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SATELLITE MAPPING OF BULGARIAN LAND COVER – CORINE 2012 PROJECT

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Abstract

CORINE Land Cover 2012 Bulgaria is a part of the Pan-European project CORINE Land Cover (CLC). Experts from 39 countries participate in this GMES/Copernicus program's project. The main aim of the project is to identify and map the changes of land cover/land use for the period 2006–2012 using multitemporal/multispectral satellite imagery. Harmonized methodology with a 44 class nomenclature and a computer assisted photo-interpretation are applied for creating a geospatial database of Bulgarian territory for the year 2012. In addition to the CLC work, a task for evaluation of five High Resolution Layers (HRL) is included. They are complementary to CLC and provide information on specific land cover characteristics: degree of imperviousness; forest, permanent grasslands, wetlands and permanent water bodies. A brief description of the applied methodology and the main results achieved are presented. The whole Bulgarian territory is mapped in details adequate for the 1:100 000 scale with a minimum mapping unit of 25 ha and a minimum change area of 5 ha. For the investigated period (2006–2012) dominant changes are observed in forests and semi-natural areas – 27,628 ha or 54.65 % of all changes, followed by agricultural lands (21 618 ha or 42.76 %). The statistical analysis of the created databases and a comparison between main land cover changes for the 1990–2000, 2000–2006 and 2006–2012 time periods are discussed. The average annual land cover change rate is 0.17 % which positions Bulgaria among the majority of the European countries having relatively small land cover changes.

Key words: change detection, CORINE Land Cover 2012, HRL, land use, remote sensing, satellite images.

Introduction

Until recently, it was generally assumed, that in the long term, human activity had little lasting effect on lands thanks to nature's ability to restore itself. This view remained prevalent for a long time, despite the fact that farming practices have been causing irreversible damage in certain areas for centuries (Heymann et al. 1994). Over the next few decades the global effects caused by land use

and cover changes may be as significant as those associated with the climate changes. Changes in Land Use and Land Cover (LCLU) are directly linked to many facets of human health and welfare, including biodiversity, food production, and the origin and spread of diseases. Yet, we know very little about this important human-caused agent of global change (Fisher 1995, Skole 1996). As a response to these challenges many Land Cover projects are implemented on national, regional and global level. Most of them, including CORINE Land Cover are based on series of satellite imagery interpretation and classification. There are two main reasons making this approach extremely suitable for land cover mapping and change detection of large territories:

- Earth observation satellites provide repetitive coverage of our planet territory with an abundance of spatial and spectral resolution and rich archive data for the last 40 years;
- Changes in land cover result in changes in radiance values registered by satellite multichannel scanners;
- Changes in radiance due to land cover changes are large with respect to radiance changes caused by others factors such as differences in atmospheric conditions, differences in soil moisture and differences in sun angles.

Strategic discussions among European Environmental Agency (EEA) member countries and the main EU institutions, responsible for environmental policy, reporting and assessment, have underlined an increasing need for quantitative information on the state of the environment based on timely, quality-assured data, concerning in particular land cover and land use (Heymann et al. 1994). Based on these requirements EEA has been collaborating since 2006 with the European Commission and the European Space Agency in the implementation of a fast track service on land monitoring as part of the implementation of GMES (now – Copernicus Land Monitoring Services).

EEA aims at providing those responsible for and interested in the European environmental policy with qualitative and quantitative land cover data, which is consistent and comparable across the continent. As a part of the EEA mandate, the CORINE Land Cover (CLC) database initiated by the Commission in 1985 should be further maintained and updated regularly. Consistent geo-referenced land cover information has been identified by different national and European policies as a key database for integrated environmental assessment.

CORINE Land Cover 2012 (CLC2012) is the fourth European Land Cover inventory (1990, 2000, 2006 and 2012). The number of participating countries is increasing, at present being 39 with a total of mapped area of 5.8 million km^2 (Fig. 1).

In Bulgaria the project has been implemented by a team of academic experts – five from the Space Research and Technology Institute (SRTI), two from the University of Forestry (UF) and one from the National Institute of Geophysics, Geodesy and Geography (NIGGG). The monitoring and the control have been provided by the Executive Environment Agency at the Ministry of Environment and Waters.

Methodology and Data Used

The CORINE Land Cover 2012 Bulgaria project includes two main tasks: a) CLC2012 visual computer assisted

LCLU mapping and 2006–2012 change detection (the focus of this paper) and b) Verification and Enhancement of five land cover High Resolution Layers (HRL).

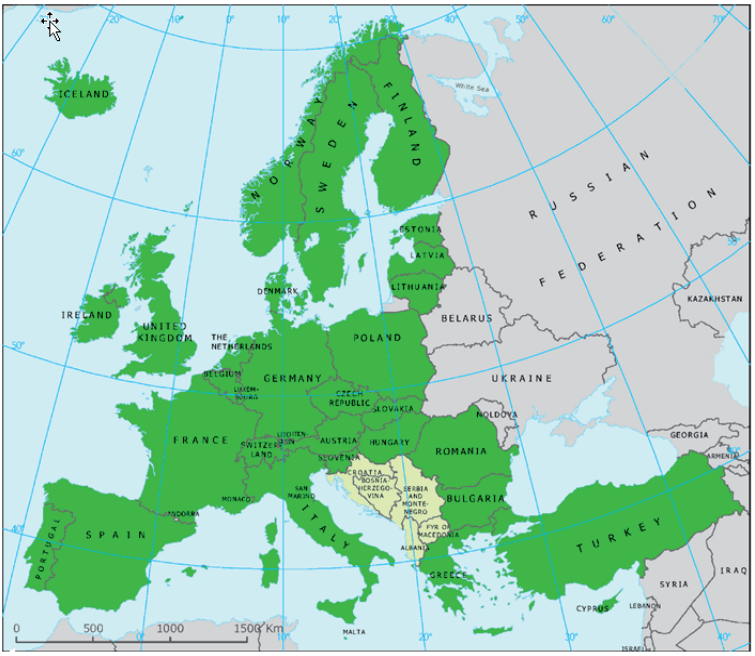

Fig. 1. Countries participating in CORINE Land Cover 2012 pan-European Project.

Methodology

The CLC2012 project's implementation is based on a harmonized and approved by all participating countries methodology. A detailed description of the first developments is described in EEA guideline publications (Heymann et al. 1994, CORINE … 1997, Bossard et al. 2000, CLC2006 … 2006) and accessed through the EEA official CORINE Land cover website (http://www.eea.europa.eu/publications/COR0-landcover). Developed in the 1980s, the methodology has been permanently improved to respond to the new technological achievements of Remote Sensing and Geoinformatics. The last methodological elaborations are described in a series of EEA documents and scientific publications (Büttner et al. 2011, 2012, 2004).

The main features of the methodology are:

- Basic input data – high resolution multispectral, multitemporal satellite images, covering vast territories in a short time;
- Use of a large amount of ancillary/*in situ* data – mainly orthophotos, topographic and thematic maps, specialized geo-databases (agriculture, forest, hydrology etc.);
- A land cover nomenclature on three levels: First level – 5 headings (1. Artificial surfaces, 2. Agricultural areas, 3. Forests and semi-natural areas, 4. Wetlands, 5. Water bodies), Second level – 15 headings and Third level – 44 headings;
- Creation of GIS databases by means of a Computer Aided Photo-Interpretation (CAPI), scale – 1:100 000 (for best cost/performance ratio);
- Minimum area of a mapped polygon – 25 ha;
- Minimum area of a mapped change – 5 ha;
- Minimum separation between the borders of polygons – 100 m.
- Time consistency: 2011/2012.
- Only real changes mapped – thematic accuracy: ≥ 85 %.

The developments in automated LCLU classification during the last 15 years result in a CLC2012 project extension – production of High Resolution Layers: imperviousness, forests, grasslands, wetlands and permanent water bodies. HRL mapping unit is 20 m × 20 m – 625 times smaller than the previous minimal mapping unit of 25 ha. The compromise is a drastically reduced nomenclature – only 6 LCLU classes. The input HRLs produced by a consortium of European companies are subject to verification and enhancement activities implemented by separate countries (Langanke 2013). The purpose of the verification is to identify the systematic classification errors in a HRL (commission and omission) suitable for further correction. It is accomplished through visual inspection using stratified sampling and involving in-situ data sets. The enhancement based on the results of verification is then applied aiming at HRL improvement (Büttner G. 2013). Ultimately, final HRL products are obtained at a country level.

Forest HRLs include two forest products: Tree Cover Density and Forest Type (Table 1). The latter, in turn, consists of two raster layers: Dominant Leaf Type and Additional Support layer.

Table 1. Forest HRL overview.

Product	Layer	Description
Tree cover density	Tree cover density	Pixel values from 1–100 %
Forest type	Dominant Leaf Type	Binary product: coniferous and broadleaved. MMU of 0.5 ha and 10–100 % tree cover density
	Additional Support layer	Marks non-forest trees: under agricultural use and in urban context (from CLC and imperviousness)

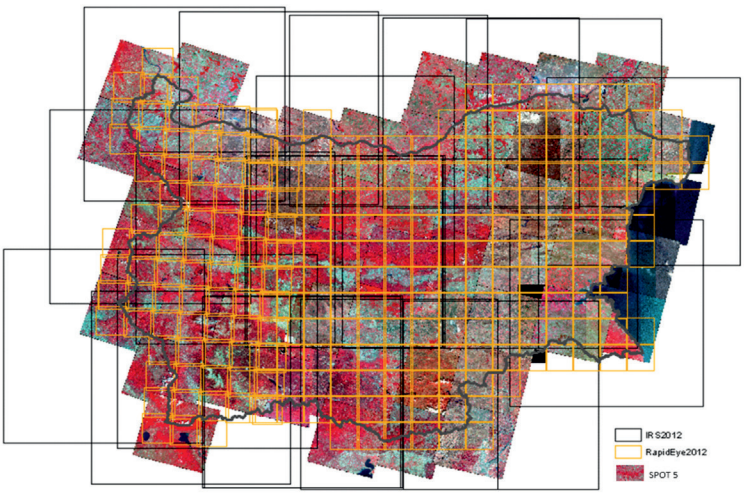

Fig. 2. IMAGE2012 database for Bulgaria – 1236 scenes.

Satellite image data used

Satellite imagery used includes IMAGE2006 database (IRS P6, SPOT4 and SPOT6 – a total of 78 scenes) and IMAGE2012 database (IRS P6, Rapid Eye and SPOT5 – 1236 scenes, see Fig. 2). The basic input data are high resolution multispectral, mul-

titemporal satellite images and a large amount of ancillary data.

Ancillary (*in-situ*) data

Large amount of geo-referenced vector and raster data are used:

- Digital orthophoto map from 2005–2006 and 2011–2012, scale 1:5,000;
- Topographic maps in scales 1:25,000, 1:50,000 and 1:100,000;
- Physical blocks from the LPIS system 2011 and 2012 – a vector database;
- National database of Water – vector data for rivers, channels, lakes;
- Cadastral database of the settlements;
- Database of land property restitution, 1: 5,000;
- RAMSAR sites – a vector database (polygons);
- Digital Elevation Model (DEM) from SRTM mission;
- 2006 Pan-European forest cover map;
- Forest database with detailed attributes;
- Databases of the national parks Rila, Pirin and Central Balkan.

Computer Aided Satellite Imagery Interpretation

Land cover change detection is performed in interactive mode by means of a specialized Hungarian InterChange 3.1. software package (CLC2012 2012). Two synchronized windows are used – "revision" and "change" (Fig. 3).

In the "revision" window satellite images (IMAGE2006 database) are visualized in false colors and also the respective ancillary (*in situ*) data current for the year 2006 overlaid. In the "change" window – 2012 imagery (IMAGE2012 database) and the respective ancillary (*in situ*) data current for the year 2012 are displayed. The CLC2006 vector database to be corrected is visualized in both the windows – "revision" and "change". The interpreter is correcting eventual thematic and/or geometric mistakes in the CLC2006 database followed by a change detection based on spectral, texture and ancillary images visualized in the right window. To the thematic and geometric accuracy of the produced databases of key importance are the 0.5 pixel size color digital orthophoto maps produced by the Ministry of Agriculture and Food for 2006 and 2011, together

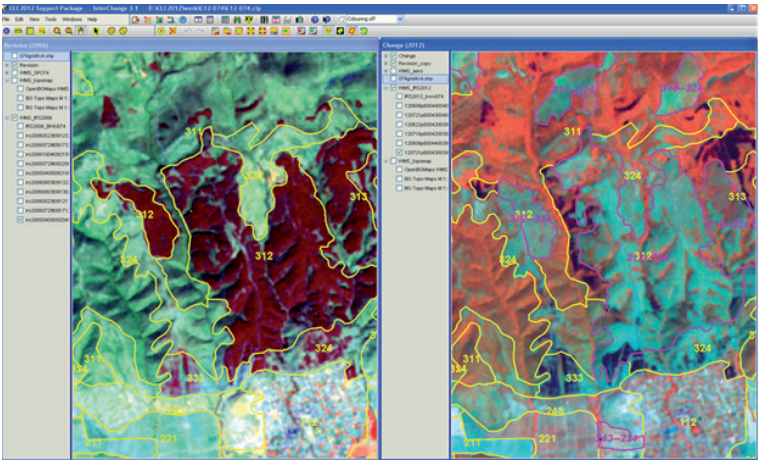

Fig. 3. Left window – Revision coniferous forest in 2006 and right window – Change 312–324 coniferous forest to burned area in 2012, Dalboki village, Stara Zagora region.

with GoogleEarth historic images used (in some cases with StreetView).

Results and Discussion

As a result of the interpretation process two databases are created – the revised CLC2006 and CLC-Change$_{2006–2012}$ complemented with respective Metadata. After an exhaustive internal and external (by EEA Technical Team experts) verification and validation procedures the new CLC20012 DB is produced with a complex overlay GIS operation presented by the (+) symbol in the following equation:

CLC2012=CLC2006(+)CLC-Change$_{2006–2012}$

A comprehensive statistical analysis of the CLC2012 data and a comparison with the results from the previous 3 projects are presented in the National team report. Table 2 shows the LCLU class distribution for CLC level 1 nomenclature.

More than 93 % of country territory is occupied by two classes – Artificial surfaces and Forest and semi-natural areas. If only pure forests areas are in count (broadleaved, coniferous and mixed) their total area is 3,531,711 ha or 31.42 % of the territory of the country. Moors and heathlands and Natural grasslands will add 26,738 ha (0.24 %) and 414,911 ha (3.69 %) respectively.

Table 2. CORINE Land Cover Bulgaria 2012 Level 1 statistics.

Code	CLC class name	Area, ha	Part of total area, %	Number of polygons
1	Artificial surfaces	532,731	4.74	5,862
2	Agricultural areas	5,774,288	51.37	23,826
3	Forest and semi-natural areas	4,769,853	42.43	23,406
4	Wetlands	11,319	0.10	85,000
5	Water bodies	152,558	1.36	462,000
	Total	11,240,749	100.00	53,641

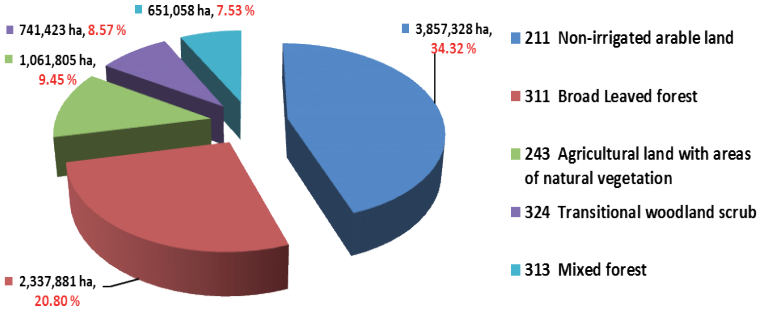

Fig. 4. The 5 CLC2012 level 3 classes forming ¾ of all the area of the country, ha.

Fig. 4 shows the five CLC classes which total area is more than 75 % of the area of the country. The non-irrigated arable land (3 857 328 ha) and Broadleaved forests (2 337 881 ha) cover more than half of the Bulgarian territory.Of special interest are the LCLU changes for the period of investigation (2006–2012). Table 3 illustrates the changes of pure forest areas for the time period 2006–2012.

Totally 21,511 ha of forests have been transformed, the largest changes being in class 311 (Broadleaved forest) – 15,190 ha. Most of these changes

Table 3. Transformation (changes) of forest areas during the period 2006–2012 – area, ha.

Labels	122	131	132	133	142	211	231	321	323	324	334	512	Total
311	22.9	326.3	55.8	32.1	56.9	73.9	6.3	48.0	5.7	14,317.2	15.0	230.3	15,190.4
312					12.7	5.5				3,726.7	68.9		3,813.8
313		30.5		32.1						2,444.3			2,507.0
Total	22.9	356.8	55.8	64.3	69.6	79.3	6.3	48.0	5.7	20,488.2	83.9	230.3	21,511.1

(14,317 ha) are towards class 324 (clear cuts, burned forests, deforestation). Transformations into artificial surfaces include: change 311 to 122 (Road and rail networks) – 23 ha; 311 to 131 (Mineral extraction sites) – 326 ha; 311 to 132 (Dump sites) – 55.8 ha; 311 to 133 (Construction sites) – 32 ha and 311 to 142 (Sport and leisure facilities / golf courses) – 57 ha.

Implementing the verification task on Tree Cover Density and Dominant Leaf Type HRLs, respectively 15 and 12 thematic strata were created. Between 5 and 10 samples were taken in each stratum. During the enhancement work, the logically connected three forest layers were changed together. Automated changes were accomplished through relevant thematic selections of features in the reference data sets, accompanied with a lot of manual editing.

Conclusions and Future Work

In this paper a brief description of the methodology and the results of the CORINE Land Cover 2012 Bulgaria project are published. More detailed explanation could be found in the National CLC 2012 Final Report. Detailed statistical analysis and explanation of the change processes driving forces will be accomplished and published after the official validation of our report by EEA. Comparisons will be made and discussed with the results of other participating countries.

Acknowledgments

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