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Expansion of artificial surfaces in Slovakia in 2000-2006: assessment based on the CORINE land cover data and national statistics

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The aim of this paper is to demonstrate on example of Slovakia:

- The possibilities of using CORINE land cover (CLC) data for monitoring the expansion of artificial surfaces with emphasis on analysis of individual CLC classes: 11 (urban fabric), 12 (industrial, commercial and transport units), 13 (mine, dump and construction sites) and 14 (artificial, non-agricultural vegetation areas)

- The possibilities of using national statistics (NS) data for monitoring the expansion of artificial surfaces

- Results of comparison of expanded artificial surfaces in Slovakia identified by traditional NS with the CLC data

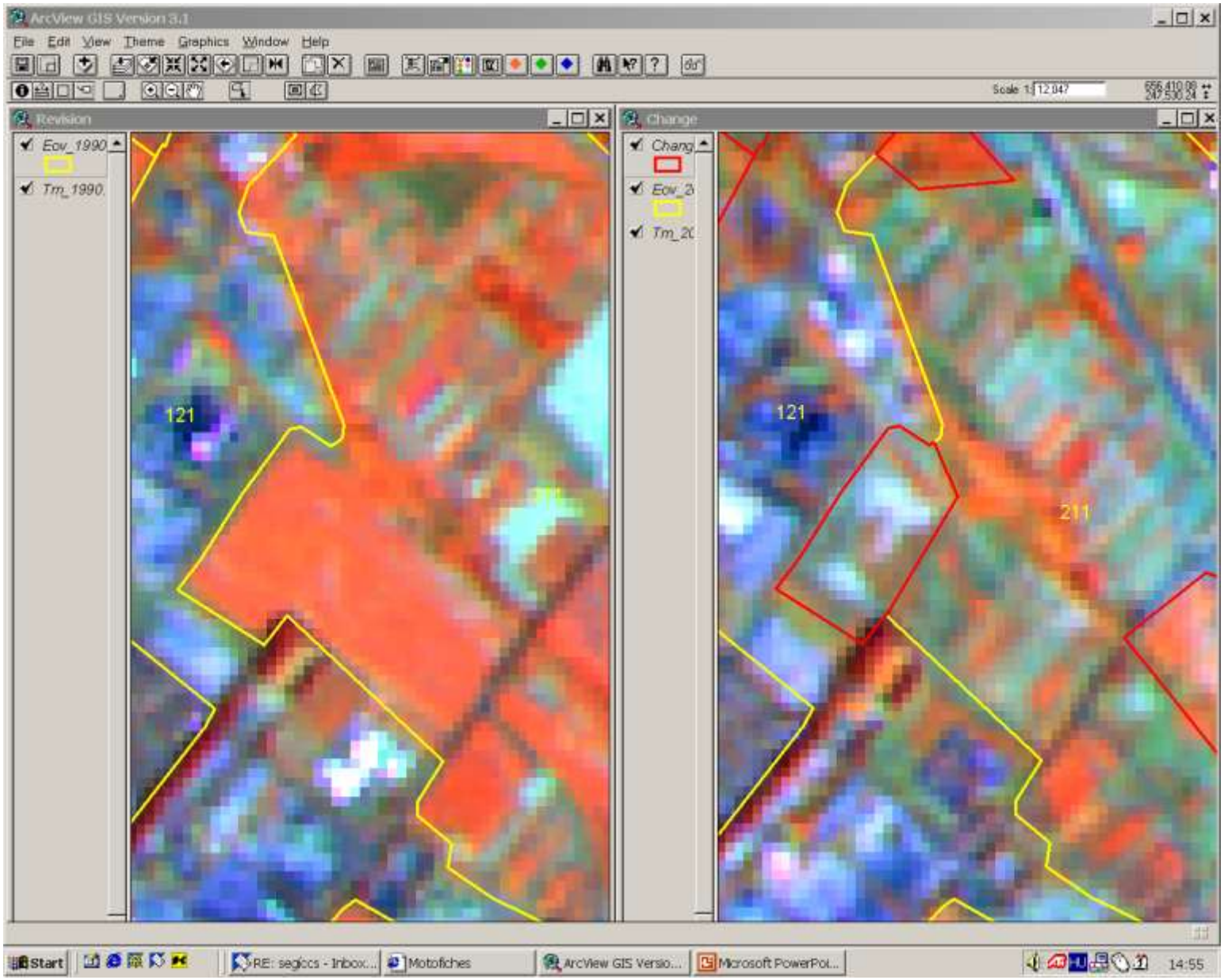
- Identification and analysis of differences and assessment of causes and the spatial aspect of artificial surface expansion

Changes 133, 21, 22, 23, 24, 31, 32, 33, 41, 51 and 52 into 11, 12, 13 and 142. Changes here mean “expansion (enlargement)” of artificial surfaces (areas of CLC classes, as well as artificial surfaces and courtyards which are parts of NS Slovakia in the period of 2000-2006

Among the most marked landscape transformations under the impact of human activities is the one in favour of constructions. A distinctly changed landscape component is normally the land

The EEA publication (2000) – constructions of buildings and roads cover 20 mill. ha of agricultural land of the world annually

Hasse (2007) reports that in the years 1992-2002 as much as 2,080,000 acres of land was built-up annually in USA (3.95 acre/min or 1.6 ha/min)



Example of change area (211-121)

Occupation with subsequent isolation of land by construction is the phenomenon referred to by the term *soil sealing* – the EEA glossary (2006) points to implication with the changing soil properties. Soil becomes an impermeable medium as it is covered by impermeable materials (concrete, metal, glass asphalt or plastics)

The basic aspects of the methodology applied to identification and measurement of soil sealed areas are in the study of Kampouraki et al. (2006)

Wood et al. (2006) consider soil sealing the act of covering the soil by structures of urban development (soil sealed areas ≠ urban land use area)

Scalenghe and Marsan (2009) provide an overview of topical approaches concerned with the definition, phenomenology, conceptual and empirical modelling associated with soil sealing with emphasis on urban areas in Europe

Projects involved: Soil Service for the Provision of advanced Geoinformation on Environmental Pressure and State (*Soil*SAGE), the Global Monitoring for Environment and Security (GMES) Urban Services (GUS), the GMES Service Element (GSE) Land Monitoring, the Monitoring Urban Dynamics (MURBANDY), the Monitoring Land Use-Cover Change Dynamics (MOLAND) project (Burghardt et al., 2004)

The *GMES Fast Track Service Precursor on Land Monitoring* (Kopecky and Kahabka 2009) project deserves a special attention as it established the rate of soil sealing for the 100 × 100 m grid covering 38 European countries (27 EU Member States and 11 neighbouring states), divided into five classes: 0-29%, 30-49%, 50-79%, 80-99%, and 100%

Used data and methods

CORINE land cover nomenclature (Heymann et al. 1994, Bossard et al. 2000)

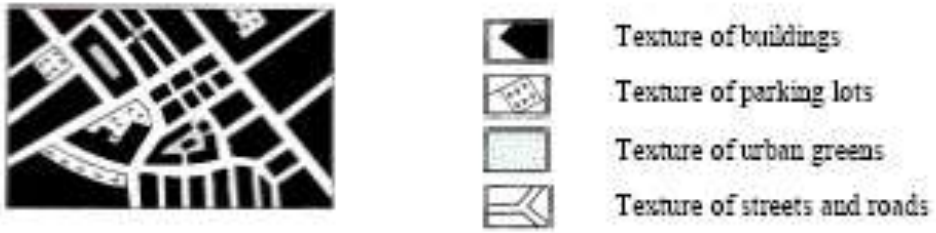
1 Artificial surfaces
11 Urban fabric
111 Continuous urban fabric
112 Discontinuous urban fabric
12 Industrial, commercial and transport units
121 Industrial or commercial units
122 Road and rail networks and associated land
123 Port areas
124 Airports
13 Mine, dump and constructions sites
131 Mineral 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
212 Permanently irrigated land
213 Rice fields
22 Permanent crops
221 Vineyards
222 Fruit trees and berry plantations
223 Olive groves
23 Pastures
231 Pastures
24 Heterogeneous agricultural areas
241 Annual crops associated with permanent crops
242 Complex cultivation patterns
243 Land principally occupied by agriculture, with significant areas of natural vegetation
244 Agro-forestry areas

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
321 Natural grasslands
322 Moors and heathland
323 Sclerophyllous vegetation
324 Transitional woodland-scrub
33 Open spaces with little or no vegetation
331 Beaches, dunes, sands
332 Bare rocks
333 Sparsely vegetated areas
334 Burnt areas
335 Glaciers and perpetual snow

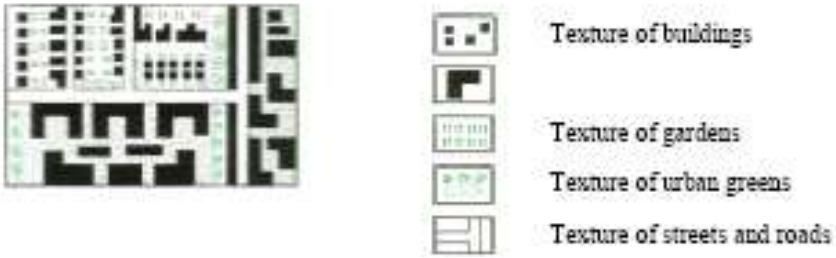
4 Wetlands
41 Inland wetlands
411 Inland marshes
412 Peat bogs
42 Maritime wetlands
421 Salt marshes
422 Salines
423 Intertidal flats

5 Water bodies
51 Inland waters
511 Water courses
512 Water bodies
52 Marine waters
521 Coastal lagoons
522 Estuaries
523 Sea and ocean



A generalised pattern of the class 111

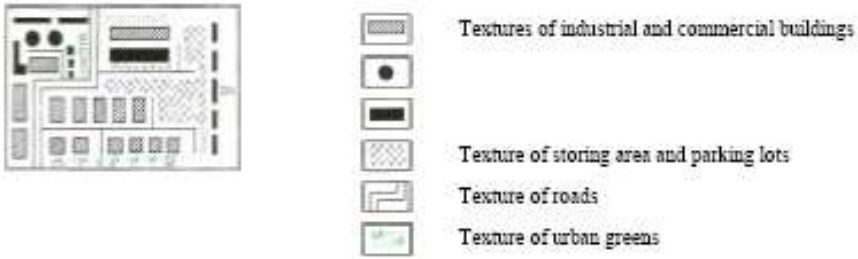
111 Continuous urban fabric
Most of the land covered by structures and the transport network (more than 80% of the total surface is impermeable). Non-linear areas of vegetation and bare soil are exceptional.



A generalised pattern of the class 112.

112 Discontinuous urban fabric

Between 30 to 79% of the land is covered by structures which are impermeable and associated with vegetated areas and bare soil (at least 30% of urban fabric within patchwork area and the distance between houses or group of urban fabric areas less than 25 ha is 300 m are the threshold values for this class).

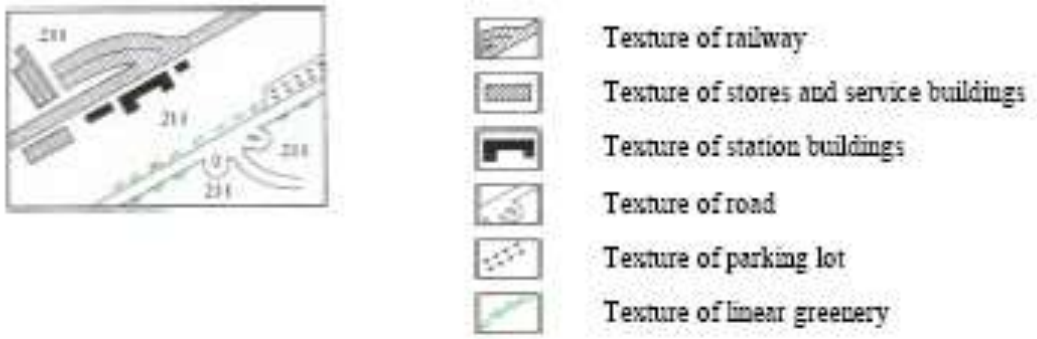


A generalised pattern of the class 121.

A generalised pattern of the particularity of class 121.

121 Industrial or commercial units

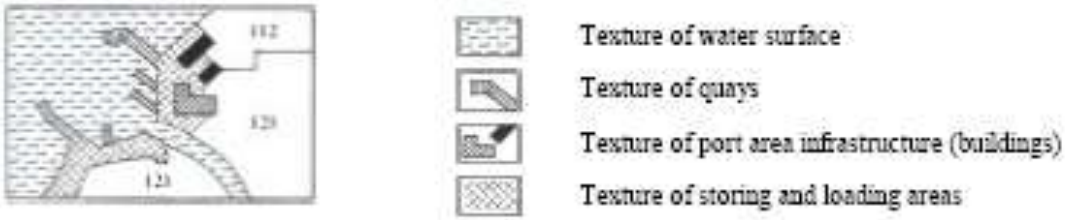
Artificially surfaced areas which can be discontinued by urban greens. The threshold value for artificial surfaces of this class is not specified for "urban fabric". In some specific cases less than 30% of the total surface should be impermeable (e.g. sparse military barracks in training ground, transmitting and receiving stations).



A generalized pattern of the class 122.

122 Road and rail networks and associated land

Motorways and railways with associated installations (stations, platforms, embankments, vegetated trenches, etc.). Minimum width of components is 100 m.



A generalized pattern of the class 123.

123 Port areas

Infrastructure of port areas, with quays, dockyards and marinas.

A generalized pattern of the class 124.

124 Airports
Airport installations: runways, buildings and associated land.

A generalized pattern of the class 132.

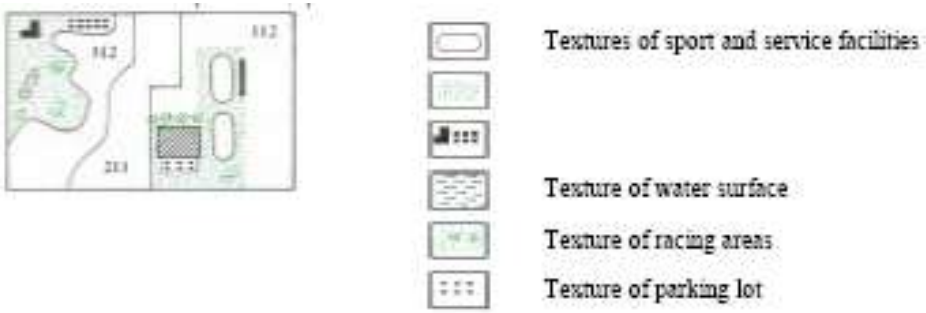
132 Dump sites
Public, industrial or mine dump sites.

Texture of buildings under construction

A generalized pattern of the class 133.

133 Construction sites

Areas under construction development, soil or bedrock excavations, earthworks.



A generalised pattern of the class 142.

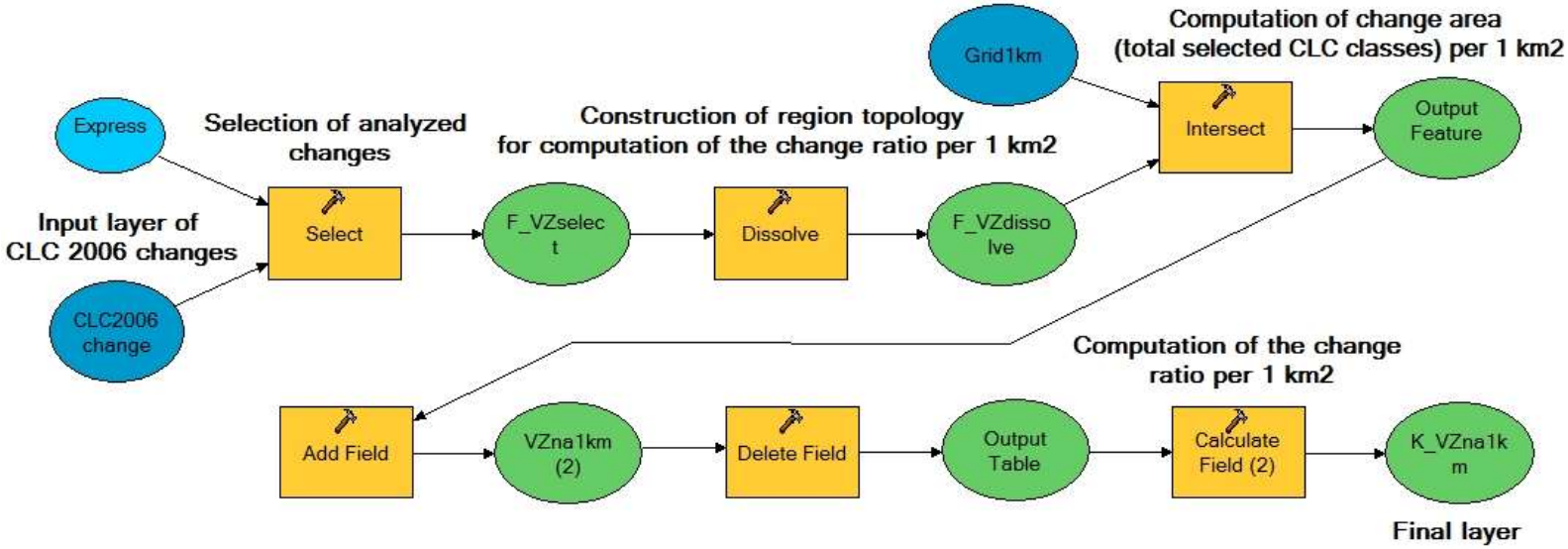
142 Sport and leisure facilities

Camping grounds, sport grounds, leisure parks, golf courses, race courses. Not all these objects create impermeable surfaces.

NS data of built-up areas and courtyards were taken from *Statistical yearbooks about land pool in the SR* pursuing the cadastre of real estate data for the years 2001-2007. These plots have been drawn based on their functional features and the legal situation pursuing the cadastral map.

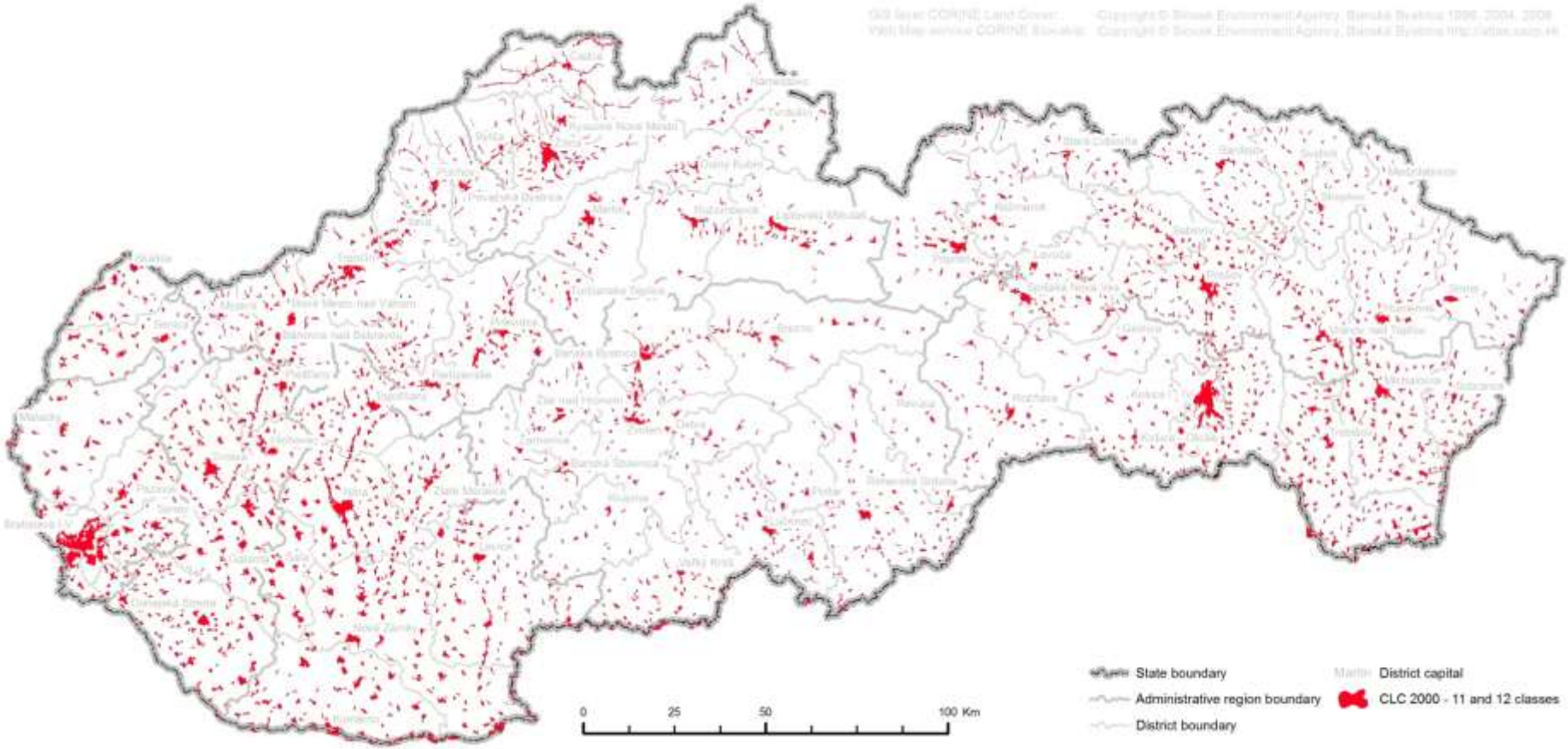
Sizes of built-up areas and courtyards in Slovakia (in ha)

Type of plot	Change 2001-2007	1.1.2001	1.1.2002	1.1.2003	1.1.2004	1.1.2005	1.1.2006	1.1.2007
Built-up areas and courtyards	**7,754**	219,338	222,475	223,355	224,671	225,566	226,257	227,092

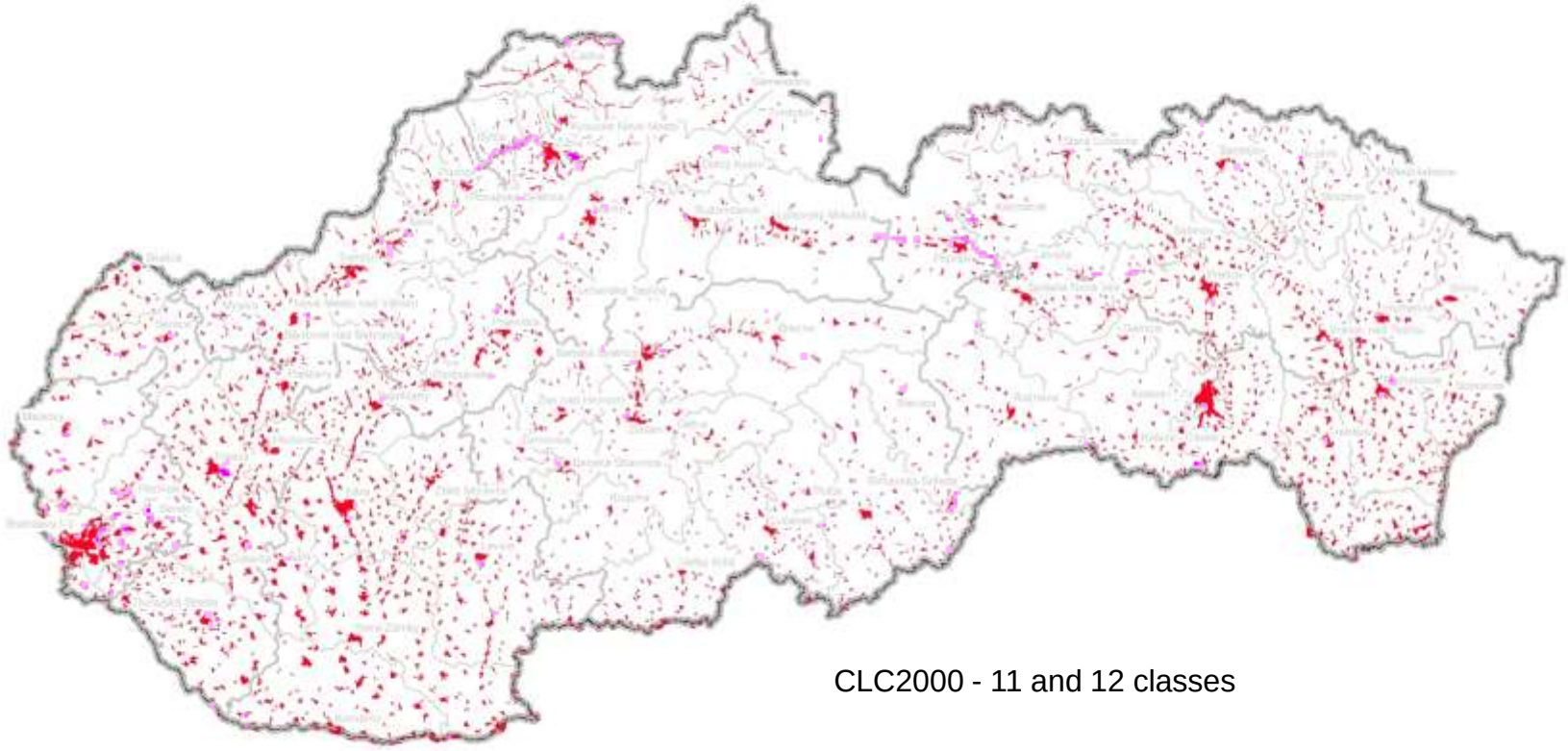


Computation of expansion of CLC classes 11, 12, 13 and 142

As the frequency of monitored CLC changes of Slovakia was not regular and the size of its areas oscillated between 5 ha (the smallest identifiable changed area) and several hundreds of ha, it was decided to express such changes by means of relative values: proportion of accruing artificial surfaces per 1 km^2, divided into five intervals: 0.0%, 0.1-10.0%, 10.1-20.0%, 20,1-40.0%, 40.1-100.0%



Frequency (occurrence) Map for CLC classes 11 and 12 in Slovakia in 2000



CLC2000 - 11 and 12 classes

Map of expansion of areas (CLC classes 11, 12, 13 and 142) in Slovakia in the period of 2000-2006

Results:

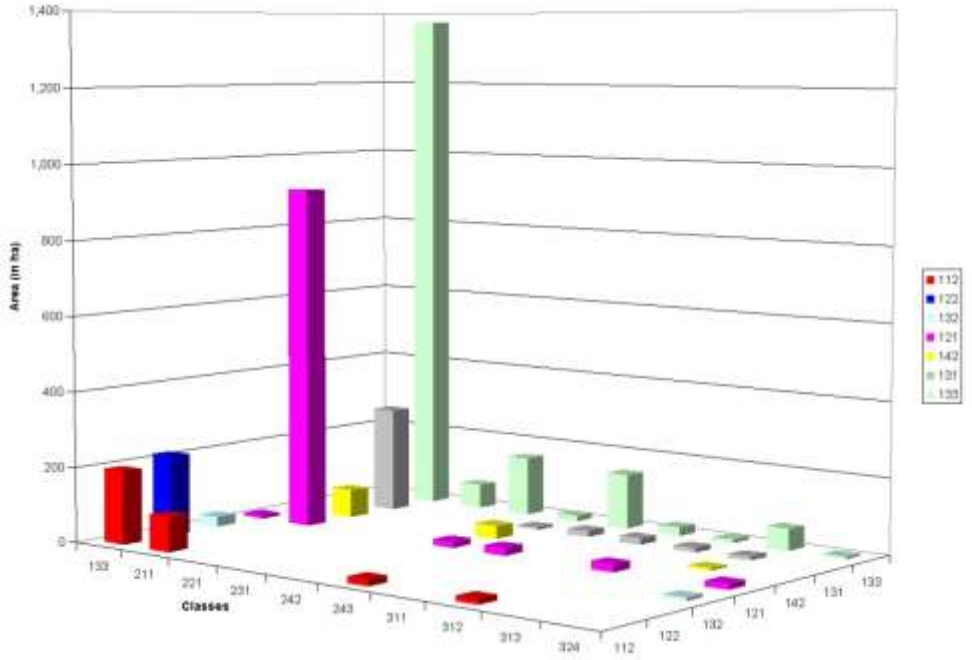
Characteristics of soil isolation in the frame of CLC (artificial surfaces) and NS (built-up areas and courtyards) classes

CLC classes	Soil isolation intensity	Note
111	80 % and more of the surface is impermeable	Impermeable surface is sporadically interrupted by small permeable parts
112	30-79% of surface is impermeable	Prevailing mosaic alternation of permeable and impermeable surfaces
121	Ambiguous determination of impermeableness %; 30% and less of surface may be impermeable	Irregular alternation of permeable and impermeable surfaces; part of areas can consist of buffer zone (for example, vegetation.)
122	Ambiguous determination of impermeableness; in case of road communication more than 50% of surface can be impermeable	Impermeable part of area is usually connected with a permeable one (strips of greenery, banks along communications, and the like.)
123	Impermeable parts dominate; % of their extent is not determined	Irregular alternation of permeable and impermeable surfaces which are more compact
124	% of impermeable parts is not determined; permeable parts may dominate	Permeable part consists of prevailingly marked buffer zone
132	% of extent of impermeable parts is not determined	Pattern of permeable and impermeable surfaces is very heterogeneous
133	% of extent of impermeable parts is not determined; permeable surface may dominate	Pattern of permeable and impermeable surfaces is very heterogeneous
142	% of extent of impermeable parts is not determined; permeable surface often dominates	Varied arrangement of permeable and impermeable parts; permeable area is often sporadically interrupted by enclaves of impermeable surfaces
Built-up areas and courtyards (NS)	Distinct prevalence of impermeable surfaces	Impermeable surface is sporadically interrupted by small permeable surfaces

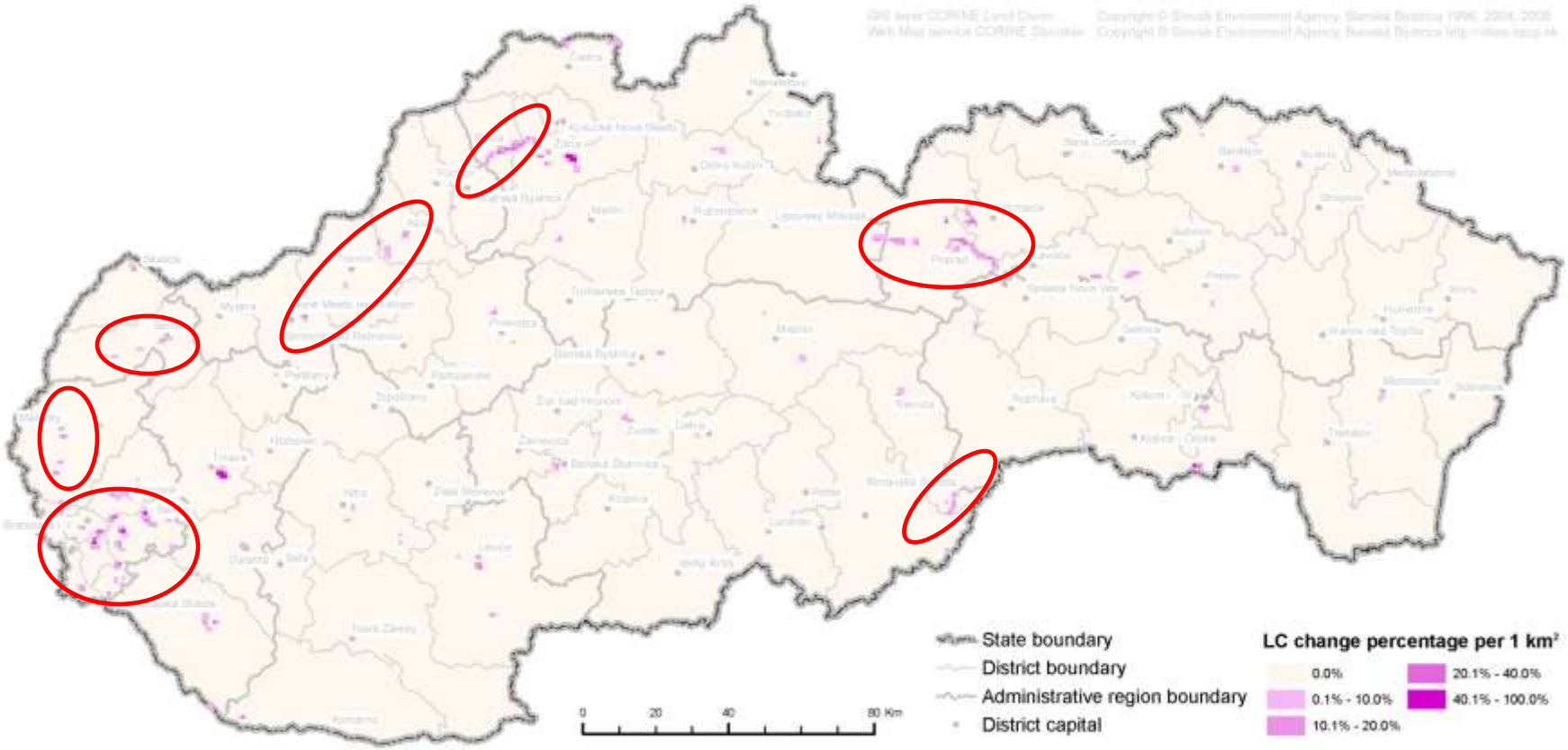
Changes of CLC Slovakia classes 21, 22, 23, 24, 31, 32, 33*, 41*, 51* and 52* into 11, 12, 13 and 142 in the period of 2000-2006 (v ha)

	2006							
2000	112	121	122	131	132	133	142	Total
133	195.42	7.92	214.43		26.45			444.21
211	92.38	916.76		280.10		1372.74	74.76	2,736.75
221						65.20		65.20
231						157.87		157.87
242		15.91		6.37		15.38	33.36	71.01
243	16.66	20.34		16.82		146.51		200.32
311				16.48		22.05		38.54
312	15.14	20.97		12.23		9.57		57.90
313				10.43		58.26	5.75	74.44
324		14.75			7.90	5.86		28.51
Total	319.60	996.64	214.43	342.44	34.35	1853.43	113.88	3,874.76

*Note: classes 33, 41, 51 a 52 did not change in favour of artificial surfaces in the evaluated period.

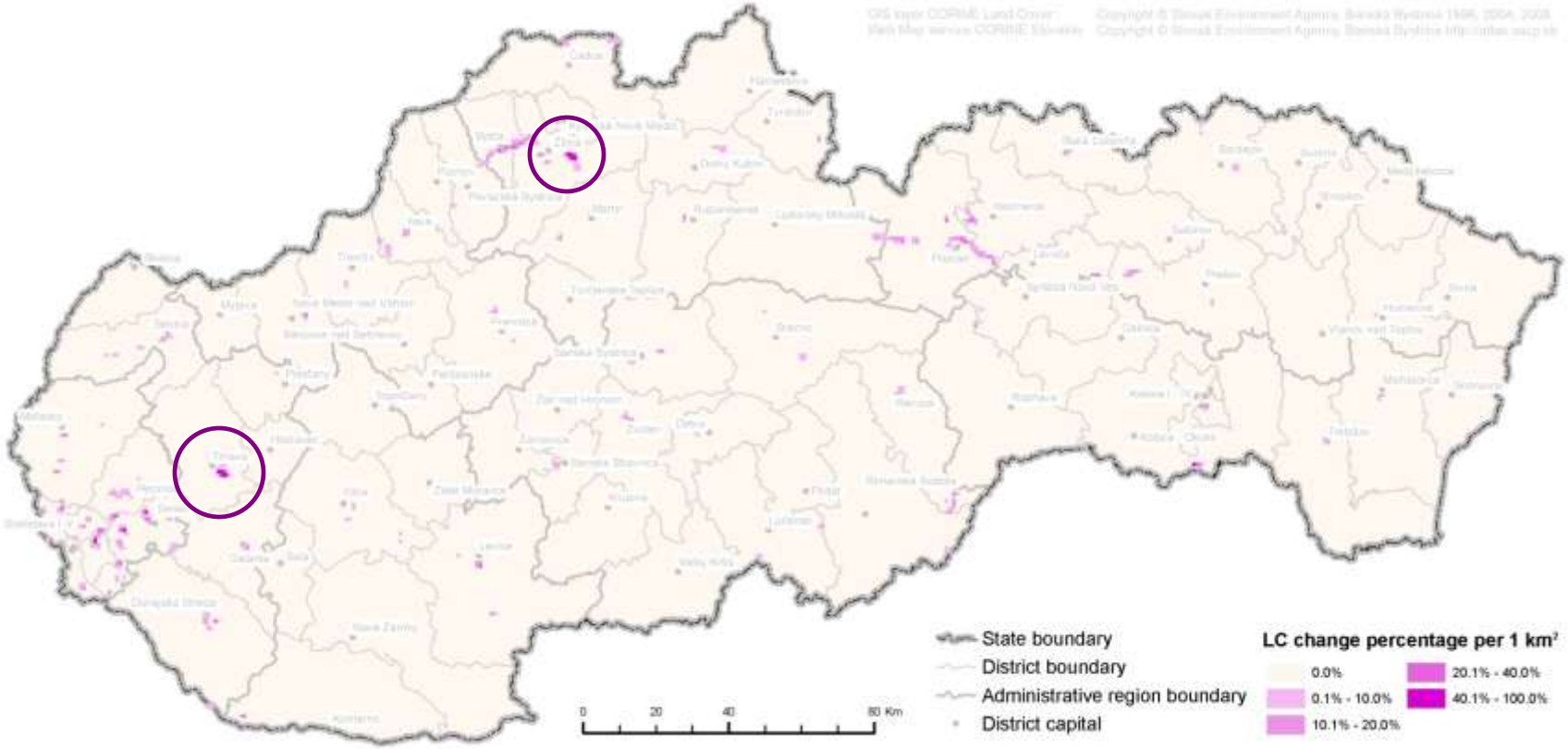


Changes of selected CLC classes in favour of artificial surfaces



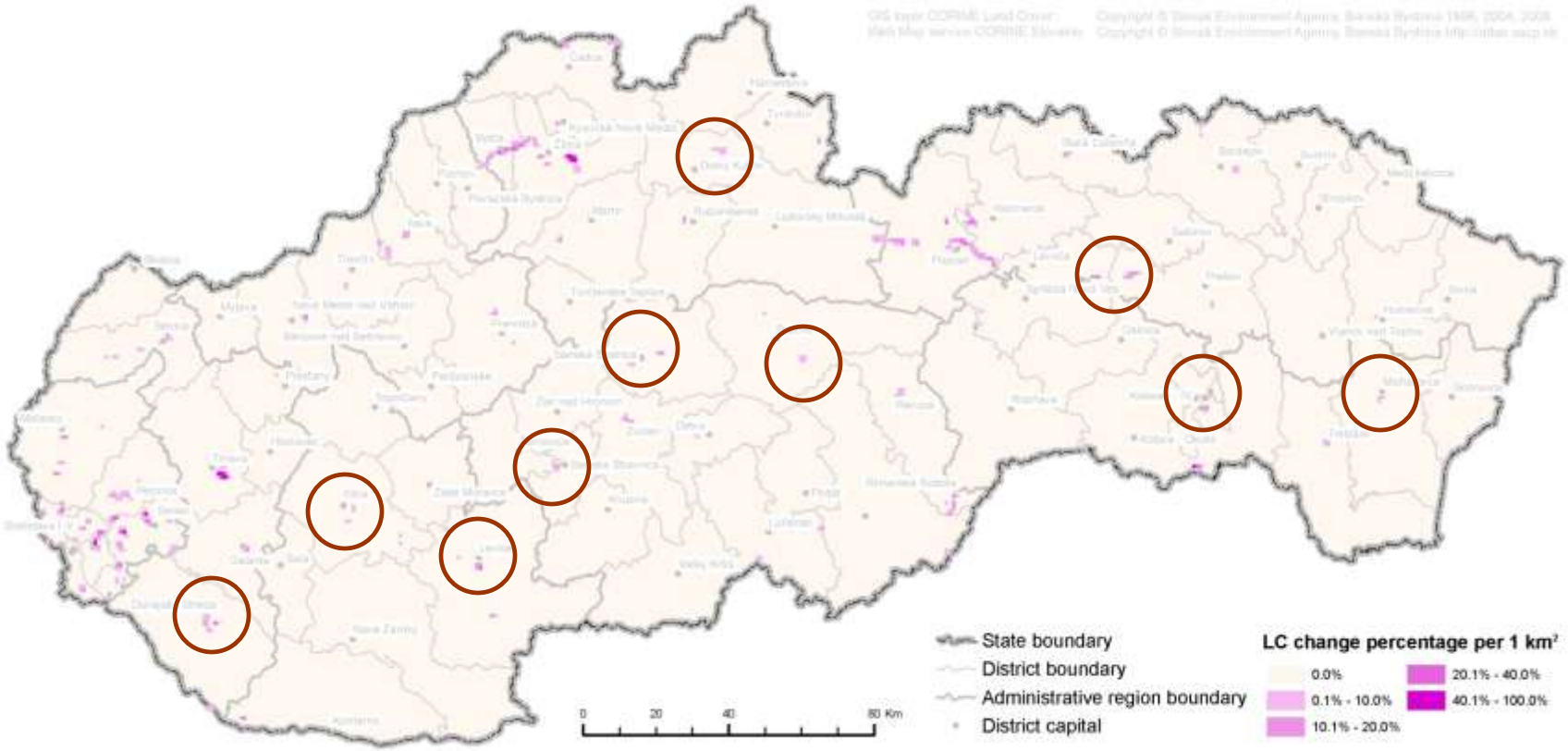
Map of expansion of areas (CLC classes 11, 12, 13 and 142) in Slovakia in the period of 2000-2006

The most distinct changes in terms of area were shrinkage of arable land (211), but also of other classes in favour of construction sites (133): in environs of Bratislava, in the region of Záhorie, central and upper parts of the region Považie, in eastern part of the Liptovská and Popradská Basins



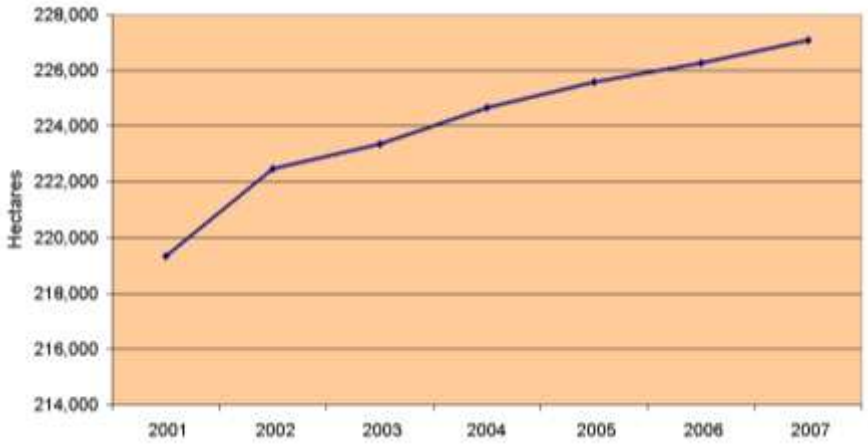
Map of expansion of areas (CLC classes 11, 12, 13 and 142) in Slovakia in the period of 2000-2006

The second largest change is shrinkage of arable land (211) in favour of industrial or commercial units (121): A conspicuous part of this change is represented by the area of car factories KIA and Peugeot – Citroën (environs of Trnava and Žilina)



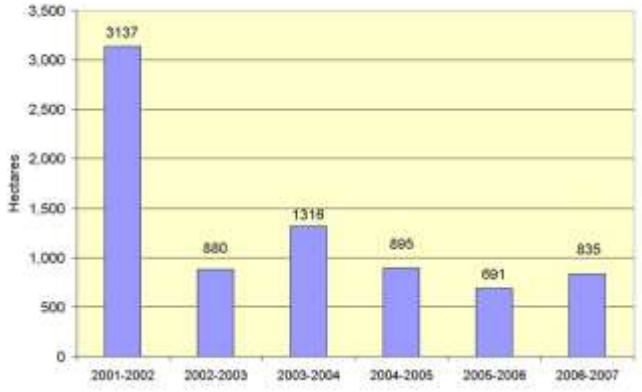
Map of expansion of areas (CLC classes 11, 12, 13 and 142) in Slovakia in the period of 2000-2006

Changes of construction sites (133) in favour of road and rail networks and associated land (122) and discontinuous urban fabric (112) are also worth mentioning: in upper part of the region of Považie, east of the Liptovská Basin and in Popradská Basin while the expansion of discontinuous urban fabric manifested all over Slovakia, and mainly in its western part

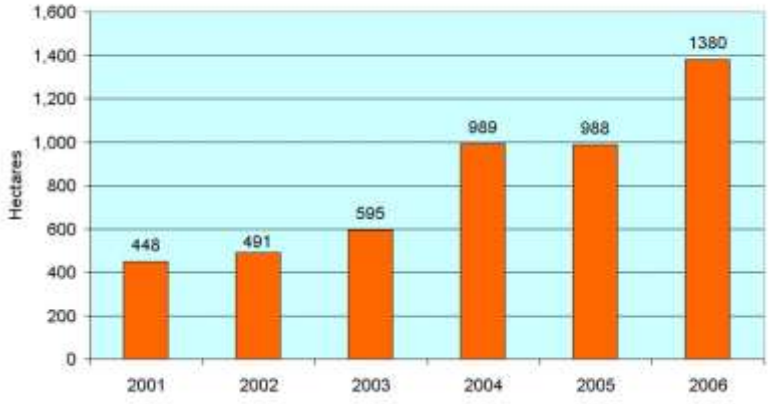


Expansion of built-up area and courtyards in the territory of the SR
in the period 1 January 2001-1 January 2007 (in ha)

Analysis of data from Statistical Yearbooks about Land Pool pursuing the data from the cadastre of real estate reveals a continuous expansion of built-up areas and courtyards during the whole period in question

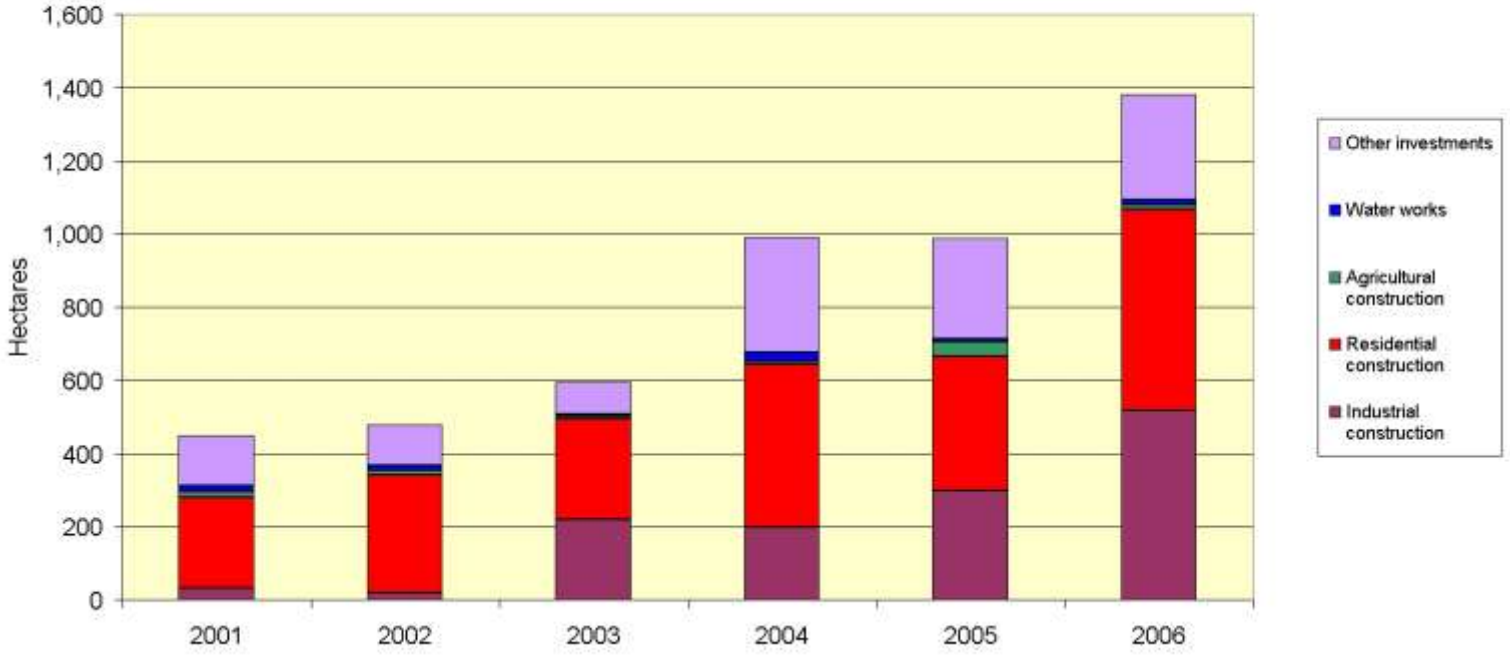


Inter-year increase of built-up area in the SR (in ha)



Occupation of agricultural land for construction (in ha)

A conspicuously biggest inter-year increase was observed at the beginning of the studied period in 2001-2002 (expansion of the building coverage in this period proceeded most probably within the inner territories of municipalities and industrial structures, as it did not require any larger occupation of arable land)



Shrinkage of agricultural land due to constructions in Slovakia in the period of 2001-2006 (in ha)

Areas of CLC classes11 and 12 and NS classes “built up areas and courtyards” of Slovakia in the periods of 2000 and 2006 (in ha)

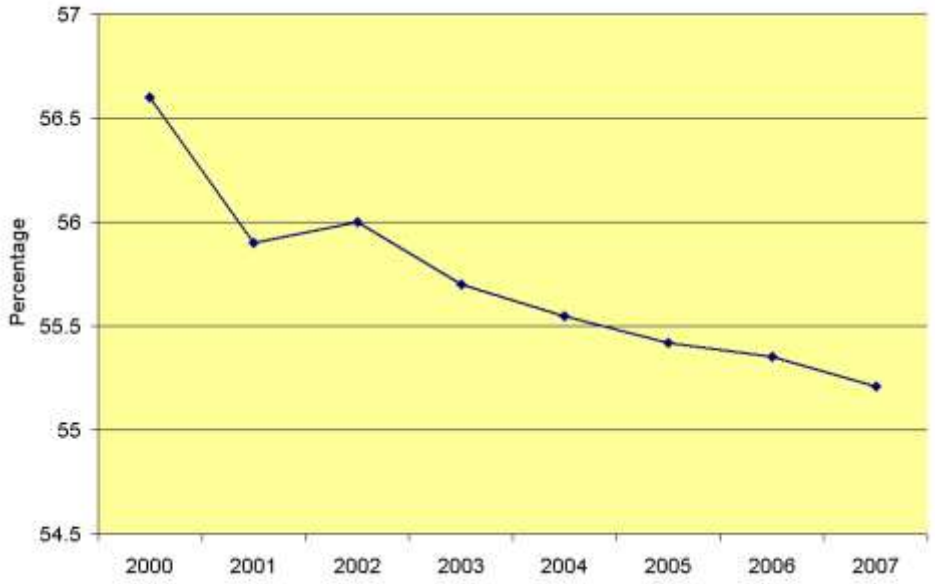
NS	CLC	2000		2006	
		CLC 2000	NS 2000*	CLC 2006	NS 2006**
Built-up areas and courtyards	11 + 12	256,040	219,338	257,895	227,092
Expansion of area NS 2000/2006		227,092 – 219,338 = **7,754**			
Expansion of area CLC 2000/2006		257,895 – 256,040 = **1,855**			
Difference in presented change		7,754 – 1,855 = **5,899**			

* as of 1.1.2001, ** as of 1.1.2007

Different approaches to identification of CLC and NS changes:

- Only LC changes larger than 5 ha were recorded by CLC methodology;

- NS records all changes (no area limit); and precisely this size of change is associated with enlargement of artificial surfaces (construction of residential houses above all) in urban but also rural settlements; it is presumed, that precisely construction of family houses in rural areas dominated, but the constructed areas were smaller than 5 ha;



Urbanization level in Slovakia (in %)

➢Urbanization level is the index which represents proportion of population living in urban areas, source: www.statistics.sk; decreasing index values were observed in all regions of Slovakia and this fact suggests a generally increasing share of population living in rural area.

Another possible cause of this difference is the disparity between the real and legal status of plots that were exempted from the arable land for construction which was not realized for various reasons; when CLC methodology, using the physiognomy of objects for their identification was applied such plots manifested in the image as unchanged; for instance in 2006, 1,380 ha of arable land was exempted for construction but the inter-year increase of built-up areas represented only 835 ha.

Results of thematic precision assessment of the CLC2000 data by the LUCAS (European Land Use/Cover Area Erame Statistical Survey) data confirmed precision of identification exceeding 95% for classes 112 a 121 (Büttner and Maucha 2006)

Conclusions:

➢Presented results in the study confirmed expansion of built-up areas in Slovakia in the period of 2000-2006. However, the new artificial surfaces cannot be automatically identified with soil sealing. NS data of "built-up areas and courtyards" coincide at a greater rate with the characteristics of impermeable surfaces, but they lack attributes of position only obtainable by demanding procedures from cadastral maps.

➢Pursuing NS, built-up areas and courtyards in Slovakia in the period of 2000-2006 increased by 7,754 ha (0.16% of total country's area) and pursuing CLC data it was by 1,855 ha (0.04% of total country's area). The difference of 5,899 ha is the consequence of different approaches to acquisition of these data but also the disparity between the real and legal statuses of areas.

➢Progressive unification of the content of classes that are parts of both characterized datasets and increased precision of CLC classes identification by means of satellite images (under CLC projects only LC changes larger than 5 ha were identified) will contribute to increased compatibility of CLC and NS data.

➢Civil and housing constructions along with industrial construction and other investment purposes (particularly construction of motorways) dominated in Slovakia in the studied period.

➢Artificial surface areas (CLC) are considered adequate input data only for detailed identification and monitoring of artificial/impermeable landscape surfaces (soil sealing) based on high resolution satellite imagery (for instance, Ikonos, Quick Bird, GeoEye and the like).

Thank you for your attention