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METHODOLOGICAL ASPECTS OF LANDSCAPE CHANGES DETECTION AND ANALYSIS IN SLOVAKIA APPLYING THE CORINE LAND COVER DATABASES

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The aim of the study is to document the individual steps of methodology of identification and analysis of landscape changes in Slovakia for the years 1976-1992 (applied in the framework of the Phare Topic Link Project on Land Cover) applying the CORINE land cover (CLC) databases and to provide the test results using the example of the districts of Dunajská Streda, Poprad, and Snina. The described methodology is based on the assumption that land cover changes can be used for derivation of landscape changes. The CLC database and satellite images became an important information source, which along with the geoinformation technologies makes it possible to follow the landscape changes on the local and global scales. The result of the methodology tests was creation of a database of land cover changes in Slovakia and definition of the following types of landscape changes: intensification of agriculture, extensification of agriculture, urbanization (industrialization), enlargement (exhaustion) of natural resources, afforestation, deforestation and other. Deforestation (8.6 % of total area of the district of Snina), extensification of agriculture (3.5 % of total area of the district of Snina) and urbanization plus industrialization (3.3 % of total area of the district of Dunajská Streda) are the largest identified changes in terms of area.

Key words: CORINE land cover, land cover change, landscape change, satellite data, the districts of Dunajská Streda, Poprad and Snina

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INTRODUCTION

Remote sensing data represent an important information source, which contributes to recognition of changes taking place in the landscape. The previous studies (Feranec 1992 and 1996, Feranec et al. 1997a and 1997b) and others documented, the theoretical-methodological aspects of application of the remote sensing data to landscape change identification. The knowledge of the characteristics of aerial and satellite images accompanied by the progress attained in application of the geographical information systems provided new possibilities of monitoring landscape changes at the national level and were used in the framework of the Phare Topic Link on the Land Cover Project of the European Environmental Agency. The key tasks of the project was identification, analysis, and assessment of landscape changes in Czechia, Hungary, Romania, and Slovakia by use of the CORINE land cover (CLC) database from two time horizons. The project worked on in 1997-2001 was coordinated by the GISAT company of Prague in co-operation with the Institute of Geography of the Slovak Academy of Sciences of Bratislava, Romanian Geological Institute of Bucharest, and HNIT-Baltic company of Vilnius. The Institute of Geography of the SAS was responsible for preparation of the methodology for the project in the above-mentioned countries, identification of changes in Slovakia, analysis and assessment of the obtained results.

Land cover is applicable as an indicator or information source of identification of landscape changes as it represents the materialized reflection of the natural spatial (morphopositional and bioenergetic) assets and simultaneously of the present land use, that is the landscape created or recreated by man, which is well-identifiable in the satellite images (Feranec et al. 1996). In this context the data on land cover in the CLC database (Heymann et al. 1994) from various time horizons can be considered one of the new and important information sources on landscape changes. Definitions of categories of landscape changes based on land cover changes were presented by Stott and Haines-Young (1998, p. 248). Until now, the data obtained by conventional statistical approaches provided by the statistical yearbooks or maps from different periods (Bičík et al. 2001) were used for this purpose. The Land Cover Changes in Coastal Zones (LACOAST, Perdigao 2001) project is one of the first that applied the CLC data to identification of land cover changes of the 10 km wide belt of coast in nine countries of the European Union.

The aim of the study is to document the individual steps of methodology of identification and analysis of Slovakia's landscape changes in the years 1976-1992 (applied in the framework of the Phare Topic Link on Land Cover Project) by application of the CLC databases and to present the obtained results on the example of the districts of Dunajská Streda, Poprad, and Snina.

CHARACTERISTICS OF THE METHODOLOGY OF LANDSCAPE CHANGE ASSESSMENT

Significant progress has been achieved since the times of Brunschweiler (1957) who was the first to point to the possibilities of application of remote sensing data with the aim to obtain information on landscape changes. Satellite images became an important information source, which along with the geoinformation technologies make it possible to observe landscape changes on scales ranging from the local to the global. Methodology presented here is based on the assumption that the land cover changes can be used for derivation of landscape changes. It consists of two basic parts:

- creation of a database of land cover changes characterizing the 1970's-1990's,
- identification of landscape changes, their analysis and visualization (Feranec et al. 2000a).

CREATION OF A DATABASE OF LAND COVER CHANGES

Identification and analysis of Slovakia's landscape was based on use of two vector CORINE land cover databases at a scale of 1:100,000. The first of them, (CLC90), which represents the state of land cover in Slovakia existing at the beginning of the 1990's (1989-1992) was created by the method of visual interpretation of Landsat TM satellite images followed by vectorization of interpretation schemes. The second database (CLC70) was generated by modification of the primary CLC90 database by the method of retrospective analysis (downdating), making use of the LANDSAT MSS images from the second half of the 1970's (1976-1979). The database of changes is the result of integration of both, CLC70 and CLC90, databases by overlay.

The methodology applied to creation of the database concerning Slovakia's land cover changes can be summarized into the following steps (Feranec et al. 1999 and 2000a):

1. Preparation and segmentation of Landsat TM and Landsat MSS satellite images for identification of land cover in the 1970's.
2. Preparation of the raw database for identification of land cover of the 1970's from the CLC90 database by aggregation of areas (classes) of the third level into the areas of the second CLC hierarchic level and segmentation of this database following the sequence of sheets of topographic maps at 1:100,000 scale.
3. Identification of CLC70 classes by modification of the raw database by means of Landsat MSS satellite images. Revision of the original CLC90 data by application of TM Landsat satellite images was part of this step.
4. Mosaicing of the individual CLC70 database segments, checking on their physical and logical integrity.
5. Identification of land cover changes for the 1970's and 1990's (hereafter only CLC70/90) by overlay of the CLC70 and CLC90 data files.
6. Application of control procedures and tests followed by retrospective derivation of the final version of CLC70 database from CLC70/90.

Part of the preparative stage was segmentation of digital satellite data according to the sheet sequence of topographic maps (S-42 system of coordinates). Colour contrast-adjusted compositions (Landsat TM 542 and MSS 421 spectral bands) were created and imported in the GeoTIF format to the ArcView GIS environment. As the resolution of the Landsat MSS images compared to Landsat TM images used in identification of the CLC90 database classes is poorer (spatial resolution of 80 m, radiometric resolution of 6 bites, 4 spectral bands), the content of the CLC70 data layer was reduced to 15 classes of the second hierarchic level of the CLC nomenclature (Heymann et al. 1994).

Tab. l. The CORINE land cover nomenclature (Heymann et al. 1994)

1 ARTIFICIAL SURFACES	3 FOREST AND SEMI-NATURAL AREAS
11 Urban fabric	31 Forests
111 Continuous urban fabric	311 Broad-leaved forest
112 Discontinuous urban fabric	312 Coniferous forest
12 Industrial, commercial and transport units	313 Mixed forest
121 Industrial or commercial units	32 Scrub and/or herbaceous vegetation associations
122 Road and rail networks and associated land	321 Natural grasslands
123 Port areas	322 Moors and heathland
124 Airports	323 Sclerophyllous vegetation
13 Mine, dump and constructions sites	324 Transitional woodland-scrub
131 Mineral extraction sites	33 Open spaces with little or no vegetation
132 Dump sites	331 Beaches, dunes, sands
133 Construction sites	332 Bare rocks
14 Artificial, non agricultural vegetated areas	333 Sparsely vegetated areas
141 Green urban areas	334 Burnt areas
142 Sport and leisure facilities	335 Glaciers and perpetual snow
2 AGRICULTURAL AREAS	4 WETLANDS
21 Arable land	41 Inland wetlands
211 Non-irrigated arable land	411 Inlands marshes
212 Permanently irrigated land	412 Peat bogs
213 Rice fields	42 Maritime wetlands
22 Permanent crops	421 Salt marshes
221 Vineyards	422 Salines
222 Fruit trees and berry plantations	423 Intertidal flats
223 Olive groves	5 WATER BODIES
23 Pastures	51 Inlands waters
231 Pastures	511 Water courses
24 Heterogeneous agricultural areas	512 Water bodies
241 Annual crops associated with permanent crops	52 Marine waters
242 Complex cultivation patterns	521 Coastal lagoons
243 Land principally occupied by agriculture, with significant areas of natural vegetation	522 Estuaries
244 Agro-forestry areas	523 Sea and ocean

This raw database for identification of the CLC70 database classes was generated from the CLC90 database by aggregation of areas (classes) of the third level into the areas of the second hierarchic level of the CLC nomenclature (Tab. 1) and by segmentation of so prepared CLC90 vector data according to the sheet sequence of topographic maps at the scale of 1:100,000.

Downdating was used for identification of the CLC70 areas. This method consists of comparison of land cover classes of the CLC90 database with the Landsat MSS images. If the shape and size of the CLC90 area on the image from the 1970's were different, it was modified according to the state identifiable on the satellite image. The detected change in the CLC70 database was accepted only when the extent of the changed area was more than 4 ha. It was also necessary for identification of changes to accept the requests concerning spatial characteristics of the data layer under preparation in the sense of the CORINE land cover methodology, that is the resulting area had to comply with the criterion of the minimum size of 25 ha and width of at least 100 m. Part of the identification of the CLC70 classes was also verification of the original CLC90 database. The revised CLC90 database was then created after corrections.

The working version of the CLC70 data layer for the whole of Slovakia was created by mosaicing of the individual map segments. While they were connected, tests and corrections of physical and logical data integrity, the objective of which was elimination of areas inconvenient in terms of extent, removal of inconsistencies detected in the process of connection, and the like, were carried out.

The CLC70/90 data layer of land cover changes was derived by the method of integration of the CLC70 and CLC90 data by overlay. The newly created layer was tested on the presence of areas not complying with the criterion of at least 4 ha change extent. The areas smaller than 4 ha were eliminated. The exception to the above-mentioned extent criterion was applicable only to areas limited by the state boundary. Elimination of small change areas not complying with the established limit was subject to the criterion, by which the original data structure of CLC90 was maintained as priority. After all corrections were made, retrospectively the final CLC70 database was generated.

The individual steps of methodology were made applying the GIS softwares Easi/Pace (preparation of satellite images for interpretation), ArcView GIS (computer-aided visual interpretation and processing of the individual data layers), tools created by the authors using ArcView GIS scripting language Avenue (checking and adjustment of physical and logical data integrity), and Data Automation Kit (final checking and processing of vector layers).

IDENTIFICATION AND ANALYSIS OF LANDSCAPE CHANGES

The second part of the characterized methodology consists of three steps (Feranec et al. 1999):

1. Reclassification of identified CLC70/90 land cover changes pursuing the defined types of changes.
2. Computation of the extent of changes in terms of size based on CLC70 and CLC90 class analysis at the second level.
3. Cartographic expression of spatial intensity of the individual landscape change types at a small scale.

Seven types of landscape changes were defined on the basis of comparison of identified CLC70/90 land cover changes as presented in the conversion Tab. 2. The table aligns each combination of CLC70/90 changes to the corresponding landscape change type. Number of combinations of land cover changes was simplified by reclassification and the result was the database of 7 landscape change types.

Tab. 2. Conversion table of land cover changes into landscape change types (Feranec et al. 1999)

	CLC90 classes															
CLC70 classes	11	12	13**	131	14	21	22	23	24	31	32	33	41	42	51	52
11	0	7	7	4	7	7	7	7	7	7	7	7	7	7	7	7
12	7	0	7	4	7	7	7	7	7	7	7	7	7	7	7	7
13	7	7	0	0	7	7	7	7	7	7	7	7	7	7	7	7
14	7	7	7	4	0	7	7	7	7	7	7	7	7	7	7	7
21	3	3	3	4	3	0	1	2	2	5	5	7	7	7	7	7
22	3	3	3	4	3	2	0	2	7	5	5	7	7	7	7	7
23	3	3	3	4	3	1	1	0	1	5	5	7	7	7	7	7
24	3	3	3	4	3	1	1	2	0	5	5	7	7	7	7	7
31	3	3	3	4	3	6	6	6	6	0	6	6	6	7	7	7
32	3	3	3	4	3	1	1	1	1	5	0	6	7	7	7	7
33	3	3	3	4	3	1	1	1	1	5	5	0	7	7	7	7
41	3	3	3	4	3	1	7	1	7	5	5	7	0	7	7	7
42	3	3	3	4	3	1	7	1	7	5	5	7	7	0	7	7
51	3	3	3	4	3	7	7	7	7	5	5	7	7	7	0	7
52	3	3	3	4	3	7	7	7	7	5	5	7	7	7	7	0

** CLC 132 + 133 classes

Landscape change types: 0 – no change, 1 – intensification of agriculture, 2 – extensification of agriculture, 3 – urbanization (industrialization), 4 – enlargement or exhaustion of natural resources, 5 – afforestation, 6 – deforestation, 7 – other changes

Definition of landscape change types is one of the contributions of the characterized methodology:

1. *Intensification of agriculture* – changes of meadows and pastures or forest to arable land, as well as the changes of arable land to vineyards, orchards, berry plantations, greenhouse management, etc.
2. *Extensification of agriculture* – changes of vineyards, orchards and berry plantations to arable land or meadows and pastures and changes of arable land to meadows and pastures. Both definitions respect the general principles of intensity of agricultural production in the context of analyzed land cover classes.
3. *Urbanization (industrialization)* – changes of agricultural and forest land cover classes to those of urbanized landscape (construction of buildings destined for dwelling, education, recreation, and the like) and industrialized landscape (construction of facilities of industrial and agricultural production, construction of all types of communications, water reservoirs, and the like).
4. *Enlargement or exhaustion of natural resources* – changes of agricultural and forest classes and other land cover classes to areas of surface mining of minerals.
5. *Afforestation* – natural or man-induced landscape changes after clear cuts, change of agricultural land cover classes – meadows, pastures or arable land to forest land cover classes in various stages of growth.
6. *Deforestation* – changes of forest land cover classes following clear cuts, devastation by anthropic activity, natural disasters, etc.
7. *Other changes* – for instance, recultivation, waste depositions, and the like.

Changes of area extent of the CLC70 and CLC90 classes at the second level are expressed by means of contingency tables, which simultaneously document thematic redistribution of land cover classes in the evaluated period. Information from the contingency table is the source used for assessment of processes caused by landscape changes.

It was necessary to find the way of transformation of landscape areal changes from the scale 1:100,000 to small 1:3,000,000 scale for the needs of well arranged cartographic expression of spatial intensity of the quoted landscape change types identified in Czechia, Hungary, Romania, and Slovakia. Vector databases of changes of four countries were transformed into raster data format by computation of the area extent of changes to an area unit – raster with resolution of 1.5×1.5 km cell. Four intervals of landscape change intensity were proposed based on the area representation of changed areas expressed in cells:

1. 76-100 % of the cell area was changed – complete change of landscape,
2. 25-75 % of the cell area was changed – substantial change of landscape,
3. 1-24 % of the cell area was changed – small change of landscape,
4. 0 % without landscape change.

Selection of raster cell is determined above all by the scale of the resulting map. It is obvious that a more detailed expression of spatial aspects of landscape changes requires a raster with higher resolution. The way, in which the maps were prepared strove to preserve the maximum amount of information even at a high degree of generalization.

LANDSCAPE CHANGE ASSESSMENT ON THE EXAMPLE OF SELECTED DISTRICTS OF SLOVAKIA

Application of characterized methodology is documented on the example of analysis and assessment of landscape changes in the districts of Dunajská Streda (DS), Poprad (PP), and Snina (SV) as the representatives of the lowland, basin, upland and high-mountain landscape of Slovakia. Selection of the districts took into account the structure of natural landscape of Slovakia and the character of its economic and social use.

The district of Dunajská Streda lies in the typical lowland landscape (Danubian Lowland) next to the river Danube. Construction of the Gabčíkovo dam caused important changes in the agricultural and forest landscape of this fluvial plain.

The district of Poprad occupies part of the cool basin and high-mountain landscape (Poprad Basin, High Tatras and Low Tatras). The region is characterized by important interests of tourism and nature conservation. Its selection was motivated by potential changes to natural, forest, and agricultural landscape in the hinterland of tourist centres and national parks.

The district of Snina is located in the upland landscape of eastern Slovakia (Laborec Upland, Bukovec Hills and Vihorlat Hills, and the Beskyd Foothills). Landscape changes were caused above all by water-management problems of flysch territories and forest-management interests of this region.

Analysis of the created CLC databases from the 1970's and 1990's is the way to obtain information on areas of land cover classes of Slovakia, their changes and spatial aspects.

Tab. 3 and Figs. 1-3 offer an overview of areas of the individual CLC classes of the second level. Arable land (class 21) distinctly dominates in the district of Dunajská Streda, where its share in the total district area in both time horizons is more than 70 %. On the other side, the share of forests (31) in the areas of the districts Poprad and Snina is more than 50 %. The share of other land cover classes in the area of the individual districts is not more than 15 %. The class inland waters (51) in the sense of the CORINE methodology was not identified in Snina in the 1970’s. It was registered in the CLC90 database after construction of the Starina water reservoir. Similar situations occur with mining areas, dump site and construction sites (13), which were not identified in the district of Dunajská Streda in the 1970’s. Areas of this class were identified on an extensive territory during the CLC90 mapping during time the Gabčíkovo dam was being constructed.

Tab. 3. Extent of areas of the second level CLC classes in hectares

	CLC70			CLC90			Changes CLC70 – CLC90		
CLC	DS*	PP**	SV***	DS*	PP**	SV***	DS*	PP**	SV***
11	6 785.6	2 711.3	2 368.5	6 971.8	2 874.8	2 272.4	186.2	163.6	-96.1
12	743.4	469.1	133.7	879.4	504.8	133.7	136.0	35.6	
13		192.4		3 247.0	151.1		3 247.0	-41.3	
14	126.4	704,6	59.1	126.4	704.6	59.1			
21	83 314.0	16 513.9	7 128.9	79 819.7	16 372.1	6 855.9	-3 494.3	-141.8	-273.0
22	2 030.4			2 383.3			352.9		
23	231.5	6 431.6	3 140.3	194.1	6 857.5	4 641.0	-37.4	425.9	1 500.7
24	3 728.1	4 692.4	11 464.9	4 202.6	4 574.5	10 138.4	474.6	-117.9	-1 326.5
31	7 474.2	59 085.7	54 538.7	4 792.4	57 728.4	48 062.3	-2 681.8	-1 357.3	-6 476.4
32	184.8	13 220.3	1 767.2	2 247.0	13 751.0	8 171.8	2 062.2	530.7	6 404.6
33		8 092.2			8 594.7			502.5	
41	814.5			754.3			-60.1		
51	2 042.8	25.4		1 857.5	25.4	266.6	-185.3		266.6
Total	107 475.5	112 138.9	80 601.2	107 475.5	112 138.9	80 601.3	0.0	0.0	0.0

* Dunajská Streda, ** Poprad, *** Snina

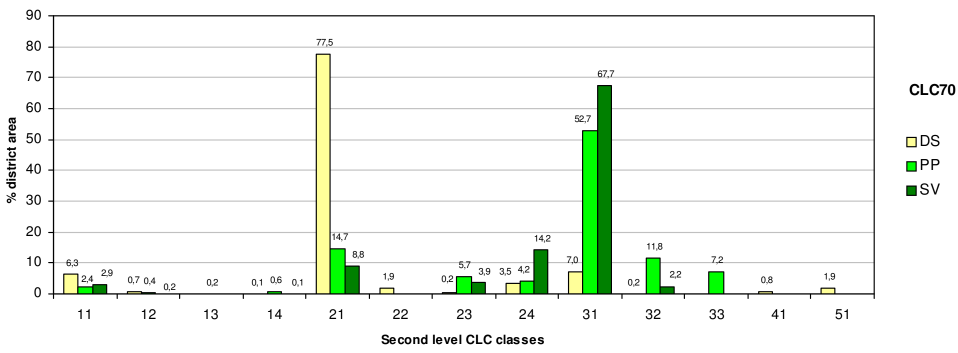


Fig. 1. Share of the CLC70 database classes in the total area of districts (%)
DS – Dunajská Streda, PP – Poprad, SV – Snina

Land cover data from 1970’s and 1990’s make it possible to express structural changes of landscape of the individual districts or the whole territory of Slovakia (at scale 1:100,000 or smaller) in precision of the CLC methodology (Heymann et al. 1994). Contingency tables (Tab. 4) constitute an important tool, which shows the thematic redistribution of land cover classes within the boundaries of the individual districts for the assessed period.

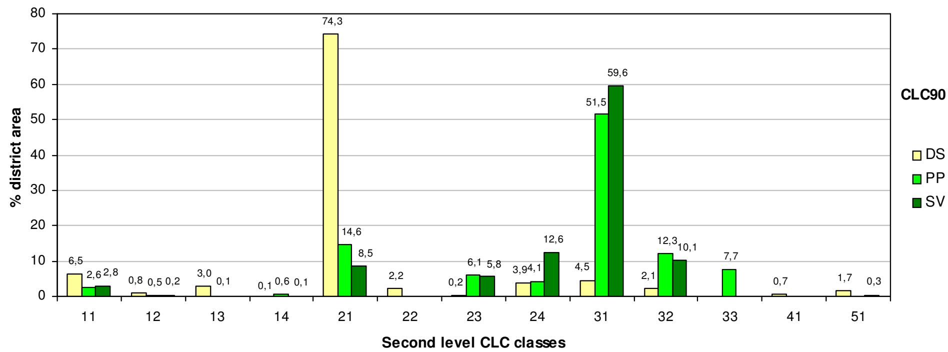


Fig. 2 Share of the CLC90 database classes in the total area of districts (%)
DS – Dunajská Streda, PP – Poprad, SV – Snina

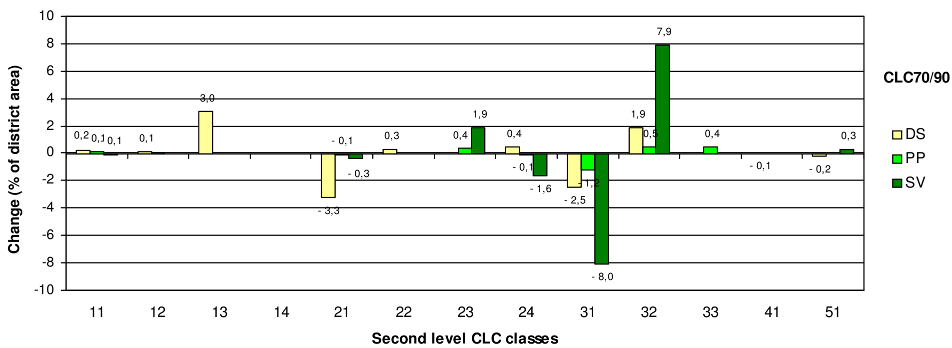


Fig. 3 Share of the CLC70/90 land cover changes in the total area of districts (%)
DS – Dunajská Streda, PP – Poprad, SV – Snina

Comparison of the CLC70 and CLC90 shows that the extent of identified changes was the largest in forests, the area of which diminished by 1.357 ha in the district of Poprad, 2.682 ha in the district of Dunajská Streda, and 6.476 ha in the district of Snina. Compared to their original area the most important decrease has been recorded in the district of Dunajská Streda (by 36 % of their original area in the 1970's). It was also in this district, that the area of arable land decreased most (by 3.494 ha). If the stabilizing elements of landscape structure are assessed, enlargement of the area of pastures (23) by 1,501 ha in the district of Snina (increase in comparison with area in the CLC70 by as much as 48 %) and by 426 ha in the district of Poprad is considered a positive trend. A negative trend is the decrease of heterogeneous agricultural areas with presence of natural vegetation (24) by 118 ha in the district of Poprad. The decrease by 1.326 ha in the district of Snina was transformed into the class of grasslands above all. In the case of Dunajská Streda, the areas of mine, dump and construction sites (13) rose by 3.247 ha, during construction of the Gabčíkovo dam.

From the point of view of area size, the most important changes in the district of Dunajská Streda affected arable land (3.3 % decrease of the district area), where, from the original area of 83.314 ha in the 1970's, 217 ha were transformed into urban (settlement) fabric (11), 92 ha into industrial, commercial, and transport areas (12), 1.970 ha into mine, dump and construction sites, 372 ha into permanent crops (22), 121 ha into pastures, 533 ha into heterogeneous agricultural areas, 14 ha into forests, 7 ha into shrubs (32), 23 ha into inland wetlands (41), and 328 ha were transformed into inland waters (51) by the

Tab. 4. Structure of land cover changes identified in the CLC70 and CLC90 databases (in hectares)

DS *	CLC90														Total
CLC70	11	12	13	131	14	21	22	23	24	31	32	33	41	51	CLC70
11	6 741.3	44.3													6 785.6
12		743.3													743.3
13															
14					126.4										126.4
21	217.0	91.8	1 969.7			79 637.4	371.6	121.2	533.3	14.3	6.8		22.9	328.0	83 314.0
22						18.7	2 011.7								2 030.4
23	7.7		44.4			59.6		72.9						47.0	231.5
24	5.8		36.9						3 458.2	91.5	50.4		60.0	25.2	3 728.1
31			960.7			93.0			102.5	4 214.9	1 810.1		164.5	128.5	7 474.2
32											184.7				184.7
33															
41						4.3			30.5	139.2	92.9		457.4	90.1	814.5
51			235.4			6.7			78.1	332.5	101.9		49.6	1 238.7	2 042.8
Total CLC90	6 971.8	879.4	3 247.0		126.4	79 819.7	2 383.3	194.1	4 202.6	4 792.4	2 247.0		754.3	1 857.5	107 475.5

PP **	CLC90														Total
CLC70	11	12	13	131	14	21	22	23	24	31	32	33	41	51	CLC70
11	2 711.3														2 711.3
12		469.1													469.1
13	73.3			110.0					9.0						192.4
14					704.6										704.6
21	53.0	35.6				15 910.3		474.5	40.6						16 513.9
22															
23	6.2			41.1		166.1		5 489.6	550.5	64.6	113.6				6 431.6
24	31.0					291.3		766.6	3 603.5						4 692.4
31						4.5		92.4	110.2	57 444.1	1 434.5				59 085.7
32								34.4	260.7	219.8	12 080.7	624.7			13 220.3
33											122.2	7 970.0			8 092.2
41															
51														25.3	25.3
Total CLC90	2 874.8	504.8		151.1	704.6	16 372.1		6 857.5	4 574.5	57 728.4	13 751.0	8 594.7		25.3	112 138.9

SV ***	CLC90														Total
CLC70	11	12	13	131	14	21	22	23	24	31	32	33	41	51	CLC70
11	2 191.1								125.6					51.8	2 368.5
12		133.7													133.7
13															
14					59.1										59.1
21	35.0					6 033.0		602.1	458.7						7 128.9
22															
23								2 242.6	897.7						3 140.3
24	46.3					755.9		1 789.7	8 466.3	120.3	71.7			214.8	11 464.9
31						24.2			51.6	47 612.5	6 850.4				54 538.7
32						42.7		6.6	138.6	329.6	1 249.7				1 767.2
33															
41															
51															
Total CLC90	2 272.4	133.7			59.1	6 855.8		4 641.0	10 138.4	48 062.3	8 171.8			266.6	80 601.2

* Dunajská Streda, ** Poprad, *** Snina

1990's. In contrast, only 19 ha of permanent crops, 60 ha of grassland, 93 ha of forests, 4 ha of inland wetlands, and 7 ha of inland waters changed into arable land in this period. Tab. 4 shows that in the district of Dunajská Streda the most important transformation was that of arable land in favour of mine, dump and construction areas and forests transformed in favour of shrub areas and those of mine, dump and construction. In the districts of Poprad and Snina the largest changes in terms o extent were those of forests (decrease by 1.2 % or 8 % of the district area) above all in favour of ecologically less valuable shrubs. With regard to the spatial stability of areas, the most important changes in the district of Dunajská Streda affected the class of pastures where in comparison with the CLC70 database only 32 % of the district area did not change. Likewise, in the course of about 15 years there were rather distinct shifts in the case of forest areas, inland wetlands, and inland waters. The least stable areas, relatively speaking, in the district of Poprad are the areas of mine, dump and construction, shrubs, and heterogeneous agriculture. The least stable areas in the district of Snina are the classes of pastures, heterogeneous agricultural areas and shrubs.

Information on landscape change types was obtained by reclassification of land cover changes (Tab. 2). The individual landscape changes can be assessed from the point of view of their size in terms of the total area of districts or from the point of view of the total area of identified changes in districts (Tab. 5, Figs. 4 and 5).

Tab. 5. Areas of the individual change types in the districts of Dunajská Streda, Poprad, and Snina (in hectares)

Type of change	Dunajská Streda			Poprad			Snina		
	in ha	in %*	in %**	in ha	in %	in %**	in ha	in %	in %**
No change	98 887.0	92.0		106 518.5	95.0		67 988.1	84.4	
Intesification of agriculture	435.5	0.4	5.1	1 302.9	1.2	23.2	1 841.4	2.3	14.6
Extensification of agriculture	673.2	0.6	7.8	1 281.7	1.1	22.8	2 850.5	3.5	22.6
Urbanization (industrialization)	3 569.2	3.3	41.6	125.9	0.1	2.2	81.3	0.1	0.6
Enlargement (exhaustion) of natural resources	0.0	0.0	0.0	41.1	0.0	0.7	0.0	0.0	0.0
Afforestation	829.5	0.8	9.7	520.1	0.5	9.3	521.6	0.6	4.1
Deforestation	2 170.1	2.0	25.3	2 266.3	2.0	40.3	6 926.2	8.6	54.9
Other changes	910.9	0.8	10.6	82.4	0.1	1.5	392.2	0.5	3.1
District area	107 475.5	100.0		112 138.9	100.0		80 601.2	100.0	
Extent of changed landscape	8 588.5	8.0	100.0	5 620.4	5.0	100.0	12 613.1	15.6	100.0

* percentage of total district area
** percentage of changed landscape of district area

Intensification of agriculture with regard to its area in relation to the extent of the district is the largest in the district of Snina and in relation to changed landscape it is the largest in the district of Poprad. This type of change identifiable by means of satellite images is connected with change of agricultural landscape with a lower rate of use into that with a higher rate of use. In assessed districts they are above all the changes of pastures into arable land and heterogeneous agricultural areas, changes of heterogeneous agricultural areas into arable land, and changes of arable land into permanent crops.

Extensification of agriculture prevailed in the district of Snina. It is connected with a changes of agricultural landscape with higher rate of use to that with a lower rate of use. Changes of arable land into pastures and heterogeneous agricultural areas were identified in the selected districts.

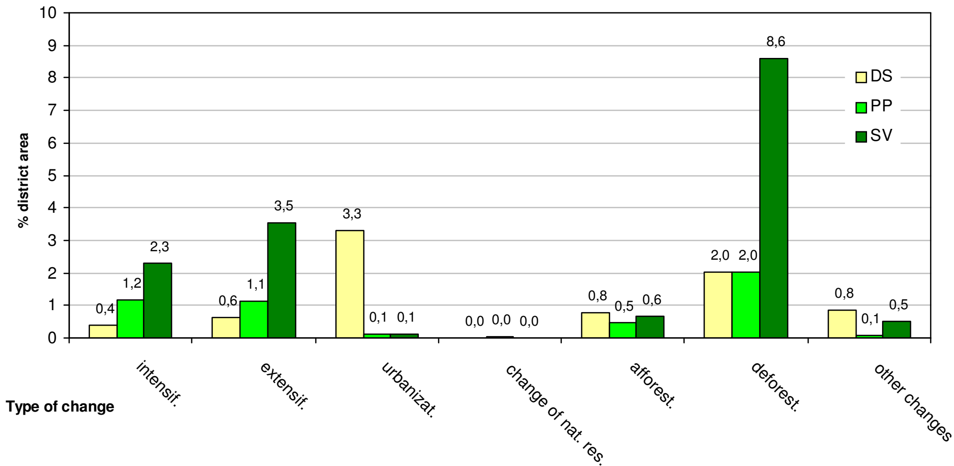


Fig. 4. Comparison of landscape changes in the districts of Dunajská Streda, Poprad, and Snina by percentage from the district area

DS – Dunajská Streda, PP – Poprad, SV – Snina

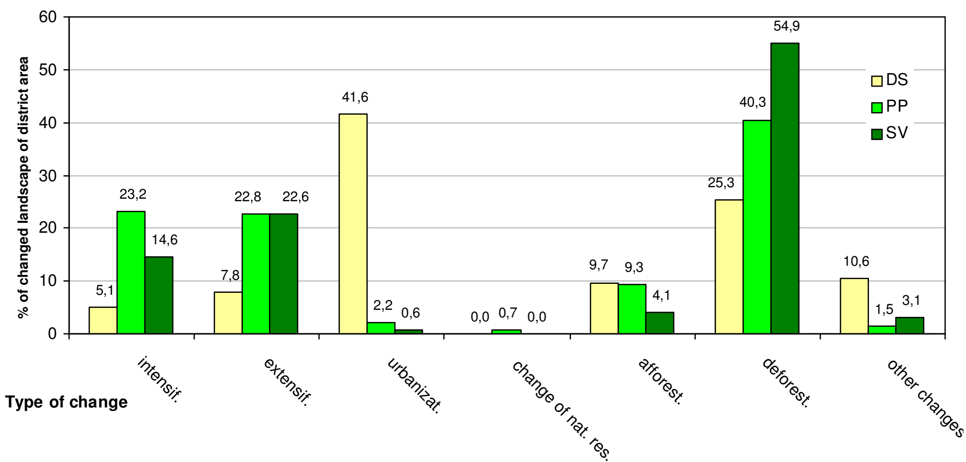
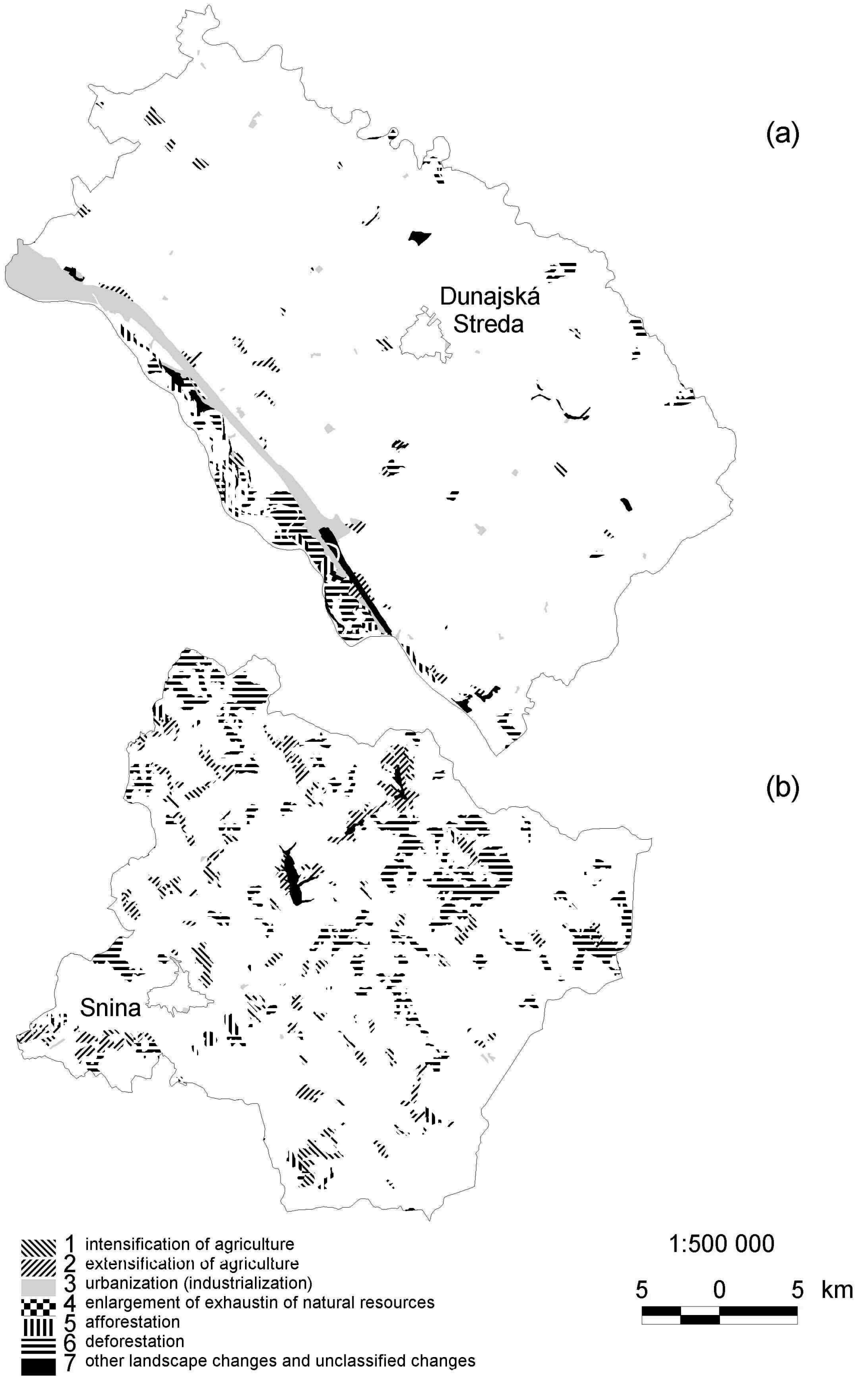


Fig. 5. Comparison of landscape changes in the district of Dunajská Streda, Poprad, and Snina by percentage of the changed landscape

DS – Dunajská Streda, PP – Poprad, SV – Snina

Urbanization and industrialization was connected with population growth and political decisions (concentration of population in towns, industrial construction, and the like). Construction of the Gabčíkovo dam in the district of Dunajská Streda is the phenomenon, which manifested most distinctly in the analyzed districts.

In the case of change of the type *enlargement or exhaustion of natural resources* the smallest changes were detected (enlargement of the area of gravel extraction near Svit). Spatial resolution of the used satellite images and the criteria of the methodology of landscape change identification did not allow for more detailed information.



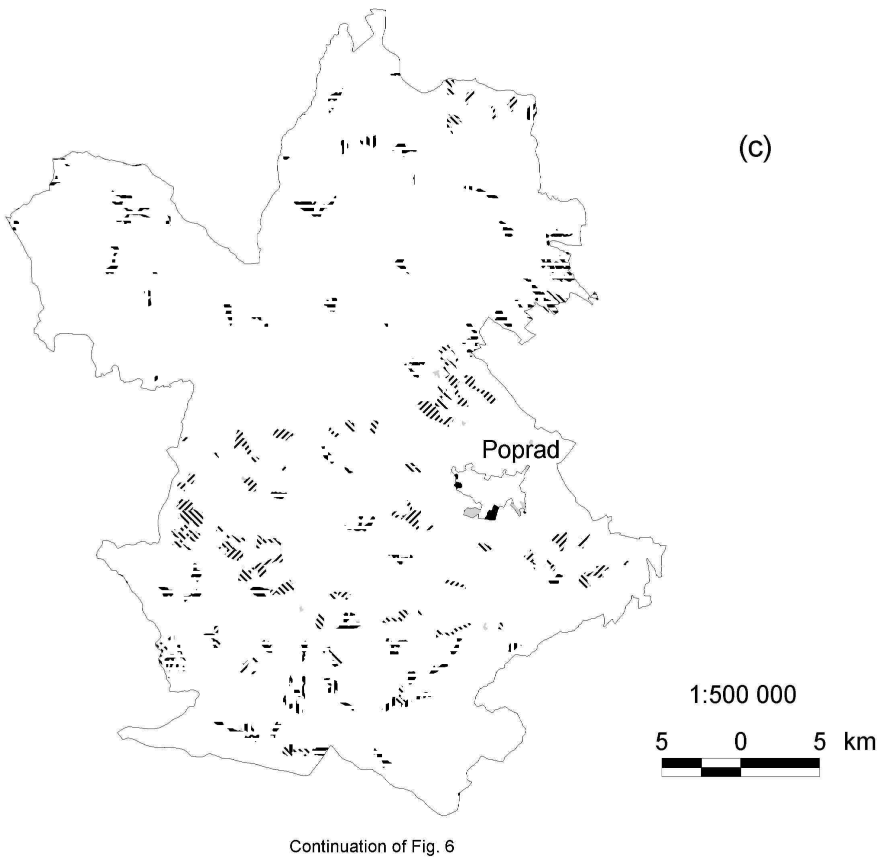


Fig. 6a, b, c. Spatial extent of landscape changes in the districts of Dunajská Streda, Snina and Poprad

Landscape changes classified as *afforestation* are minor in terms of extent They represent above all natural, as well as antropogenic changes of clear cuts into forest landscape, natural overgrowing of meadows and pastures, and the like.

From the point of view of area *deforestation* represents the most extensive landscape change in the districts of Poprad and Snina and the second largest landscape change in the district of Dunajská Streda. The principal causes of these changes are related to privatization of forests and subsequent logging or the devastating effect of wind and biological pests. In case of the district of Dunajská Streda, deforestation is connected with the construction of the Gabčíkovo dam.

The category of *other landscape changes* covers the territorially minor changes with limited possibilities for their identification on satellite images. They include the permanent flooding of a part of the territory of the district of Snina after the construction of the Starina water reservoir.

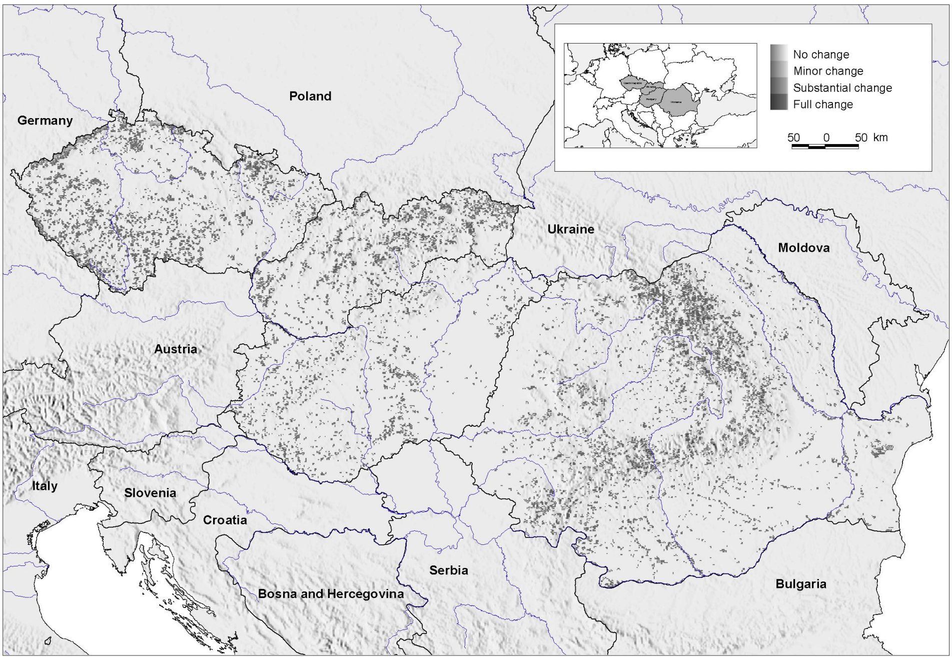


Fig. 7. Spatial extent of deforestation in the territories of the Czech Republic, Hungary, Romania, and Slovak Republic

The possibility of expressing the spatial extent of landscape changes on maps at different scales is an important aspect of the used methodology. The scale of the landscape change database (1:100,000) and the area of 4 ha as the criterion for identification of the minimum change determine the basic possibilities of cartographic representation of identified changes. It is obvious that representation of identified changes in their original not transformed form at a scale of 1:500,000 (Fig. 6) reached the limit of reproduction possibilities. For the needs of cartographic representation of identified landscape changes of all four countries the scale of 1:3,000,000 was proposed. In the sense of the above-described methodology the data on changes were computed for raster with cell resolution of 1.5×1.5 km, as Fig. 7 shows. The characteristics of the results are presented in the study Feranec et al. (2000a).

The CLC70/90 database of landscape changes created in this way is also applicable in the process of assessment at the level of natural or administrative units of Slovakia (for instance, basins, districts, regions, etc.).

CONCLUSION

Observation of landscape changes by means of this methodology is based on the presumption that information on landscape changes can be derived from land cover changes. Characteristics of land cover (extent and shape of areas) are well identifiable on satellite images and expand the potential of statistical data or topographic and thematic maps by the opportunity to learn about the spatial aspects of assessed landscape changes, thus contributing to improved understanding of their causality.

While testing the described methodology in the process of land change identification and analysis in the period from the end of the 1970's to the beginning of the 1990's using the example of the districts of Dunajská Streda, Poprad, and Snina the authors acquired the knowledge summarized in the following paragraphs.

Information on changes obtained by the applied procedure is especially relevant for the 1:100,000 scale, as the minimum area of identified land cover class in the sense of the described methodology is 25 ha and the area of the minimum identifiable change is 4 ha.

Precision of identification, analysis, and assessment of landscape changes applying the CLC database is enhanced by comparison at the more detailed, third or fourth level of CLC nomenclature (results of the above-quoted test characterize landscape changes only at the second level of the CLC nomenclature, as they were obtained in the framework of the Phare Topic Link on Land Cover Project, cf. Feranec et al. 1999, 2000a).

The proposed reclassifying table (Tab. 2), which enables derivation of landscape changes from land cover changes is flexible and modifiable if some type of landscape change is to be highlighted.

The possibility to provide spatial information on landscape changes is an important asset of this methodology. In connection with the small extent of areas of landscape changes, expression of the spatial rate of these changes on maps at a considerably smaller scale than 1:100,000 requires derivation of the unit area from the changed area (for the raster with corresponding resolution or other network of spatial units).

Results acquired only by this methodology do not allow for an exhaustive assessment of landscape changes.

Assessment of the identified landscape changes in Slovakia was carried out by applying the DPSIR model, that is Driving force, or causes of changes, Pressures or manifestation of changes, State or state of landscape, Impacts or consequence of the new state, and Responses or reactions to the new state (Smeets and Weterings 1999, Feranec et al. 2000b). The results will be published in a separate study.

Verification of the precision of the identified landscape changes by comparison with official results published in statistical yearbooks is problematic, as the content of the CLC database classes does not coincide with that of the classes used by the Statistical Office (Feranec et al. 2001). It will be necessary to seek for solutions leading to improvement of compatibility of these two datasets.

Acquisition of information on landscape changes from the periodically updated CLC database will contribute to progressive creation of a complementary part of the national statistics.

Updating of the CLC database will also offer favourable conditions for operative identification and analysis of landscape changes at national levels, as well as in the all-European context.

This study is one of the outputs of the EEA Phare Topic Link on the Land Cover Project (supported by the Phare Programme) and the Project No. 2/1037/22 Landscape Mapping and Assessment by Application of the Remote Sensing and Geographical Information System Methods (supported by VEGA Grant Agency) solved at the Institute of Geography of the Slovak Academy of Sciences. The authors are grateful to H. Contrerasová for translating the manuscript into English.

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METODICKÉ ASPEKTY IDENTIFIKÁCIE A ANALÝZY ZMIEN KRAJINY SLOVENSKA VYUŽITÍM DATABÁZ CORINE LAND COVER

Identifikácia a analýza zmien krajiny Slovenska vychádzali z využitia dvoch vektorových databáz krajinnej pokrývky CORINE land cover (CLC) v mierke 1:100 000. Prvá databáza, reprezentujúca aktuálny stav na Slovensku začiatkom 90. rokov (1989-1992), bola vytvorená metódou vizuálnej interpretácie satelitných snímok Landsat TM. Druhá databáza vznikla modifikáciou pôvodnej, metódou retrospektívnej analýzy (downdating), využívajúcej snímky Landsat MSS z druhej polovice 70. rokov (1976-1979). Databáza zmien je výsledkom naloženia oboch údajových súborov, ktoré reprezentujú krajinnú pokrývku zo 70. a 90. rokov.

Metodický postup tvorby databázy zmien krajinnej pokrývky Slovenska má tieto kroky:
- príprava a segmentácia satelitných snímok Landsat TM a Landsat MSS na identifikáciu krajinnej pokrývky reprezentujúcej obdobie 70. rokov;
- príprava podkladov na identifikáciu krajinnej pokrývky reprezentujúcu 70. roky z databázy CLC 90. rokov (CLC90) – agregáciou areálov (tried) 3. úrovne do areálov 2. hierarchickej úrovne CLC (tab. 1) a segmentáciou takto pripravených vektorových údajov podľa kladu listov topografických máp v mierke 1:100 000;
- identifikácia tried CLC 70. rokov (CLC70) modifikáciou podkladov vytvorených z CLC90 pomocou satelitných snímok Landsat MSS; (súčasťou tohto kroku bola aj revízia pôvodných údajov CLC90, prostredníctvom satelitných snímok Landsat TM);
- mozaikovanie jednotlivých segmentov databázy CLC70, kontrola ich fyzickej a logickej integrity;
- identifikovanie a tvorba databázy zmien krajinnej pokrývky za 70. a 90. roky (CLC70/90) naložením súborov CLC70 a CLC90;
- aplikácia kontrolných procedúr a testov a spätné odvodenie finálnej verzie databázy CLC70 z databázy zmien CLC70/90.

Reklasifikáciou sa počet kombinácií zmien krajinnej pokrývky na druhej úrovni legendy CLC (tab. 2) zjednodušil a bola vytvorená databáza siedmich typov zmien krajiny: intenzifikácia poľnohospodárstva, extenzifikácia poľnohospodárstva, urbanizácia (industrializácia), zväčšovanie povrchovej ťažby nerastných surovín, zalesnenie, odlesnenie a iné typy zmien.

Zmeny plošného rozsahu tried databáz CLC 70. a 90. rokov druhej úrovne sú vyjadrené prostredníctvom kontingenčných tabuliek (tab. 4), ktoré zároveň dokumentujú tematickú redistribúciu tried krajinnej pokrývky v hodnotenom období.

Rozsah identifikovaných zmien krajinnej pokrývky dokumentuje obr. 3 a rozsah jednotlivých typov zmien krajiny je znázornený na obr. 4 a 5.

Získavanie informácií o zmenách krajiny z periodicky aktualizovanej databázy CLC (ktorá začala v krajinách EÚ v roku 2001 projektom CLC2000) umožní vytvoriť perspektívne komplementárnu časť národnej štatistiky.