Cent. Eur. J. Geosci. • 5(2) • 2013 • 323-330
DOI: 10.2478/s13533-012-0132-9

VERSITA

Central European Journal of **Geosciences**

Map presentation of changes in Europe's artificial surfaces for the periods 1990–2000 and 2000–2006

Research Article

Jan Feranec[1]*, Tomas Soukup[2]

1 Institute of Geography, Slovak Academy of Sciences, Bratislava, Slovakia

2 GISAT s.r.o., Prague, CzechRepublic

Received 20 November 2012; accepted 26 May 2013

Abstract: The landscapes of the world are constantly changing under the influence of human activities leading to the growth of artificial surfaces. The covering of soil by artificial surfaces is referred to as soil sealing. Aerial and satellite images or data derived from them (for instance CORINE land cover - CLC data used here) provide important information that makes it possible to assess the occurrence, area and rate of soil sealing. As the term sealed soil cannot be wholly identified with the content of the appropriate CLC classes, the term land cover flow urbanization (LCFU) will be used here. The essence of this study is the demonstration and documentation of the trends of the LCFU in Europe for the periods 1990-2000 and 2000-2006 on a single map. This may contribute to a better spatial awareness of the ongoing transformation of landscape under the effects of human activities in an pan-European context. Changes in the LCFU can be seen on a map, compiled from 3 × 3 km squares at an all-European scale, using colours and their hues, to fulfil the role both of identification and classification. The colour method employed makes it possible to perceive three groups of LCFU changes on two time horizons, that is, whether the rate of LCFU in 2000-2006 increased or remained the same (hues of red); or dropped compared to the 1990-2000 period (hues of light to dark blue). The third group represents the LCFU with rates higher or lower than the average (countries with changes recorded in only one time horizon are presented in dark and light magenta colours).

Keywords: map presentation • artificial surfaces • CLC data • change of LCFU • Europe

1. Introduction

Landscape transformation through human building and construction activities has had the greatest influence on the soil component of the landscape. One publication of the European Environment Agency (EEA [3]) reports that the area of farmland covered by buildings and road communications increases by 20 million hectares annually. Hasse's study [12] provides similar evidence, reporting that in the USA during 1992–2002 2 080 000 acres were built-up annually, which represents 3.95 acre/min (or 1.6 ha/min).

Building over or concealing soil through construction activities is referred to as soil sealing. The EEA glossary [4] explains the term by referring to a change in soil properties. After being covered by impermeable materials (e.g. concrete, metal, glass, plastic materials or asphalt), soil also becomes impermeable. Kampouraki et al. [14] de-

*E-mail: feranec@savba.sk

scribes the basic methodology used to identify and measure soil-sealed areas.

Scalenghe and Marsan [17] provide an overview of current approaches to the definition, phenomenology, and conceptual and empiric modelling of soil sealing, with a focus on the urban areas in Europe. These authors define sealed soils as a surface covered by impermeable material, a surface that occupies about 9% of Europe's land surface. Apart from information on the absolute area of the sealed zones, other aspects of urban sprawl, namely spatial information about the structure and composition of the sealed soil and the assessment of landscape fragmentation, are also important considerations.

The number of projects devoted to this subject — such as *Soil Service for the Provision of Advanced Geoinformation on Environmental Pressure and State (SoilSAGE)*; *Global Monitoring for Environment and Security (GMES) Urban Services (GUS)*; *GMES Service Element (GSE) Land Monitoring*; *Monitoring Urban Dynamics (MURBANDY)*; and *Monitoring Land Use-Cover Change Dynamics (MOLAND)* [2] —confirm that the expanding soil-sealed areas are gaining increased attention. The *GMES Fast Track Service Precursor on Land Monitoring* [15] project deserves a special mention as it established a 100 × 100 m resolution soil-sealing survey covering 38 European states (27 EU Members States and 11 neighbouring states), and divided into five classes: 0–29%, 30–49%, 50–79%, 80–99%, and 100%. The fact that soil sealing and impervious areas is one of the subjects covered as High Resolution Layers (HRL) under the *GMES Initial Operation (GIO)*[1] also confirms the need for fresh information about soil sealing.

As is obvious from the cited papers, important data sources, such as aerial and satellite images and the information derived from them (e.g. CORINE Land Cover (CLC) data), make it possible to assess the frequency, area and rate of soil sealing. In this paper, the applicability of CLC data, aided by their ready availability, will be demonstrated through the map presentation of landscape changes linked with soil sealing; i.e. the connected cover of soil by urban objects, which form impermeable surfaces. All CLC artificial surface classes represent areas or patterns where permeable and impermeable surfaces are juxtaposed. This is why CLC artificial surfaces cannot be considered identical to soil-sealing classes in terms of content. Changes of, for instance, agricultural areas or forest in favour of 'artificial surfaces' are referred to as 'land cover flow urbanization' (LCFU) [7, 11]. CLC change shows a categorical change, where one land cover (LC) class or its part(s) is replaced by other class(es). As LC is an indivisible part of the landscape, its state reflects different stages of development. This is why LC changes can be considered a relevant information source about processes (flows) in the landscape [7].
Presentation of LCFU changes using traditional maps can be carried out by either:

- a series of maps, showing the changes that took place between two time-horizons
- a single map, showing the trends of changes between more than two time-horizons.

Presenting changes on a series of maps is a frequently used way to achieve reasonable data universality. The principle is that each map represents the status or properties of a certain landscape object [5, 16].
Presenting changes on a single map is not as common employed as map series. However, it can be used if:

- the intention is to express the changes of two contiguous landscape objects; e.g. the increase or diminishment of artificial surface
- the changes of one object are simple and its environs remain unchanged; e.g. the freezing of the Arctic Sea (by weeks, decades or months), or changes in the northernmost limits of the distribution for tree species
- the changes characterize quantitative indicators; e.g. changes in the rate of forestation (cartogram by forest enterprises, districts, communes, etc.), accretion of wood mass in the forest, or changed yields of farmland [5, 16].

Animation should be also mentioned. This is the generation of images that simulate movement in the context of temporal changes of objects and their properties. Since 1960, cartographers have increased their interest in animation, and applications have been produced by means of film or television. However, new technologies introduced after 1980 are connected to computer-aided cartographic animations, and were followed by the introduction of GIS [16]. Animation helps cartographers to visualize spatial relationships and ongoing processes in the landscape.
The aim of this paper is to show one possible map presentation (in single map format) of LCFU changes for the periods of 1990–2000 and 2000–2006, using CLC data. This mapping contributes to spatial perceptions of landscape transformation by the effects of human activities at the whole-Europe level.

[1] http://ec.europa.eu/enterprise/newsroom/cf/itemlongdetail.cfm?item_id=5343&lang=en

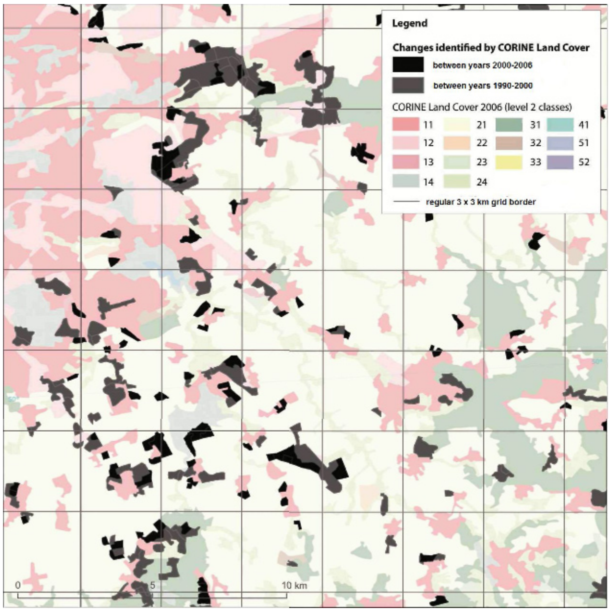

Figure 1. Examples of all land cover changes — southeast of Prague (Czech Republic).

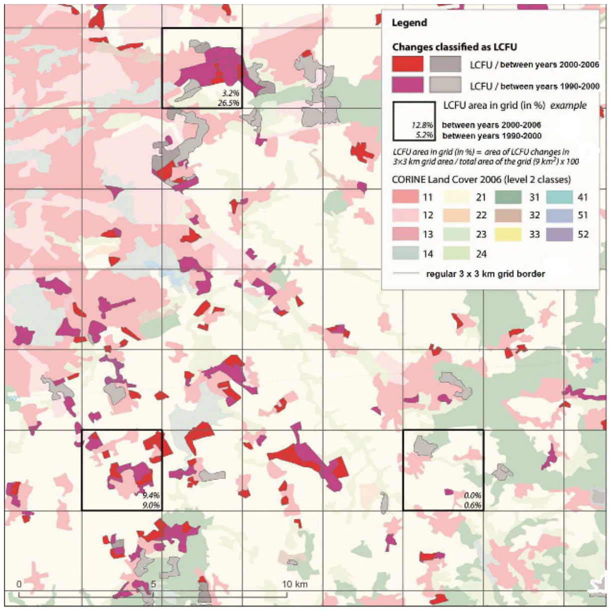

Figure 2. Examples of changes classified as land cover flow urbanization (LCFU) — southeast of Prague (Czech Republic).

2. Approach and methods

All data concerning spatial distribution, and areas of CLC1990, CLC2000 and CLC2006 classes are available from http://terrestrial.eionet.eu.int – CLC nomenclature [1, 13] (Table 1). Identified LC changes were selected; these changes, referred to as LCFU, are associated with the process of artificial surface formation, which in turn is considered part of urbanization (changing agricultural, forest and semi-natural areas into artificial areas). Certain areas of artificial surfaces were too small to be presented on a map, either at the national or the European levels — e.g. the smallest identified change area in the frame of the CLC mapping is 5 ha. A practical solution of how to 'visualize' such small areas of change is to present their intensity or rate as a regular grid-pattern. Following the study by Feranec et al. [7], a 3 × 3 km grid has been used as a compromise between the actual spatial distribution of landscape changes — through urbanisation, intensification or extensification of agriculture, afforestation, deforestation, water-body construction — and their presentation at an accessible scale at the European level. The *mean LCFU* value presented on these map is defined as a ratio of the area of LC changes standing for the LCFU to the area of all 3 × 3 km squares in which changes took place (Figs 1, 2). The mean LCFU value for 1990–2000 was 3.3%, and 2.2% for 2000–2006.

Shading on the map was achieved by comparing the obtained value of LCFU change in the square with the mean-change value of the particular LCFU. The square was then assigned red hues if the obtained change value was greater than the mean-change value, with blue hues assigned if the percentage of the obtained changed value was smaller than the mean-change value (Fig. 3). The following codes were also used to designate the change, where **G** is a value greater than the 'mean value of LCFU' (changes in favour of LCFU), **S** is a value smaller than the 'mean value of LCFU', **1** indicates the 1990–2000 time horizon, **2** indicates the 2000–2006 time horizon, and N is an area without LCFU identification:

G1 – G2: LCFU above-mean value — LCFU above-mean value

S1 – G2: LCFU below-mean value — LCFU above-mean value

N1 – G2: Without LCFU — LCFU above-mean value

S1 – S2: LCFU below-mean value — LCFU below-mean value

N1 – S2: Without LCFU — LCFU below-mean value

G1 – S2: LCFU above-mean value — LCFU below-mean value

G1 – N2: LCFU above-mean value — Without LCFU

S1 – N2: LCFU below-mean value — Without LCFU

N1 – N2: Without LCFU — Without LCFU

For countries with only one change value (time horizon of 1990–2000 or 2000–2006; Table 2), a dark magenta colour (**G1** or **G2**) was used for an above-mean LCFU value, and a light magenta colour (**S1** or **S2**) for below-

Table 1. CORINE Land Cover (CLC) class nomenclature [1, 12].

1 Artificial surfaces	**3 3 Forest and semi-natural areas**
11 Urban fabric	*31 Forests*
111 Continuous urban fabric	311 Broad-leaved forests
112 Discontinuous urban fabric	312 Coniferous forests
12 Industrial, commercial and transport units	313 Mixed forests
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 construction 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 Inland 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 Inland 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

mean LCFU value, on the corresponding country's light-grey background.

As LCFU changes were assessed within a 3 × 3 km grid, presentation of the results, which are comparisons of the mean LCFU value with the real LCFU values in the frame of the square, is exacting for the selection of the correct expression means for a small-scale map. Basically, only one option of the graphical variables was left — the difference in colour hue — although Kraak and Ormeling [15] assert that 'colour hue' only offers a qualitative differences between observed objects. Colour (and its hues) fulfils two functions in the context of the map produced here: identification and classification [5].

3. Results

The applied approach of colour distinction (Fig. 3) allows the identification of three groups of the LCFU rate changes in the two time-horizons:

G1 – G2, ***S1 – G2***, ***N1 – G2***, ***S1 – S2***, and ***N1 – S2*** (red hues) show an enlargement or standstill of the LCFU — that is, changes characterized by the expansion of the LCFU rate during the second time-horizon (2000–2006), or else show a rate that was the same in both time horizons (but did not diminish; Fig. 3). This type of change dominates in the eastern part of Ireland, western Netherlands, west and south of France, central and southern Spain, north and south of Portugal, along the River Po in northern Italy, and in the north of Hungary.

G1 – S2, ***G1 – N2***, and ***S1 – N2*** (light-blue to dark-blue hues) show a decrease of the LCFU rate in the period of 2000–2006 as compared to the period 1990–2000. This decreased LCFU rate (Fig. 3) is most distinguishable in eastern Belgium, northern Netherlands, and in the south-west, northwest and east of Germany.

Among the countries where only one time-horizon has was identified (Table 2; Fig. 3), northern Albania dominates with a LCFU rate higher than its mean value. A similar trend was observed in the central part of Great

Table 2. Participants of the CLC project [10].

Country	CLC1990	Change 1990/2000	CLC2000	Change 2000/2006	CLC2006	Country	CLC1990	Change 1990/2000	CLC2000	Change 2000/2006	CLC2006
Albania	no	no	yes	yes	yes	Italy	yes	yes	yes	yes	yes
Austria	yes	yes	yes	yes	yes	Kosovo	no	no	yes	yes	yes
Belgium	yes	yes	yes	yes	yes	Liechtenstein	yes	yes	yes	yes	yes
Bosnia/Herzegovina	no	no	yes	yes	yes	Lithuania	yes	yes	yes	yes	yes
Bulgaria	yes	yes	yes	yes	yes	Luxembourg	yes	yes	yes	yes	yes
Serbia	yes	yes	yes	yes	yes	Latvia	yes	yes	yes	yes	yes
Cyprus	no	no	yes	yes	yes	Montenegro	yes	yes	yes	yes	yes
Czech Republic	yes	yes	yes	yes	yes	Macedonia FYR	no	no	yes	yes	yes
Germany	yes	yes	yes	yes	yes	Malta	yes	yes	yes	yes	yes
Denmark	yes	yes	yes	yes	yes	Netherlands	yes	yes	yes	yes	yes
Estonia	yes	yes	yes	yes	yes	Northern Ireland	no	yes	yes	yes	yes
Spain	yes	yes	yes	yes	yes	Norway	no	no	yes	yes	yes
Finland	no	no	yes	yes	yes	Poland	yes	yes	yes	yes	yes
France	yes	yes	yes	yes	yes	Portugal	yes	yes	yes	yes	yes
Greece	yes	yes	yes	no[1]	no[1]	Romania	yes	yes	yes	yes	yes
Croatia	yes	yes	yes	yes	yes	Sweden	no	no	yes	yes	yes
Hungary	yes	yes	yes	yes	yes	Slovenia	yes	yes	yes	yes	yes
Switzerland	no	no	no[1]	no[1]	no[1]	Slovakia	yes	yes	yes	yes	yes
Ireland	yes	yes	yes	yes	yes	Turkey	no	no	yes	yes	yes
Iceland	no	no	yes	yes	yes	Great Britain	no	yes	yes	no[1]	no[1]
						Total	**27**	**29**	**39**	**37**	**37**

[1] In project, but data not available for the study

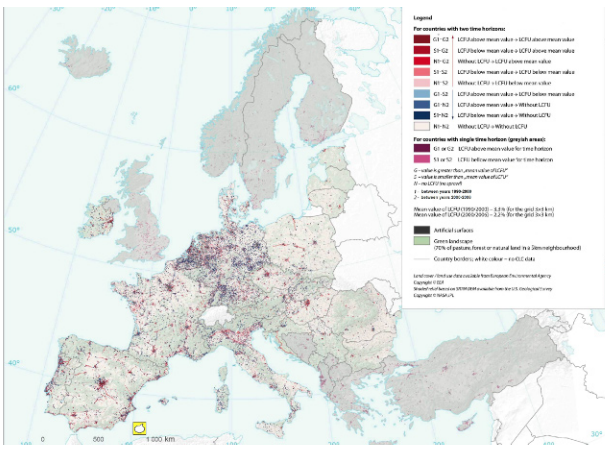

Figure 3. Spatial distribution of urbanisation in European countries for the periods 1990–2000 and 2000–2006.

Britain, northwestern Turkey, and in the centre of Bosnia and Herzegovina. Areas with LCFU rate lower than its mean value are observable in the southern parts of Sweden and Finland.

In terms of statistics, 980 620 ha of landscape (mean yearly value of 98 062 ha) in 1990–2000 and 686 397 ha (mean yearly value of 114 400 ha) in 2000–2006 changed in favour of artificial surfaces (urbanisation) throughout Europe. These changes are more clearly demonstrated by the share of the mean annual LCFU in total LCFs (land-coverflows), which grew from 1.11% (in the period 1990–2000) to 1.74% (in the period 2000–2006; Table 3).

The fragment of LC change map seen in Figure 1 demonstrates that the corresponding squares of the 3 × 3 km grid also contain other types of landscape change (LCFs). However, those were not taken into account in the applied methodology used in LCFU rate assessment in this study.

4. Discussion and conclusions

Colour was chosen as the means for expressing LCFU changes in two time-horizons. As only one property has to be distinguished on the compiled map (Fig. 3) — that is, *artificial surfaces* and their changes within the 3 × 3 km squares in an overview, whole-Europe scale — colours and their hues fulfil the two intended functions of identification and classification.

Colours and their hues were also used to unite and simultaneously distinguish eight LCFU-change trends within the above-quoted square grid (Fig. 3). This means that the red hued squares indicate areas of increased (enlargement) or stable LCFU rates, but not decrease. Blue hued

Table 3. Changes in proportions of artificial surfaces (LCFU) in Europe for the 1990–2000 and 2000–2006 time periods [9].

	1990–2000			2000–2006		
	Total area (ha)	Mean early increase in the period (ha)	Mean yearly LCFU of total LCF area (%)	Total area (ha)	Mean yearly increase in the period (ha)	Mean yearly LCFU of total LCF area (%)
LCFU	980 620	98 062	1.11	686 397	114 400	1.74
Total LCF area	8 850 550			6 572 187		
Total countries area	369 012 006*			542 417 086**		

*29 countries
**37 countries — as new countries joined the CLC programme after 1990, the total area mapped in the 2000–2006 period was considerably larger.

squares were assigned to areas where LCFU rate was identified to decrease.

Distinguishing the LCFU rate in only one time-horizon was expressed by two magenta hues against a light-grey background.

It should be noted that although all hues are well discriminated in the map legend (Fig. 3), discriminability is poor at the scale of the overview map. However, in spite of this handicap, the map (Fig. 3) provides ready information about areas of increasing or decreasing LCFU.

Such information, especially in combination with demographic or socio-economic data, may facilitate the analysis of ongoing changes in the landscape.

The statistical results confirmed expansion of artificial surfaces in Europe in the periods of 1990–2000 and 2000–2006. Such LCFU rate-change assessments are based on CLC data derived from satellite images (e.g. see the map of LCFU changes in Europe; Fig. 3). National Statistics (NS) data were also used for a pilot assessment of LCFU changes. Plots of the NS data (e.g. from the Statistical Yearbook of the Land Pool of the Slovak Republic) are based on the functional signs and their legal status, following cadastral mapping. A difference may exist between the legal status and the real land-use; e.g. forestland does not necessarily have to be covered by forest. This is why the size of a forestland area does not have to be the same as the area of the real forest growth; a plot exempted from the farmland for future construction does not have to be built-up at the moment of analysis and assessment by using satellite data. These differences also appeared in comparisons of artificial surface areas identified by CLC and NS data (Table 4).

According to the NS, between 2000 and 2006, built-up areas and courtyards in Slovakia increased by 7754 ha (0.16% of country's total area), as compared to the figure of 1855 ha (0.04%) obtained from the CLC data for the same period. The difference of 5899 ha is initially attributable to the different approaches to data collection and inconsistencies between the legal status (represented by NS data) and real status (represented by CLC data) of the areas in question. It must also be emphasized that the area of artificial surfaces is considerably greater than the sum of built-up areas (as defined by NS) because the content of these classes is not identical. Changes smaller than 5 ha in the mosaic of artificial surfaces (CLC) were not taken into account, which also biased the overall area of real changes in favour of this class. The graphical representation of the relationship between the CLC and NS classes for 1990 is presented in Figure 4 [6]. This figure suggests two principal reasons why the combination and comparison of the quoted data are very problematic:

- There is a much greater number of classes in CLC nomenclature (15 in level 2, with only 13 represented in Slovakia) than in NS scheme (10 represented in Slovakia, but only eight in Figure 4 as vineyards, orchards and hop plantations were combined into a single class) and it contains classes, which NS does not.
- There are distinct differences in the content of CLC and NS classes in relation to their differing functions, and the size of the minimum identified area, which was 25 ha for CLC data and limitless in the NS.

Map presentation of changed artificial surfaces, their spatial distribution, and their intensity represents a valuable source for the identification and assessment of factors causing landscape changes, from both a research and applied point of view. Apart from enriching thematic cartography, this representation style has proved useful to environmental planning.

Table 4. Comparison of areas indentified as CLC 11 and 12 classes versus the National Statistics (NS) 'Built-up areas and courtyards' for Slovakia in the 2000–2006 period (in ha) [8].

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 = **7754**			
Expansion of area, CLC 2000–2006		257 895 – 256 040 = **1855**			
Difference in presented change		7754 – 1855 = **5899**			

* as of 1 January 2001
** as of 1 January 2007
Source: Statistical Yearbooks 2001–2007 [17]

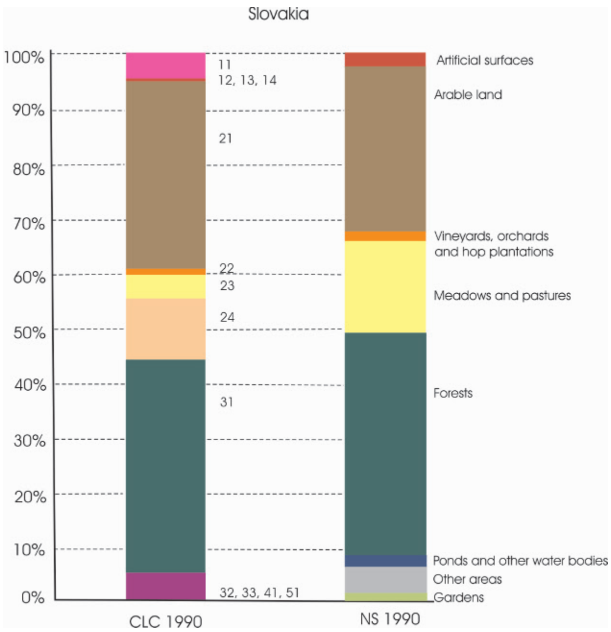

Figure 4. Comparison of CLC (level 2 in Table 2) and NS classes for Slovakia in 1990 [6].

Acknowledgement

This paper is one output of the VEGA Grant Agency No 2/0006/13 project 'Changes of cultural landscape: analysis of extension of urban fabric and farmland abandonment processes applying land cover databases', pursued at the Institute of Geography of the Slovak Academy of Sciences. The authors are grateful to Hana Contrerasová for translation of this paper into English, and for its thorough reading by Dr Michael Wood.

References

[1] Bossard M., Feranec J., Oťaheľ J., CORINE land cover technical guide – Addendum 2000, Technical report, 40, 2000, European Environment Agency, http://eea.europa.eu/publications/tech40add

[2] Burghardt W., Banko G., Hoeke S., Hursthouse A., de L'Escaille T., Ledin S., Marsan F. A., Sauer D., Stahr K., TG 5 – soil sealing, soils in urban areas, land use and land use planning. In: Van-Camp L. et al. (Ed.) Reports of the Technical Working Groups Established under Thematic Strategy for Soil Protection, 6, Office for Official Publications of the European Communities, Luxembourg, 2004

[3] EEA, Down to earth: Soil degradation and sustainable development in Europe. Environmental Issues Series, 16, Office for Official Publications of the European Communities, Luxembourg, 2000

[4] EEA glossary web-site, 2006 http://glossary.eea.europa.eu/EEAGlossary/S/soil_sealing (accessed: 8 October 2012)

[5] Feranec, J., Cebecauerova, M., Cebecauer, T., Husár, K., Otahel, J., Pravda, J., Suri, M., Analýza zmien krajiny aplikáciou údajov diaľkového prieskumu Zeme (Analysis of the landscape changes by application of the remote sensing data). *Geographia Slovaca*, 13, 1997 (in Slovak with English summary)

[6] Feranec J., Suri M., Otahel J.,Cebecauer T., Cebecauer T., Soukup T.,Výsledky porovnania národných statistic Česka, Maďarska, Rumunska a Slovenska s údajmi CORINE land cover (Results of comparing the National Statistics of the Czech Republic, Hungary, Rumania and Slovakia with CORINE land cover data). *Geodeticky a kartograficky obzor*, 2001, 47, 208-213 (in Slovak with English summary)

[7] Feranec J., Jaffrain G., Soukup T., Hazeu G., Determinig changes and flows in European landscapes 1990-2000 using CORINE land cover data. *Applied Geography*, 2010, 30, 19-35

[8] Feranec J., Kopecka M., Otahel J., Novacek J., Zväčšovanie zástavby na Slovensku v období 2000-2006 (Expansion of built-up area in Slovakia 2000-2006), *Geographia Cassoviensis*, 2010b, 4, 13-21 (in Slovak with English summary)

[9] Feranec J., Soukup T., Artificial surfaces in Europe: map of changes in 1990-2006. ICC 2011 Abstracts (electronic source), International Cartographic Association, Paris, 2011

[10] Feranec J., Soukup T., Hazeu G., Jaffrain G., Land cover and its change in Europe: 1990–2006. In: Giri Ch. (Ed.), Remote Sensing of Land Cover: Principles and Applications. CRC Press, Boca Raton, 2012, 285-301

[11] Haines-Young R., Weber J.L., Land accounts for Europe 1990-2000. Towards integrated land and ecosystem accounting. EEA Report, 11. European Environment Agency, Copenhagen, 2006

[12] Hasse J., Using remote sensing and GIS integration to identify spatial characteristics of sprawl at the building-unit level. In: Mesev V. (Ed.), Integration of GIS and Remote Sensing. Wiley, Chichester, 2007, 117-147

[13] Heymann Y., Steenmans C., Croisille G., Bossard M., CORINE Land Cover. Technical Guide. Office for Official Publications of the European Communities, Luxembourg, 1994

[14] Kampouraki M., Wood A. G., Brewer T., The application of remote sensing to identify and measure sealed areas in urban environments. In: Lang S., Balschke Th., Schöpfer E. (Eds.), 1st International Conference on Object-based Image Analysis (OBIA), 2006 http://www.isprs.org/proceedings/XXXVI/4-C42/papers.htm

[15] Kopecký M., Kahabka H., GMES Fast Track Service Precursor on Land Monitoring. Updated Delivery Report European Mosaic, European Environment Agency, Copenhagen, 2009, EEA-FTSP-Sealing-Enhancement_DeliveryReport-EuropeanMosaic_F1v0.pdf

[16] Kraak J. M., Ormeling J. F., Cartography: Visualization of Spatial Data. Longman, Essex, 1996

[17] Scalenghe R., Marsan A. F., The anthropogenic sealing of soil in urban areas. *Landscape and Urban Planning*, 2009, 90, 1-10

[18] Štatistické ročenky o pôdnom fonde SR za roky 2001-2007(Statistical Yearbooks) Úrad geodézie, kartografie a katastra SR, Bratislava, 2001-2007 (in Slovak)