FOREST CHANGE DETECTION BY MEANS OF REMOTE SENSING TECHNIQUES FROM THE EU PROJECT CORINE LAND COVER

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Abstract

The main aims of the Pan-European project CORINE Land Cover (38 countries participating, including Bulgaria) are to identify and map the changes in land cover/land use for the period 2000–2006 using multispectral satellite imagery and producing a 1:100 000 digital map of Europe for the year 2006 (creating a geospatial database). The change detection is a process of a comparison and analysis of vector and raster data from the two time horizons. The adopted unified nomenclature for the 44 interpreted and mapped land cover classes includes 6 classes directly and closely connected with the thematic mapping of timber productive areas of the forest fund. Three of the most frequent changes in the Bulgarian forests are analysed by means of the CORINE Land Cover database – clear cuts, burnt areas and spots of sport and leisure facilities construction. A large scaled research has been also carried out for assessing the locations, the areas of the Mountain pine (*Pinus mugo* Turra) associations in Bulgaria and their long period changes.

Key words: satellite images, computer assisted image interpretation, land cover classes, clear cuts, burnt areas, Mountain pine (*Pinus mugo* Turra) associations.

Introduction

Forests are a huge resource to our economics and one of the most important parts of our environment. Remote sensing techniques allow us to gather information about our forests from a distance through the use of sensors mounted on satellites or airplanes that collect digital images of the Earth.

The project "Mapping the territory of the country by land cover/land use classes by means of satellite images interpretation – CORINE Land cover methodology" for Bulgaria is a part of the EU project "CORINE Land Cover 2006" (CLC 2006). The main aims of the this Pan-European project are to identify and map the changes of land cover/land use for the period 2000–2006 using multispectral satellite imagery and to produce a 1:100 000 land cover/land use map of Europe for the year 2006 (creating a geospatial database) (Bossard et al. 2000, Büttner et al. 2002, Feranec et al. 2006). The project (38 countries participating)

is a direct continuation of the previous CORINE Land Cover mapping campaigns (1990, 2000) and it has been finished in 2008.

Methodology

The CORINE 2006 project is implemented in all participating countries strictly following a standard methodology described in details in CLC2006 technical guidelines (CLC2006 technical guidelines 2007). The methodology includes choice of satellite images, choice of software and ancillary data and detection and mapping of land cover changes.

Satellite images

For the project, the following satellite images have been used:

– Satellite images for the year 2000 from the American satellite Landsat 7 ETM+ (database IMAGE2000) – 11 scenes.

– Satellite images for the year 2006 ± 1 year – database IMAGE2006 (see Table 1).

Table 1. Number of images by year of acquisition and satellites.

Satellite:	2005	2006	2007	Total
IRS P6	5	17	2	24
SPOT 4	0	32	3	35
SPOT 5	1	16	2	19
Total	4	65	7	78

As a total 24 images are provided from the Indian satellite IRS P6 and from the French satellites SPOT 4 and SPOT 5 – respectively 35 and 19 images. Their distribution by year of acquisition is presented in Table 1.

Raw satellite images first have been pre-processed and enhanced to yield a geometrically correct document in a certain map projection.

Choice of software and ancillary data

Methodology of the project requires creation of an optimal software environment: software for satellite image processing PCI Geomatics, version 10.2. – modules Orthoengine and FOCUS, specialized software for the preparation of data and throughout the interpretation of the satellite images, ESRI software ArcInfo for the creation of the CLC2006 database, the transformation and the integration of the data.

For the implementation of CLC 2006 project for Bulgaria a number of additional products have been used: digital topographic maps at 1:100 000; 1:50 000 and 1:25 000 scales, thematic maps: vegetation, soil, climatic etc., digital georeferenced aerial orthophotographs, high and very high spatial resolution satellite images: all accessible images from Google Earth; the available in our archive images from the American satellites QuickBird and IKONOS, the Israeli satellite EROS-B, the French satellites SPOT 4 and SPOT 5 and Russian images from the KWR-1000 and statistical data.

Detection and mapping of land cover changes

The location of land cover/land use changes for the period 2000–2006 or the creation of CLC Change 2000–2006 database is an essential step in the process of mapping, which defines the accuracy of the new CLC2006 database too (Feranec et al. 2007). According to the CORINE methodology, a change in a given land cover/land use class is registered when the following geometric requirements are met:

– The obligatory minimum area of a change is 5 ha.

– A special type of "elementary" changes can be smaller than 5 ha, but the total group area of these neighboring polygons should be greater than 5 ha;

– The minimum width of a polygon is 100 m.

Change detection is a process of comparing and analysing vector and raster data from the two time horizons. It totally depends on the expertise and the skill of the interpreter. The correctness of the decisions is also determined by the good knowledge of the territory of research as a natural geographic region, the social and economic conditions, the seasonal changes in the reflectance of land cover, the knowledge and the experience in computer assisted interpretation of satellite images.

Technically changes are located by means of an analysis of all available data. Change polygons are delineated in the images from 2006. During the process of change detection the following rules are followed:

– only real land cover changes that reflect certain natural, social and economical processes and trends are mapped;

– the development of landscape as a natural and anthropogenic system are taken into account;

– for each change the likelihood and the chance of occurrence within the 6 years period are considered;

– short term and periodic changes (daily or seasonal), are not marked.

Land Cover Classes of Interest to Forestry

The adopted unified nomenclature for the 44 interpreted and mapped land cover classes (Feranec et al. 2006) includes 6 classes directly and closely connected with the thematic mapping of the timber productive areas of the forest fund, with the inventory of the forest stands and their monitoring referring to forest fires. The multitemporal analysis of satellite images, being in the basis of the project methodology, provides a study of the development of these land cover classes and facilitates for forest changes detection. The CLC classes of interest to this study are shown in Table 2, where those directly related to forestry are bold.

The multitemporal analysis of satellite images provides a study of the territorial distribution of these land cover classes and detection of the most important changes in Bulgarian forests.

Territorial distribution of land cover classes of interest to forestry

In the CLC2006 Bulgaria database 36 land cover classes by the CORINE nomenclature are presented by 52,478 polygons covering a total area of 11,242,620.6 ha

(112,242.6 km^2) (Stoimenov 2008). The mapped territory exceeds the country territory (110,993.6 km^2). The reason is the project methodology – mainly the 2 km buffer zone mapped along the terrestrial country borders and national borders.

More than half of the territory of the country belongs to two classes:

– "Nonirrigated arable land" – 3,899,946.4 ha (34.69%).

– "Broadleaved forests" – 2,360,819.0 ha (21.00%).

The Land Cover nomenclature classes of interest to forestry distribution for the CLC 2006 database statistics – number of polygons, class area and class percent of the all territory mapped are summarized in Table 3.

Level 1 class distribution is presented in Table 4. Almost 99% of the territory is occupied by 3 Level 1 land cover classes:

• "Arable lands" – 5 760,750 ha (51.24%);

• "Forest and seminatural areas" – 4,795,873 ha (42.66%);

• "Artificial surfaces" – 558,410 ha (4.97%).

Table 2. Land cover classes of interest to forestry.

Level 1	Level 2	Level 3
3. Forest and semi natural areas	3.1. Forests	**3.1.1. Broad leaved forest**
		3.1.2. Coniferous forest
		3.1.3. Mixed forest
	3.2. Scrub and/ or herbaceous vegetation associations	3.2.1. Natural grassland
		3.2.2. Moors and heath lands
		3.2.4. Transitional woodland scrub
	3.3. Open spaces with little or no vegetation	3.3.2. Bare rocks
		3.3.3. Sparsely vegetated areas
		3.3.4. Burnt areas

Table 3. Class of interest to forestry distribution for CLC 2006 Bulgaria database statistics.

№	Code	Level 3	Polygons	Area, ha	%
1	3.1.1.	Broad leaved forest	5,429	2,360,819.0	21.00
2	3.1.2.	Coniferous forests	1,988	543,044.3	4.83
3	3.1.3.	Mixed forest	4,008	645,219.5	5.74
4	3.2.1.	Natural grassland	2,886	406,735.8	3.62
5	3.2.2.	Moors and heath lands	90	31,753.1	0.28
6	3.2.4.	Transitional woodland-scrub	7,765	751,310.9	6.68
7	3.3.2.	Bare rocks	148	12,558.4	0.11
8	3.3.3.	Sparsely vegetated areas	382	41,420.3	0.37
9	3.3.4.	Burnt areas	1	368,8	0.00
		Total	**22,697**	**4,793,230.1**	**4,263**

Table 4. Level 1 class distribution for CLC 2006 Bulgaria data base statistics.

Level 1	CLC class	Polygons	Area, ha	%
1	Artificial surfaces	5,734	558,410	4.97
2	Arable land	23,024	5,760,750	51.24
3	Forest and semi-natural areas	22,276	4,795,873	42.66
4	Wetlands	82	11,399	0.10
5	Water bodies	425	116,189	1.03
	Total	**51,541**	**11,242,652**	**100.00**

Table 5. CLC 2006–2000 changes (level 1).

Level 1	CLC 2006-2000 changes	Area, ha	%
1	Artificial surfaces	4,594.73	7.86
2	Arable land	4,893.29	8.37
3	Forest and semi-natural areas	48,810.57	83.49
4	Wetlands	165.97	0.28
5	Water bodies	0.00	0.00
	Total	**58,464.57**	**100.00**

Change detection in the land cover classes of interest to forestry

During the investigated period of 6 years the identified changes are presented in 2,706 polygons with total area of 528,272 ha, which cover 0.53% of the country territory.

The biggest changes are in class "Forest and seminatural areas", followed by "Arable lands" and "Artificial surfaces". The Level 1 changes are presented in Table 5.

Table 6 shows the changes in land cover classes of interest to forestry in Bulgaria arranged in descending order. The greatest changes detected for the period 2000–2006 refer to two classes – "Transitional woodland-scrub" – 3.2.4. (59.5%) – deforestation and "Broad leaved forest" – 3.1.1. (20.1%) – aforestation.

Most Important Changes in the Land Cover Classes of Interest to Forestry

Three of the most frequent changes in the Bulgarian forest over a 6 years period can be analysed through data collected from the CORINE Land Cover database:

3.1. "Clear cuts" – class 3.2.4.

Land cover class 3.2.4. is derivative of the sub-class 3.2. – "Scrub and/or herbaceous vegetation associations" included in the major class 3 –

"Forest and semi natural areas" (CLC2006 technical guidelines, 2007).

Class 3.2.4. "Transitional woodland/shrub" includes before all bushy or herbaceous vegetation with scattered trees. It can represent either woodland degradation or forest regeneration/decolonization. Young plantations, forest nurseries and clear cuts in forest areas are also included here. Since the Bulgarian regulations no matter the case do not allow clear cuts larger than 5 ha (and this is the lower area limit for a CLC Change polygon) this class gives a brilliant possibility for identifying and quan-

Table 6. CLC 2000–2006 changes in the land cover classes of interest to forestry.

CLC code	Area, ha	%
3.2.4. Transitional woodland-scrub	34,810.2	59.54
3.1.1. Broad leaved forest	11,777.1	20.14
3.1.3. Mixed forest	1,176.5	2.01
3.1.2. Coniferous forests	609.9	1.04
3.3.4. Burnt areas	382.6	0.65
3.3.3. Sparsely vegetated areas	33.0	0.06
3.2.2. Moors and heath lands	21.3	0.04
Total	**48,810.6**	**83.48**

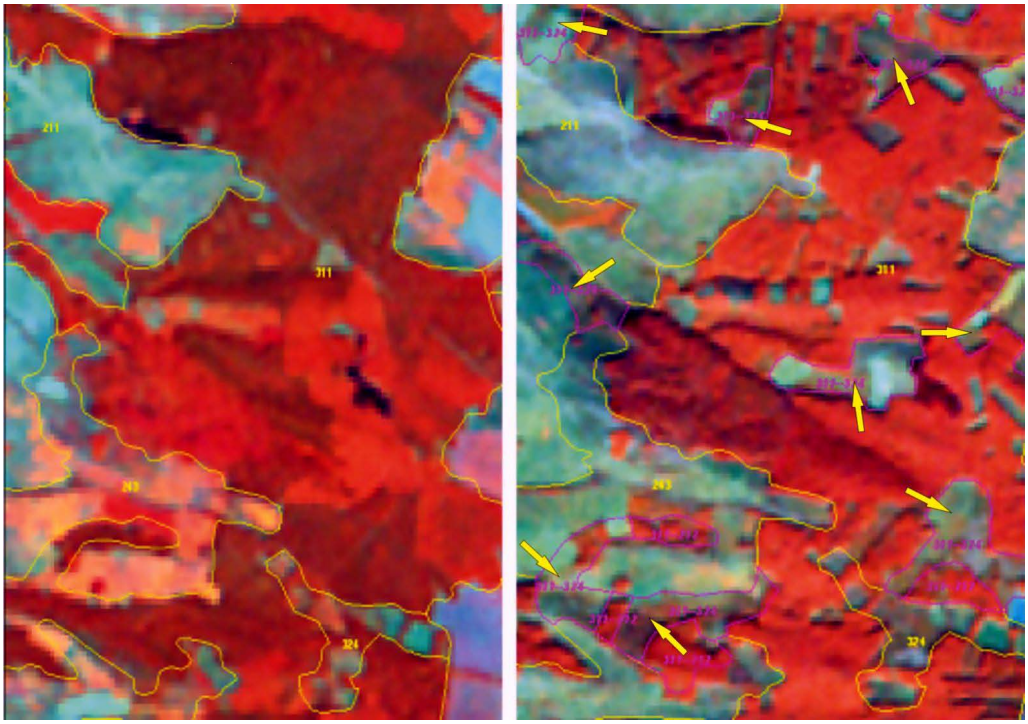

Fig. 1. Multiple clear cuts larger than 5 ha, found eastwards from Lukovit – the total area of such clear cuts for the working unit (one 1:100 000 map sheet) amounts to 1752 ha.

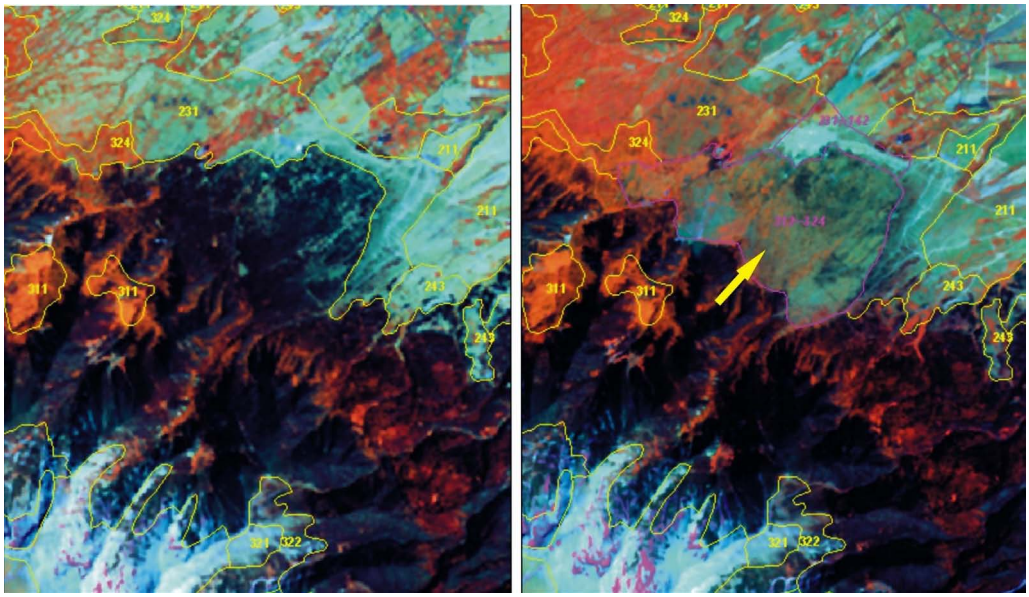

Fig. 2. Changes due to a forest fire and consequent cuts of coniferous forests in the region of Bansko.

tification of illegal cuts. Such an example of multiple clear cuts larger than 5 ha, found eastwards from Lukovit, are shown in Fig. 1 (dark green coverage with brownish spots in the right window).

Changes of this type amount to 59.5% of all changes in land cover classes in Bulgaria.

"Burnt areas" – class 3.3.4.

Land cover class 3.3.4. "Burnt areas" is a derivative of the sub-class 3.3. – "Open spaces with little or no vegetation" included in the major class 3 – "Forest and semi natural areas" and includes areas (mainly forest and heathlands and moorlands) after recent fires.

An example can be given from the region of Bansko (Fig. 2) – burnt and consequently cut of forest stands of Austrian pine (*Pinus nigra* Arn.) with a total area of 642 ha.

Spots of "sport and leisure facilities" construction – class 1.4.2.

Land cover class 1.4.2. "Sport And Leisure Facilities" is a derivative of the sub-class 1.4. "Artificial, non-agricultural vegetated areas", included in the major class 1 "Artificial surfaces". This class contains camping ground, sport ground, leasure parks, golf courses, race courses, etc. There are included also formal parks not surrounded by urban areas.

Spots of "Sport and leisure facilities" construction are connected with clear-

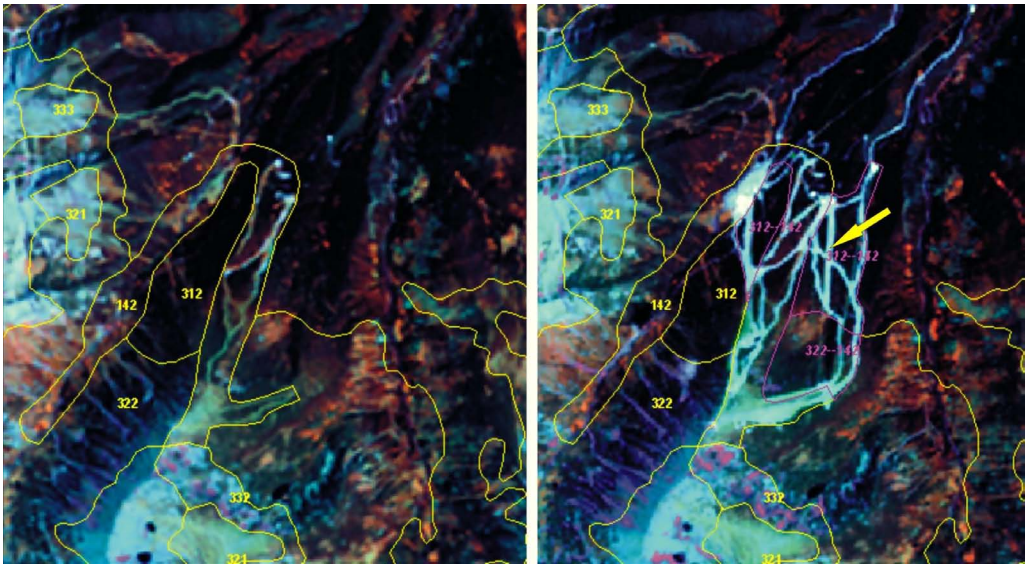

Fig. 3. Cuts of coniferous forests for new skiing tracks in the region of Bansko.

ance of large territories, often clear cuts. Such an example is presented in Fig. 3, but the total area of similar changes on the whole Bulgarian territory amounts to 586 ha.

Assessment of the Locations and the Area of Mountain Pine Assosiations in Bulgaria

On the basis of data, satellite imagery and technology of the project CORINE Land cover – Bulgaria, a large scaled research has been carried out for assessing the locations and the area of the Mountain pine (*Pinus mugo*) associations in Bulgaria. The results of the research are compared to the official data of the national Executive Forest Agency.

In Bulgaria the only large enough areas that should be assigned the 3.2.2. code are those covered with dwarf pine (*Pinus mugo*). Such associations proved out to be wide spread in the high mountain belt (altitude between 1400–2500 m) of the Rila and Pirin mountains and some separate stands could be found in the high parts of the Vitosha mountain and the Western Balkan mountain. High in the mountains the vast *Pinus mugo* associations prove to be usually pure. Their spectral reflectance makes them easy to identify by color in the satellite images, separate them from the other coniferous stands and delineate the 3.2.2. CLC polygons. They are also characteristic with their smooth texture (see the left window in Fig. 4).

The total area of the CLC 3.2.2. polygons for the country is 24,753 ha. It is compared with the available ground truth data of the 4 Regional forest de-

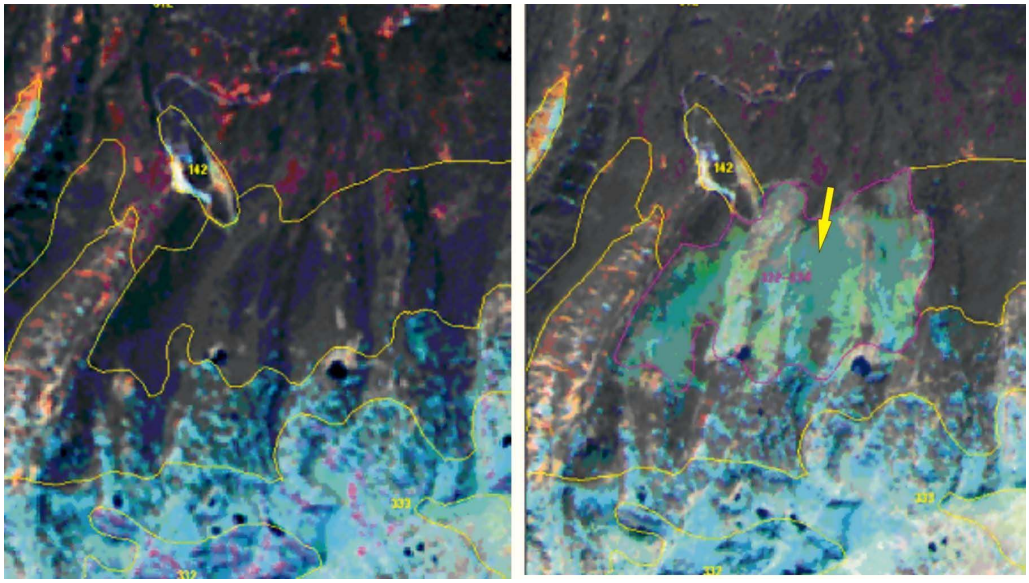

Fig. 4. A burnt and consequently submitted to clear cut 369 ha areas of *Pinus mugo* near the Malyovitsa peak.

partments which territories take in the *Pinus mugo* associations – Blagoevgrad, Kyustendil, Pazardjik and Sofia. According to these data the total area of interest is 23,073 ha. The difference is due to the availability of some rare stands on rocky grounds that have been delineated as CLC polygons, but are not accounted as a part of the forest fund.

All the work has been done within several days, whereas having in mind the hard terrain access to the spots, the precise solving of the task by terrain methods is very time-taking, expensive and for some places impossible.

Changes in the *Pinus mugo* associations are very slow. Cuts in them are not allowed in Bulgaria as it is everywhere in Europe. Nevertheless, some large changes in this CLC class have been found due to forest fires and consequent cuts. Such an example for the region of the Malyovitsa peak is shown in Fig.4. In the left image from Landsat-7 ETM+ (2000) the dark patch with smooth texture in the middle represents the high mountain *Pinus mugo* stands, touching a skiing track in the north direction. The burnt and cleared area can be seen as a large dark green patch in the right image from SPOT 4 (2006). The southern boundary is tong-like – typical of burnt areas because of the specific way in which fires spread due to the relief.

Conclusion

The more than 15 years history of the CLC Project data applications shows

that this huge database is the only periodically updated pan-European spatial database. It strongly impacts the policy and the applications in the regional development and spatial planning; coastal zone management; implementation of the biodiversity conventions, habitats and protected sites; integrated watershed analysis; assessment of air emission and air quality measures; impacts of agriculture policies on the environment etc. The CLC project methodology, based on multitemporal analysis of satellite images, provides data which can be used in enormous number of scientific and application projects.

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