devínska Nová Ves, north of Devínska Nová Ves and in the western part of Stupava. The mining of natural resources in the study area is of only minor importance from the aspect of economy as well as its negative influence on the environment.

The **intensification of agriculture** was the process substantially affecting the

landscape during the first period (33% of study area extent) and represented 60% of all realised changes. This process influenced 55% of agricultural land (from extent in the year 1979) at the floodplain of the Morava river and a dominant part of the undulated fluvial lowland. These changes undoubtedly indicate the rapid increase in intensity of agricultural land utilisation during the first period. Only small part of these changes were results of the transformation of other classes (3xx, 4xx) and inner changes within agricultural land were dominant (particularly changes of complex cultivation areas into arable land). During the second period the changes representing the intensification of agriculture were much smaller, but in comparison with other landscape change types still most extensive (Fig. 3). During the third period, the intensification of agriculture was fading and became insignificant.

The **extensification of agriculture** was insignificant during the first two periods and was represented by the change of mosaic of heterogeneous cultivation areas into pastures and fruit tree plantations into arable land. Considerable decrease in the intensity of agricultural land utilisation was identified in the third period (almost 9% of the study area extent) represented above all by the change of arable land into pastures. This process affected mostly the areas less suitable for agricultural production on the hill slopes of the Malé Karpaty Mts, lower level of the Morava floodplain and areas of arable land in the close surroundings of settlements, which were changed into complex cultivation patterns.

The spatial extent of the **afforestation and reforestation** was stable during all three periods (3% to 4% of the study area extent) and most extensive were changes of pastures into forests. The specific change of this type was transformation of transitional woodland-scrub areas into forests, because in most cases it represented successive changes of forest development phases. With the changes of forest landscape is closely connected process of **deforestation**, specifically loss of forests and transitional woodland-scrub. The majority of these changes were initiated by human activities and the change of forests into agricultural land was the most extensive change caused by deforestation during the all three periods. During the first period, the narrow areas of trees on the edges of forests with other classes were cut down at the hill slopes of the Malé Karpaty and also the linear greenery along water courses was significantly reduced. The removal of small forested areas nearby the expanding settlements contributed to the local worsening of ecological quality (Cebecauerová, 2005).

The **water logging** and **extinction of swamps** are closely related to terrain morphologic forms namely to the lowest parts of flood plain. The water logging occurred in abandoned arms of the Morava river and local terrain depressions. The extent of waterlogged areas is conditioned by the actual water level and can vary during the year. The extinction of swamps is connected with human impacts in the natural landscape. The extinction of native swamps (swamps areas along the Morava river nearby Devínska Nová Ves and locality of old meanders and arms in the direction of Dolný les nature reserve) represents a loss of specific ecologically high value areas – geotopes with rare swamp associations (plant and animal). The revitalisation of these areas is very demanding, in some cases the changes are irreversible.

The **drainage** process is realised in the study area by the network of drainage channels, which was constructed mainly during the first period when the extensive changes in the agricultural landscape took place. The construction of network of artificial channels and modification of small streams was done at the whole floodplain and partly at the area of fluvial gravel terraces. The drainage by the network of channels helps to regulate the landscape water regime and prevent the flooding during periods of high water levels. The construction of channels helped also to create the organizationally simple landscape structure in the era of socialist management.

The **reconstruction and reclamation** areas were observed in the second and third period in the former construction sites, where the relatively large areas of arable land and pastures were out of the production function.

The **losses of agricultural land** occupied 12% of the study area during the first period and represented important process in the landscape during the other two periods as well. The majority of area changed into artificial surfaces above all into the residential, industrial, transport and construction areas. These changes are due to intensive anthropogenic influence irreversible and only small part of them is later after reclamation put back into agricultural land. The part of agricultural land changed into forest and semi-natural areas, especially at the unsuitable areas for mechanized cultivation or areas where the natural conditions limit the effectiveness of the agricultural production.

Discussion and conclusion

During the last decade, new methods of quantification and understanding of land cover/use changes have been elaborated. These changes reflect the social and biophysical changes through the series of transitions. The transition is the process of social change transforming the structural character of society and its material representation in the landscape (Lambin et al., 2003). The transition concept is based on the precondition of complex causality and coevolution of different interactively connected social segments. The transitions in the land use and in the mosaic of land cover should be treated as very unstable and dynamic phases with possible variations with respect to their future development. The explanation of land cover/use changes is nowadays moving from the explanation of simple causal relation to understanding of numerous driving forces and their interactions. The importance of cognition of driving forces and main processes behind the landscape changes steadily increases together with the need of better prediction of the future landscape (their elements) development.

The explanation of processes forming contemporary landscape is the task of the challenging interdisciplinary research and of the necessary communication among scientists, representatives of landscape engineering and decision-makers. In future it will be necessary to analyse the processes identified in presented work widely and evaluate not only their morphological demonstration through the land cover changes. As Antrop (2004) wrote, the urbanization is primarily a complex of functional changes, followed by morphological and structural ones and inversely, the actual changes of landscapes are induced by urbanization

processes such as the development of residential or industrial land and new communication infrastructures. It is important to evaluate the landscape forming processes derived from the changes of the landscape elements (land cover) with consideration of other functional analyses identifying the visual and functional disproportion of the processes. As an example Antrop (2004) describes the case of Brussels where a part of landscape still has a rural appearance, but it has been urbanized functionally. In spite of this, the analysis of morphologic changes of landscape elements remains one of the key approaches to the identification and understanding of significant processes forming the image of landscape.

The evaluation of selected landscape change types in the study area reflects main processes forming its character and appearance. The grouping of the land cover changes into the landscape change types allows a better insight into the realised changes of landscape objects and the image of changes becomes more understandable for the identification of causal relations between human activities and their reflection in the landscape. In the study area the dominant landscape change types forming the original landscape structure and partially predetermining (limiting) development possibilities of the region were identified.

The processes influencing the development of the study area during the 1954–1979 period were above all the intensification of agriculture and losses of the agriculture land. The process of the intensification of agriculture is closely connected to the transition from the private to the collective management in the agriculture with the aim to intensively utilise most of the land regardless the high production inputs. The loss of agricultural land is the result of rapid urbanization and industrialisation processes and the changes of this type were also significant in the following periods. The second period (1979–1992) gives evidence of socialist management with strong central planning of society. In the agriculture the intensification of the production still prevails and the afforestation and reforestation processes were evident in the forest landscape. During the third period (1992–2003), agriculture has undergone significant changes towards extensification of production. The response of political and social changes in the year 1989 caused the change of landscape mosaic with some delay. The transition towards market economy, the change of economic and social stimulus started to form the landscape after several years and elements of the landscape structure, especially in the agricultural landscape should be treated in the transformation period as very dynamical landscape elements. The landscape changes in the last period are affected by the market economy and partially by the effects of economic harmonisation with European Community, for example the change of subsidy schemes in the agriculture caused the change of landscape utilisation in less productive areas where agricultural land was transformed into forests and transitional woodland-scrubs.

The landscape change types should be perceived as individual processes (we have analysed their properties, particularly in the spatio-temporal context), but also as the set of processes with strong interconnections and interdependences – the processes may eliminate or stimulate each other, may tend to concentrate at the same locations and the time causality of processes may exist. Behind these major processes is the human society with its interests in the landscape as the principal driving force in the cultural landscape governing the development and forming of the actual mosaic of landscape structure.

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