LAND COVER CHANGES IN ROMANIA BASED ON CORINE LAND COVER INVENTORY 1990–2012

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Abstract. From 1990 to 2012 the European Environment Agency implemented the CORINE Programme (Co-ordination of Information on the Environment). In Romania, the National Reference Centre implemented the national CORINE Land Cover (CLC) inventory to the reference years 1990, 2000, 2006 and 2012 to derive the CLC update and land cover change data base. The information obtained within the project, as digitized land cover maps on scale 1:100 000 for the whole territory of Romania represent a reference data set for spatial and territorial analysis at different territorial levels. Land cover statistics and spatial distribution of classes and trend of changes along the 1990–2012 period are presented.

1. INTRODUCTION

CORINE Land Cover provides consistent information on land cover and land cover changes across Europe. This inventory was initiated in 1985 (reference year 1990) and established a time series of land cover information with updates in 2000 and 2006, the last reference year being 2012. CLC products are based on photointerpretation of satellite images by national teams of participating countries – the EEA member and co-operating countries. Land cover and land use (LCLU) information is important not only for land change research, but also, more broadly, for monitoring environmental change, policy support, the creation of environmental indicators and reports. CLC datasets support the implementation of key-priority areas of the Environment Action Programmes of the European Union as protecting ecosystems, halting the loss of biological diversity, tracking the impacts of climate change, assessing developments in agriculture and implementing the EU Water Framework Directive, among others. In Romania, the project was co-financed by The Ministry of Environment, Waters and Forestry and implemented by Danube Delta National Institute for Research & Development (DDNI) as National Reference Centre for land use and spatial analyses. Like in the other Central and East European countries (Feranec *et al.*, 2010), socio-economic transition became a complex and rapid process in Romania, too. Some effects of this process are deforestation, land abandonment, urbanization and industrialization. At the decision policy level, Romania is interested to know and periodically evaluate these changes in support of present and future policy-making (Popovici *et al.*, 2013). The most important initiatives for updating national land cover data in Romania are building up the "Topographic Reference Plan of Romania" (TOPRO5), the National Forest Inventory and "Natura 2000" data-base. However, because of a relative good frequency of update and its availability in the National projection, the CLC inventory represents the reference data-base in monitoring Land Cover Changes in Romania. Applications of the CLC data include environment, transport, industry and agriculture projects and it proved to be very useful for the Water Framework Directive and Natura 2000-related projects in Romania, as well. The information obtained under Corine Land Cover projects, available as digitized land cover maps on scale 1:100 000 for the whole territory of Romania, are currently used as a key-reference data set for the spatial and territorial analysis at different territorial levels. CLC data are required and used also by research institutions, universities, central and local authorities and private entities.

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2. MATERIALS AND METHODS

The basis of the identification of changes was the interpretation of visually detectable land cover differences on images from year of period I and year of period II. Ortho-corrected Landsat ETM images pan sharpened, pixel size of 12.5 m, ortho-rectified satellite images, two seasons SPOT (–4/–5) HRVIR, IRS-P6/LISS-III acquired in the reference years, and ancillary data such as topographic maps, orthophotos, SLIM 6 images, HRS layers, Google Earth imagery and Land Parcel Identification System – LPIS were used in the production process. All features in original vector data-base were classified and digitized based on satellite images following a standard methodology and nomenclature (Büttner, 2006, 2007, 2012; Bossard *et al.*, 2000) with the following base parameters: 44 classes in the hierarchical three level Corine nomenclature; minimum mapping unit (MMU) for status layers is 25 hectares; minimum width of linear elements is 100 meters; minimum mapping unit (MMU) for Land Cover Changes (LCC) for the change layers is 5 hectares. The CLC changes were interpreted by comparing the two period images and support of in-situ data in ArcView 3.1 dual-window environment using the specialized software (InterChange). The final product was produced by integrating the data of land cover changes with the land cover map using ArcInfo macro script (Pataki, 2008) for the data integration and ArcGIS software. Mapping CLC changes was carried out by applying the "change mapping first approach (Büttner, 2007). Change mapping consisted of two steps, namely, first CLC correction and second interpretation of changes occurring between two inventory periods (e.g. 2006–2012). The two processes were carried out consecutively and individual polygons correction always preceded change delineation. The interpreter gives two CLC codes to each change polygon: e.g. code2006 and code2012, both included as separate attributes. These codes represent the land cover status of the given polygon in the two dates, respectively. The resulting national land cover inventories are further integrated into a seamless land cover map of Europe. European Corine Land Cover seamless DBs represent the final product of European data integration. The process of data integration started when national deliveries were accepted and the Database Acceptance Report (DBTA) delivered and quality of the products were checked. The internal QA/QC was a permanent activity of the national co-ordinator during the production process. The national team (NT) has assessed the thematic and geometrical quality control along the project and has collected all the necessary metadata to document the different steps and products of the project. The external verification of the new CLC inventory was done by CLC Technical Team. Recommendations specified in the Verification Reports have been integrated into the data by the NT. The technical quality of deliverables has been checked internally by NT and screened using online tool according to Technical Guidelines specifications (Büttner, 2012). Delivered Romanian data were produced in Pulkovo 1942(58) / Stereo70, national system. National data were transfered into a standard European co-ordinate reference – ETSR 89.

Spatial analysis of CLC changes throughout the inventory period (1990–2012) was done using the first level of nomenclature as shown in the land cover distribution maps (Fig. 1):

– Class 1 Artificial surfaces – urban built up areas, industrial units, mineral extraction, dump sites, etc.;

– Class 2 Agricultural areas – arable, vineyards, orchards, pastures, mixture of agriculture;

– Class 3 Forests and semi-natural areas – forests, natural pastures grassland, open spaces, etc.;

– Class 4 – wetlands;

– Class 5 – water courses, water bodies.

Land cover in Romania is characterized by 37 out of 44 classes (Fig. 2) of CORINE Land Cover nomenclature.

3. ANALYSIS OF CLC CHANGES

Land cover changes dynamics is analyzed first over three periods: 1990–2000, 2000–2006 and 2006–2012. The period 1990–2000 was the most dynamic period of land cover changes summing 309,910 ha (Fig. 3). For the next two periods it was around a four-time decrease in land cover changes.

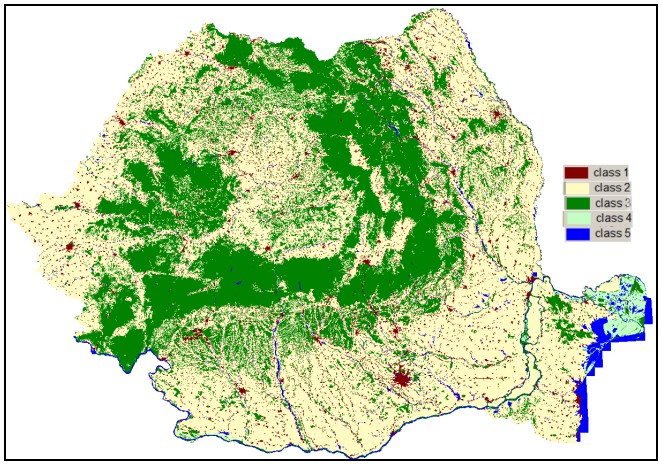


Fig. 1 – Romanian CLC2012 first level of nomenclature (5 classes).

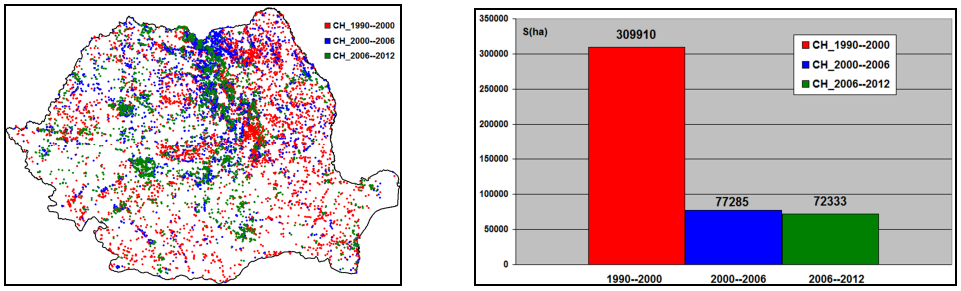
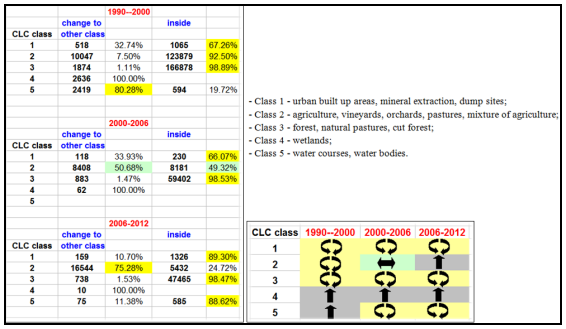


Fig. 3 – Land cover changes over 1990-2012.



1990--2000

CLC class	change to other class		inside	
1	518	32.74%	1065	67.26%
2	10047	7.50%	123879	92.50%
3	1874	1.11%	166878	98.89%
4	2636	100.00%		
5	2419	80.28%	594	19.72%

2000-2006

CLC class	change to other class		inside	
1	118	33.93%	230	66.07%
2	8408	50.68%	8181	49.32%
3	883	1.47%	59402	98.53%
4	62	100.00%		
5				

2006-2012

CLC class	change to other class		inside	
1	159	10.70%	1326	89.30%
2	16544	75.28%	5432	24.72%
3	738	1.53%	47465	98.47%
4	10	100.00%		
5	75	11.38%	585	88.62%

- Class 1 - urban built up areas, mineral extraction, dump sites;
- Class 2 - agriculture, vineyards, orchards, pastures, mixture of agriculture;
- Class 3 - forest, natural pastures, cut forest;
- Class 4 - wetlands;
- Class 5 - water courses, water bodies.

Fig. 4 – Migration of CLC changes within different classes.

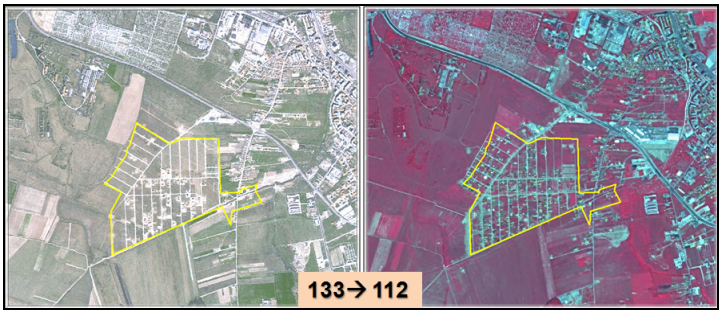


Fig. 5 – Changes from construction sites (133) to discontinuous urban fabric (112).

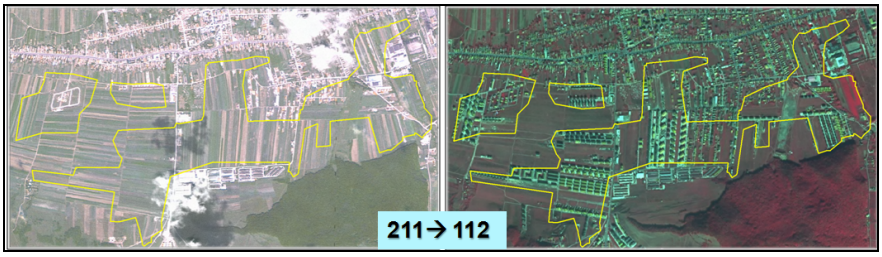


Fig. 6 – Change of agricultural land (211) to urban area (112).

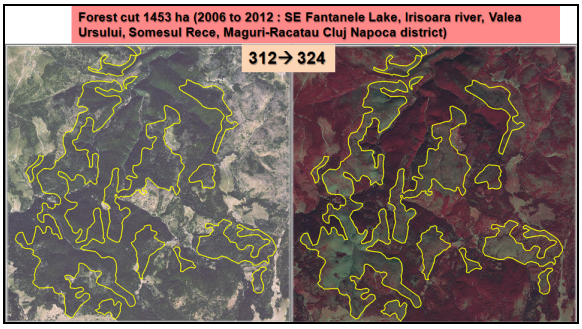


Fig. 7 – Example of deforestation.

	Class 1	Class 2	Class 3	Class 4	Class 5	*Total*
			S(ha)			
CH_1990--2000	1583	133926	168753	2636	3013	*309910*
CH_2000--2006	349	16589	60285	62		*77285*
CH_2006--2012	1485	21976	48203	10	660	*72333*
Total changes						
1990--2012	*3416*	*172490*	*277241*	*2708*	*3673*	*459528*
Weight of total changes						
1990--2012	0.74%	37.54%	60.33%	0.59%	0.80%	

Fig. 8 – Land cover change dynamics over 1990-2012 period.

	311-->324	312-->324	313-->324	Total	Weight per time
Period			S(ha)		
CH_1990--2000	18050	43521	12410	*73981*	*43.20%*
CH_2000--2006	17559	31526	7703	*56788*	*33.16%*
CH_2006--2012	11369	24961	4142	*40471*	*23.63%*
Total changes					
1990--2012	*46979*	*100008*	*24254*	*171241*	
Weight of total changes					
1990--2012	27.43%	58.40%	14.16%		

Fig. 9 – Dynamic of deforestation of coniferous, broad- leaved and mixed forest types.

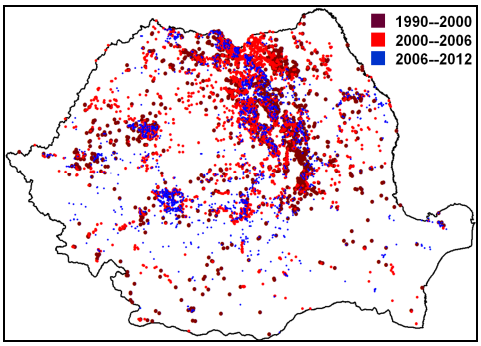


Fig. 10 – Spatial distribution of CORINE Land Cover deforestation polygons.

Deforestation is the main class with the highest change dynamics. As change weight over the three periods (Table 1), the most active period of deforestation was 2000–2006 (74.46%) and the third period (56.64%).

Code	Short name	Code	Short name	Code	Short name	Code	Short name
111	Continuous urban fabric	211	Non-irrigated arable land	311	Broad-leaved forest	335	Glaciers and perpetual snow
112	Discontinuous urban fabric	212	Permanently irrigated land	312	Coniferous forest	411	Inland marshes
121	Industrial or commercial units	213	Rice fields	313	Mixed forest	412	Peat bogs
122	Road and rail network	221	Vineyards	321	Natural grasslands	421	Salt marshes
123	Port areas	222	Fruit trees and berry plantations	322	Moors and heathland	422	Salines
124	Airports	223	Olive groves	323	Sclerophyllous vegetation	423	Intertidal flats
131	Mineral extraction sites	231	Pastures	324	Transitional woodland/shrub	511	Water courses
132	Dump sites	241	Annual and permanent crops	331	Beaches, dunes and sand plains	512	Water bodies
133	Construction sites	242	Complex cultivation patterns	332	Bare rocks	521	Coastal lagoons
141	Green urban areas	243	Agriculture with natural vegetation	333	Sparsely vegetated areas	522	Estuaries
142	Sport and leisure facilities	244	Agro-forestry areas	334	Burnt areas	523	Sea and ocean

Fig. 2 – CLC nomenclature (44 classes).

Table 1

Romanian weight of CLC changes (second level of nomenclature – 13 classes)

CLC class	1990–2000	2000–2006	2006–2012
11x>> and 14x>>	< 0.01%		
12x>>	0.01%	0.03%	0.15%
13x>>	0.73%	0.42%	1.87%
21x>>	18.35%	8.03%	20.70%
22x>>	9.15%	2.94%	2.05%
23x>>	10.60%	8.10%	5.80%
24x>>	5.01%	2.39%	1.83%
31x>>	**24.32%**	**74.46%**	**56.64%**
32x>>	29.94%	3.35%	9.91%
33x>>	0.05%	0.19%	0.09%
41x>>	0.85%	0.08%	0.01%
51x>>	0.97%		0.91%

Urban development was more active in the first period (43.21), with a slow decrease in the second period (21.46%) and revenue in the last period (30.38%).

Migration of changes within the same class and between other classes is shown in Fig. 4. For class 1, the majority of changes remains in the same class; for class 2, the majority of changes over 2006–2012 period migrate to other classes (75.28%); for class 3, the majority of changes remains in the same class; for class 4, all changes migrate to other classes and for class 5, the majority of changes (80.28%) over 1990–2000 migrate to other classes, too.

A more detailed analysis has been made for each class in order to underline the major trends:

a) For **class 1**, the major trend is represented by changes, in the same class, that shift from construction sites (133) to discontinuous urban fabric (112) (Fig. 5), or industrial, or commercial units (121).

b) For **class 2**, the major trend is represented by changes over 2006–2012 that migrate from non-irrigated arable land (211) to discontinuous urban fabric (112) as shown in Fig. 6;

c) For **class 3**, the major trend is represented by changes, in the same class, that shift from coniferous forest (312) to transitional woodland/shrub (324) that represent deforested areas. A large compact polygon of deforested area (1453 ha) over the 2006–2012 period is illustrated in Fig. 7.

d) For **class 4**, the major trend is represented by changes from 1990 to 2000 that migrate from inland marshes (411) to class 1x (built up areas) and class 2x (agriculture);

e) For **class 5** (water bodies), the major trend is represented by changes from 1990 to 2000 that migrate from 512 (water bodies) to class 231 (grassland) or 411 (inland marshes).

The dynamics of land cover changes over the whole inventory period (Fig. 8) shows that class 3 (forest), is by far the most dynamic one (60.33%), as a consequences of forest cutting, followed by class 2 (agricultural land), 37.54% representing mainly urban development and land abandonment.

Broad-leaved forest, coniferous forest and mixed forest are the main forest types in the Corine nomenclature. Coniferous forest type (class 312) is the most affected by deforestation with a percentage of change of 58.4% (Fig. 9) over the whole inventory period (1990–2012), followed by deforestation of broad-leaved forest (class 311), 27.43% and mixed forest (class 313), 14.16%.

A general overview of coniferous forest change across the Romanian territory is given in Fig. 10. In the first and second inventory period, deforestation was the most intense in the Eastern Carpathians mountain region, in the last period (2006–2012) an intensification of forest catting is observed in the Banat Mountains and the Apuseni Mountains.

4. CONCLUSIONS

Land cover change was around four time higher in the first inventory period (1990–2000), it corresponding to a rapid development in the first ten years after the 1989 political change. Deforestation and urban development are the main land cover changes with the most active period of deforestation in the second CORINE Land Cover inventory (2000–2006). More agricultural land was taken for urban development, mainly in the last period (2006–2002). The majority of changes in the forest areas fell within the same class (3xx). The coniferous forest type is the most affected by deforestation over the whole inventory period (1990–2012), followed by deforestation of broad-leaved forest and mixed forest class. Deforestation was the most intense in the Eastern Carpathian mountain region in the first two inventory periods, an intensification of forest catting is observed in the Western Carpathian region in the last inventory period (2006–2012).

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