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SATELLITE MAPPING OF BULGARIAN LAND COVER – CORINE 2018 PROJECT

Ventzeslav Dimitrov[1], Radka Koleva[2*], Youlin Tepeliev[2], Yulia Kroumova[3], Todor Lubenov[1], and Nadezhda Ilieva[3]

[1]Space Research and Technology Institute – BAS, Acad. G. Bonchev Str. Block 3, 1113 Sofia, Bulgaria.
[2]University of Forestry, 10 Kliment Ohridski Blvd., 1797 Sofia, Bulgaria.
[*]E-mails: rad_koleva@abv.bg, rad.koleva@gmail.com
[3]National Institute of Geophysics, Geodesy and Geography – BAS, Acad. G. Bonchev Str. Block 3, 1113 Sofia, Bulgaria.

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Abstract

The main aim of the CORINE Land cover 2018 project is to identify and map the changes of land cover/land use for the period 2012–2018 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 2018. 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. A statistical analysis of the created databases is made. For the investigated period (2012–2018) the largest in number (2720), the largest as area (53,558 ha) and with the highest percentage (53.54 %) of the total area of the changes are the changes occurring in class 3 'Forests and semi-natural areas'. Six types of changes prevail, forming over 3/4 of the area of all changes – loss of coniferous forests (23,392 ha – 23 %), loss of broad-leaved forests (18,389 ha – 18 %), pastures into non-irrigated arable land (14,534 ha – 14 %), vineyards into non-irrigated arable land (9451 ha – 9 %), fruit trees and berry plantations into non-irrigated arable land (6051 ha – 6 %) and restored broad-leaved forests (4865 ha – 5 %). The area of recovered broad-leaved forests (change 324-311) is 4865 ha, which is almost 4 times less than the lost (18,389 ha). Two negative change processes were identified – conversion of vineyards (221) and orchards (222) into non-irrigated arable land (211), i.e. extensification of agriculture, but also was an intensification one – change of pastures (231) to non-irrigated arable land (211).

Key words: change detection, Copernicus, CORINE Land Cover 2018, land cover/land use, remote sensing, satellite images.

Introduction

The European Commission initiated the CORINE Land Cover (CLC) project in 1985 as a part of the CORINE programme (Heymann et al. 1994). The primary mapping in Europe was performed between 1986 and 1995 in the project CLC 1990. Further, the CLC database was maintained and updated regularly, as a part of

the commitments the European Environment Agency (EEA): CLC2000 (Bossard et al. 2000), CLC2006 (Anonymous 2007), CLC2012 (Büttner et al. 2014), and CLC2018 (Kosztra et al. 2017). An in-depth analysis of four of the aforementioned CLC phases in Europe for the period 1990–2012 on the methodology, data, case studies and prospects of CLC can be found in (Feranec et al. 2016).

Currently, the CLC-related activities are part of the Copernicus programme. Copernicus is the European flagship programme and system for Earth observation and monitoring (Anonymous 2017a). Copernicus Land Monitoring Service (CLMS) provides geographical information on land cover to a broad range of users in the field of environmental terrestrial applications (Fig. 1). The European Commission's Joint Research Centre manages technically the Global Land service. The pan-European component of the CLMS is coordinated by the EEA and produces land cover/land use data in the CORINE Land Cover, the High Resolution Layers, and related products (e.g. European Settlement Map).

In ellipses at the bottom end of the Figure 1 products delivered by the CORINE Land Cover 2018 (CLC2018) mapping campaign are shown: the revised land cover map of year 2012 (CLC2012revised), land cover changes between the years 2012–2018 (CLC-Change 2012–2018) and the CORINE Land Cover database for the year 2018 (CLC2018).

The CLC nomenclature includes 44 land cover and land use classes at its third level (Heymann et al. 1994, Bossard et al. 2000). CLC uses a Minimum Mapping Unit (MMU) of 25 ha for areal phenomena and a minimum width of 100 m for linear ones, while the MMU for changes is 5 ha. Different MMUs mean that the change layer has higher resolution than the status layer. Due to differences in MMUs the difference between two status layers

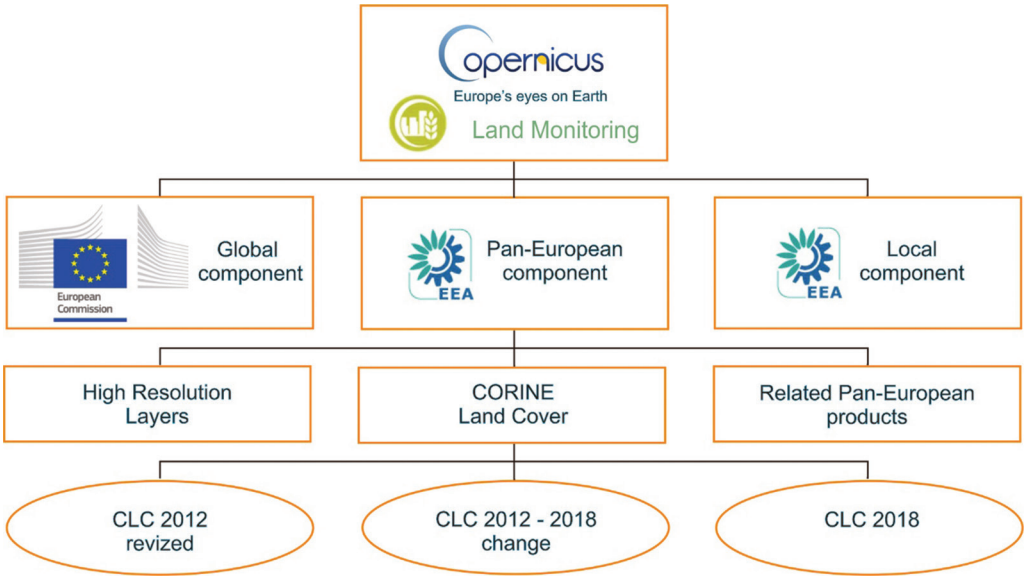

Fig. 1. Copernicus Land Monitoring Service and CORINE Land Cover 2018.

from different years will not equal to the corresponding CLC-Changes layer. One interested in CLC-Changes between two neighbour surveys should use the CLC-Change layer. The evolution of CORINE Land Cover can be seen in Table 1.

Table 1. Evolution of CORINE Land Cover (Anonymous 2017b).

CLC Feature	CLC1990	CLC2000	CLC2006	CLC2012	CLC2018
Satellite data	Landsat-5 MSS/TM single date	Landsat-7 ETM single date	SPOT-4/5 and IRS P6 LISS III dual date	IRS P6 LISS III and Rapid-Eye dual date	Sentinel-2 and Landsat-8 for gap filling
Time consistency	1986–1998	2000 +/- 1 year	2006+/- 1 year	2011–2012	2017–2018
Geometric accuracy, satellite data	≤ 50 m	≤ 25 m	≤ 25 m	≤ 25 m	≤ 10 m (Sentinel-2)
Min. mapping unit/width	25 ha/100m	25 ha/100m	25 ha/100m	25 ha/100m	25 ha/100 m
Geometric accuracy, CLC	100 m	better than 100 m	better than 100 m	better than 100 m	better than 100 m
Thematic accuracy, CLC	≥ 85 % (probably not achieved)	≥ 85 % (achieved)	≥ 85 %	≥ 85 % (probably achieved)	≥ 85 %
Change mapping (CHA)	not implemented	boundary displacement min 100 m; change area for existing polygons ≥ 5 ha; for isolated changes ≥ 25 ha	boundary displacement min100 m; all changes ≥ 5 ha are to be mapped	boundary displacement min 100 m; all changes ≥ 5 ha are to be mapped	boundary displacement min 100 m; all changes ≥ 5 ha are to be mapped
Thematic accuracy, CHA	-	not checked	≥ 85 % (achieved)	≥ 85 %	≥ 85 %
Production time	10 years	4 years	3 years	2 years	1.5 years
Documentation	Incomplete metadata	standard metadata	standard metadata	standard metadata	standard metadata
Access to the data (CLC, CHA)	unclear dissemination policy	dissemination policy agreed from the start	free access for all users	free access for all users	free access for all users
Number of countries involved	26 (27 with late implementation)	30 (35 with late implementation)	38	39	38 (Turkey to be added in 2019)

The number of countries participating in CLC2018 project is 39 with a total mapped area of 5.8 million km^2 (Fig. 2), including 33 member countries and 6 co-operating countries. The list of EEA member countries (coloured in green) includes the 28 European Union Member States together with Iceland, Liechtenstein, Nor-

Fig. 2. Countries participating in CORINE Land Cover 2018 project (Anonymous 2019).

way, Switzerland and Turkey. The six West Balkan countries (coloured in blue) are cooperating countries: Albania, Bosnia and Herzegovina, North Macedonia, Montenegro, Serbia as well as Kosovo (Anonymous 2019).

Bulgaria has participated in the Copernicus programme, in particular CLC, since the early 1990s, so this time is our country's fifth participation in the CLC successive projects within the framework of the EEA's Earth observation activities (Stoimenov et al. 2014). This time the production of CLC for the 2018 reference year was one of the tasks of a larger project for Copernicus supporting activities by countries for the period 2017–2021. In addition to the work on CLC update, three other tasks were included: verification of 2012 reference year local component products and enrichment of Urban Atlas; Post-production verification of the High Resolution Layers for the 2015 reference year; and Dissemination. The essence of CLC land cover update is to identify and map the changes of land cover/land use for the period 2012–2018 using multitemporal/multispectral satellite imagery.

Methodology

CLC is produced by the majority of countries by visual interpretation of high resolution satellite imagery. In a few countries semi-automatic solutions are applied. The methodology for interpretation of satellite images by basic working units (BWU) practically does not differ from that used in the previous projects. It is unified and harmonized for all 39 countries involved in the implementation of the project. Its full description is given in the respective EAA document (Büttner and Kosztra 2017). This guideline is based on the previously known 'CLC2006 Technical Guidelines' (Anonymous 2007) and 'CLC2012 Addendum to the CLC2006 Technical Guidelines' (Büttner et al. 2014). A CLC nomenclature with 44 classes is used (36 for Bulgaria – see Table 3).

The methodology is based on the use of multi-spectral satellite imagery from two time horizons, in this case – 2012 and 2018 (±1 year) and a wide range of *insitu* digital databases:

- digital colour orthophotos;
- LUCAS 2012 (Land Use and Coverage Area frame Survey of EUROSTAT);
- Google Earth with Street View and Google Maps;
- topographic maps M 1:25 000 and M 1:50 000;
- physical blocks from the Land Parcel Identification System.

Satellite Image Data

In Table 2 below the dates are shown of the two sets of Sentinel-2 input satellite images datasets (Coverage 1 and 2) used in the project. Figures 3 and 4 show the spatial distribution of the satellite scenes from the two image databases (IMAGE2012 and IMAGE2018) over the territory of the country.

Table 2. Satellite imagery (IMAGE2018) from Sentinel-2 satellites, acquired in the summer and early autumn of 2017 for the territory of Bulgaria.

Coverage 1			Coverage 2		
Satellite	**Acquisition date**	**Tile number**	**Satellite**	**Acquisition date**	**Tile number**
S2B	2017/06/30	t35tlg	S2A	2017/08/24	t35tlg
S2B	2017/06/30	t35tlh	S2A	2017/08/24	t35tlh
S2B	2017/06/30	t35tlj	S2A	2017/08/24	t35tlj
S2B	2017/06/30	t35tmg	S2A	2017/08/24	t35tmg
S2B	2017/06/30	t35tmh	S2A	2017/08/24	t35tmh
S2B	2017/06/30	t35tmj	S2B	2017/08/19	t35tmj
S2B	2017/07/23	t34tfp	S2B	2017/09/11	t34tfp
S2B	2017/07/23	t34tgn	S2B	2017/09/11	t34tfm
S2B	2017/07/23	t34tgp	S2B	2017/09/11	t34tfn
S2B	2017/08/02	t34tfl	S2B	2017/09/11	t34tfl
S2B	2017/08/02	t34tfm	S2B	2017/09/11	t34tgl
S2B	2017/08/02	t34tfn	S2B	2017/09/11	t34tgm
S2B	2017/08/02	t34tgl	S2A	2017/09/11	t34tgn
S2B	2017/08/02	t34tgm	S2A	2017/09/11	t34tgp

Coverage 1			Coverage 2		
Satellite	**Acquisition date**	**Tile number**	**Satellite**	**Acquisition date**	**Tile number**
S2A	2017/07/02	t35tng	S2B	2017/09/03	t35tlf
S2A	2017/07/22	t35tnh	S2B	2017/09/10	t35tng
S2A	2017/07/22	t35tnj	S2B	2017/08/26	t35tnh
S2A	2017/07/02	t35tpj	S2B	2017/08/24	t35tnj
S2B	2017/06/30	t35tlf	S2B	2017/08/24	t35tpj
S2B	2017/06/30	t35tmf	S2B	2017/09/08	t35tmf

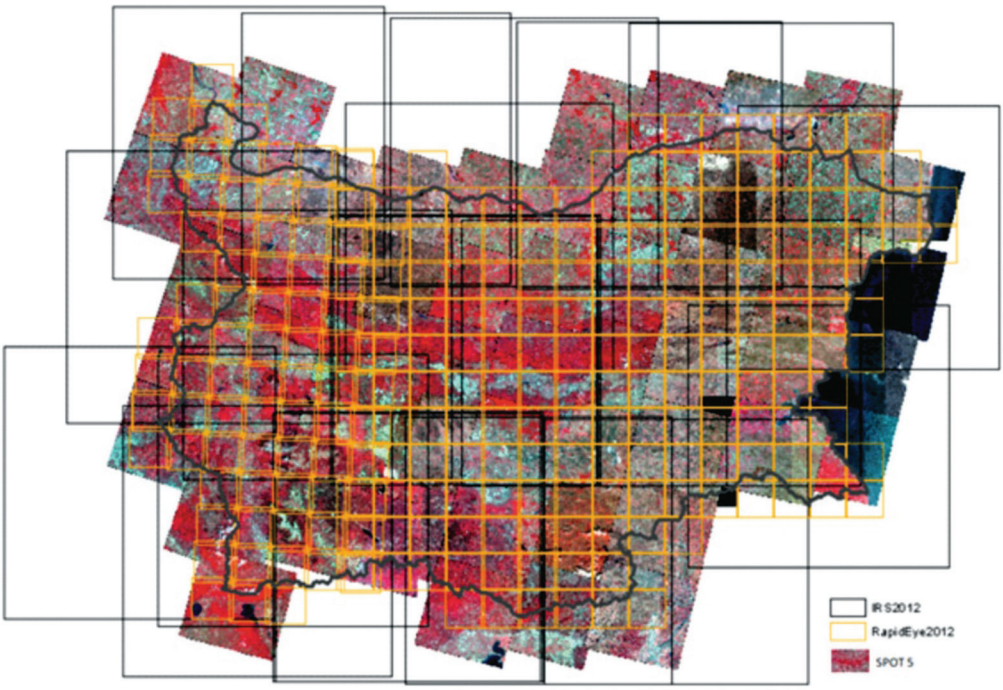

Fig. 3. Spatial distribution of satellite scenes of IMAGE2012.

Preparation of InterChange Projects for BWUs

The process of computer assisted visual interpretation is preceded by the preparation of InterChange projects by Basic Working Units (BWUs). In Figure 6 the selected division is shown of the territory of the country into BWUs. The territory is divided into 68 BWUs (Fig. 5) with outlines in which a compromise has been reached between the complete coincidence with the map sheet division of the standard topographical maps of the Military Geographic Service in 1:100 000 scale and the convenience of the interpreters' work in the border regions of Bulgaria and in the edge mathing of the neighboring BWUs.

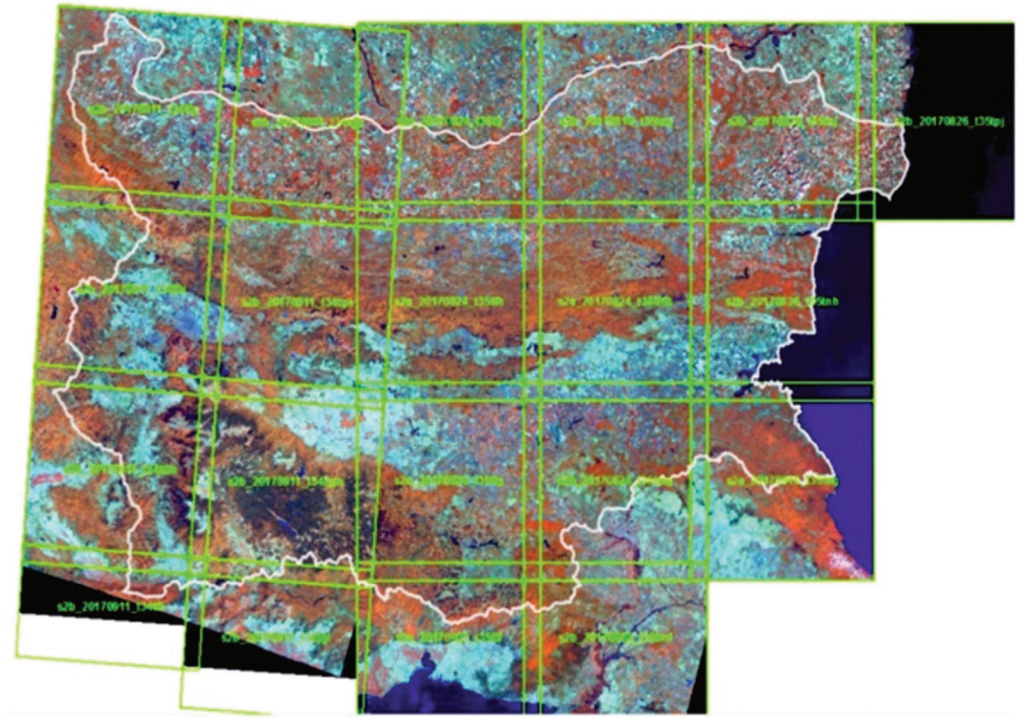

Fig. 4. Spatial distribution of satellite images of IMAGE2018.

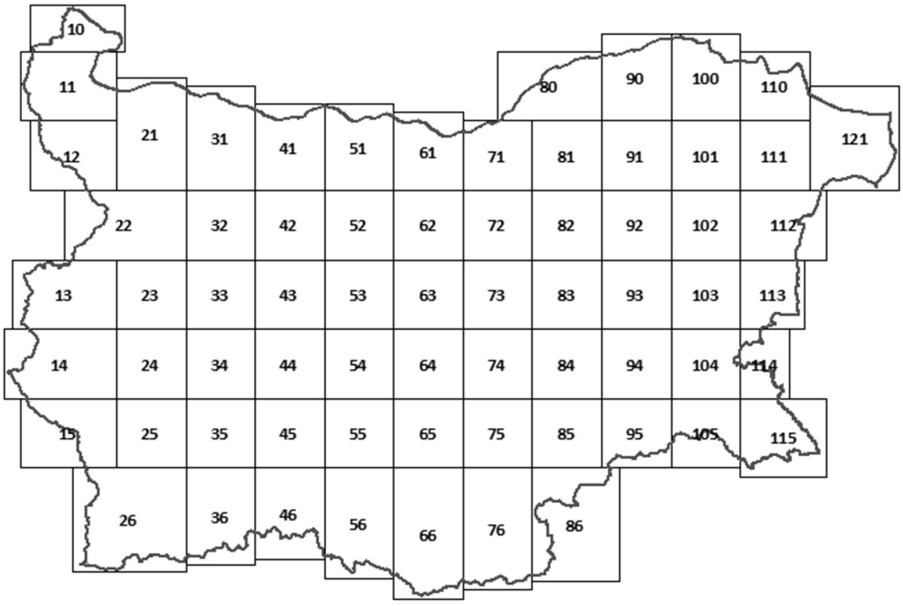

Fig. 5. Division of the Bugarian territory into BWUs.

This ensures continuity with the work within the previous CLC projects.

Each BWU prepared for the interpreters, in addition to the above-described sub-images and entire satellite scenes from the IMAGE2012 database, also contains: vector data from the CLC2012 database, WMS links to the additional data: topographic and thematic maps in digital format and orthophoto maps from 2011 to 2017.

Detection and Mapping of Land Cover Changes in the Period 2012–2018

The preferred approach of most countries in the project is first to make corrections / improvement in the CLC2012 database obtaining the so-called revised $CLC2012_{revised}$ database. Then, changes in the land cover are detected by visual comparison of all input and ancillary data and images from the IMAGE2012 and IMAGE2018 datasets.

For the computer-assisted photointerpretation (CAPI), the Hungarian software product InterChange (Anonymous 2012) has been used working in two synchronized windows for detecting the changes (see Fig. 6). False color satellite image compositions are compared – IMAGE2012, loaded in the left window (revision) and IMAGE2018 – in the right (change) window, the CLC2012 vector database being overlayed on both of them. The rich set of in-situ data and digital maps allow reliable and accurate delineation of the corrected CLC2012 polygons in the left window and the changes found in the right one.

In the process of identifying and mapping land cover and land use changes, the following principles are respected: outline real changes to reflect the natural and

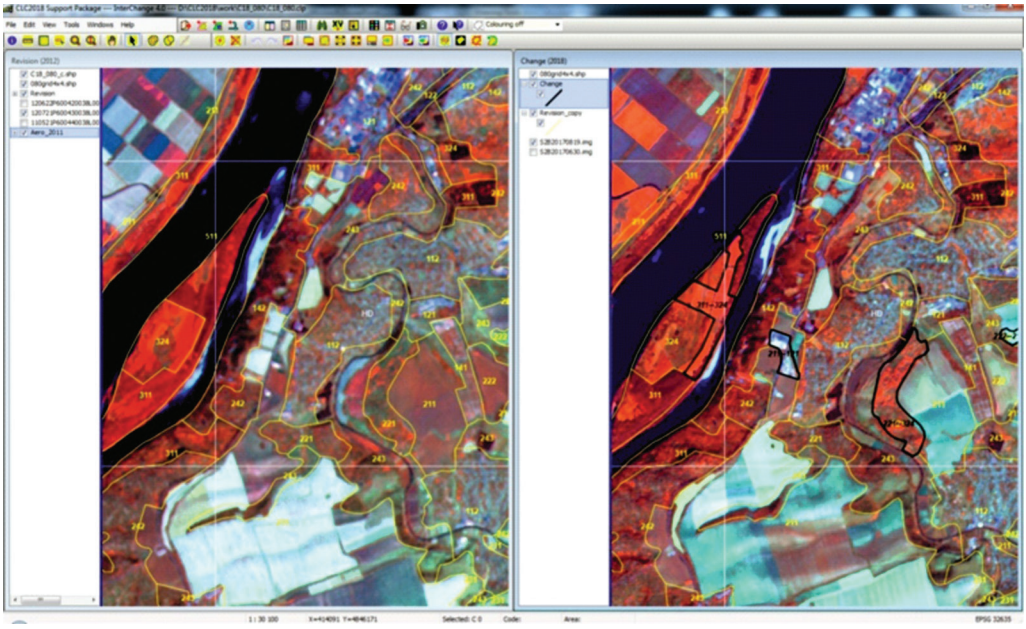

Fig. 6. InterChange screen with two synchronized windows and a set of basic GIS tools. Left window (Revision 2012) – data for 2012 and right window (Change) – CLC data for 2012, satellite and in-situ – for 2018.

socio-economic processes, take into account the logic in the landscape development as a natural-anthropogenic system. Other principles are to comply with the opportunities and the likelihood the detected changes to occur during the 6-year study period and to ignore short-term annual changes (days, seasons) that are characteristic for the agricultural crops, the water bodies and the wetlands.

The basic parameters of the created databases are:

- minimum mapping unit (MMU) of 25 ha;
- minimum width of linear elements (MMW) ≥100 m;
- minimum area of change polygons ≥5 ha (total for the so-called technical polygons);
- CLC nomenclature for the land cover – 44 classes (36 for Bulgaria);
- mapping only real changes.

Creating CORINE Land Cover Database for the Reference 2018 year

The Technical team of the Space Research and Technology institute (SRTI) at the Bulgarian Academy of Sciences implemented the technical part of the task. The overall project management, liaison with the EEA and the results dissemination was fulfilled by the Executive Environmental Agency (ExEA) of Bulgaria. The workflow of SRTI activities included a lot of procedures like image and vector datasets download and preliminary processing, InterChange projects preparation for BWUs, computer assisted image interpretation. We have to add here also activities on the quality assurance and control (QA and QC) – internal and external, creation of CLC2012revision database and CLC Change 2012–2018 databases with metadata.

For the automated creation of the CLC2018 database we used common GIS software and a specialized module provided by the EEA. The CLC2018 database is obtained by means of a complex overlay GIS operation presented by the (+) symbol:

$$CLC2018 = CLC2012_{revised} (+) CLC_{Change2012\text{-}2018}$$

Internal and External Quality Control

The internal verification of the results obtained by the interpreters was carried out on a regular basis – after completion of the BWU, before and after the external checks. The overall process of BWU-level checks is noted in the metadata.

In accordance with the terms of the agreement with the EEA, two external verifications were carried out remotely (via the Internet) by the EEA TT on BWU selections. The final chech of the photointerpretation work found that the thematic accuracy of the databases created according to the EEA TT criteria was better than 85 %.

Results and Discussion

Three databases were created as a result of the project implementation: the revised CLC2012, CLC-Change2012–2018 and CLC2018, all complemented with INSPIRE compliant metadata. These databases are the main deliveries of the project.

Furthermore, the following analysis shows inherent features of the land cover and reveals some processes on the base of registered changes.

Statistical figures of CLC2018

In Table 3 the areas of the different types of land cover/land use are given, as well as their percentage of the total area and the number of polygons from the CLC2018 database.

Table 3. CLC2018 level 3 land cover polygons.

CLC class	CLC class name	Area		Count
		ha	%	
111	Continuous urban fabric	814	0.01	4
112	Discontinuous urban fabric	388,046	3.50	3,949
121	Industrial or commercial units	77,388	0.70	1,161
122	Road and rail networks and associated land	4,486	0.04	69
123	Sea ports	739	0.01	13
124	Airports	6,255	0.06	33
131	Mineral extraction sites	32,109	0.29	316
132	Dump	4,077	0.04	41
133	Construction sites	540	0.00	9
141	Green urban areas	4,348	0.04	64
142	Sport and leisure facilities	13,372	0.12	189
211	Non-irrigated arable land	3,821,699	34.43	5,150
213	Rice fields	36,855	0.33	24
221	Vineyards	115,846	1.04	1,336
222	Fruit trees and berries plantations	45,152	0.41	711
231	Pastures	391,297	3.53	5,048
242	Complex cultivation patterns	262,278	2.36	3,088
243	Land principally occupied by agriculture with significant areas of natural vegetation	1,061,572	9.56	8,348
311	Broad leafed forest	2,297,548	20.70	5,538
312	Coniferous forests	533,561	4.81	1,857
313	Mixed forest	644,870	5.81	4,110
321	Natural grassland	408,566	3.68	2,905
322	Moors and heathlands	23,020	0.21	73
324	Transitional woodland-scrub	762,285	6.87	8,434
331	Beaches, dunes, sand	1,898	0.02	43
332	Bare rocks	12,633	0.11	121
333	Sparsely vegetated areas	38,405	0.35	395
334	Burnt areas	69	0.00	2
411	Inland marshes	8,395	0.08	67
412	Peatbogs	1,318	0.01	2
421	Salt marshes	408	0.00	2
422	Salines	1,210	0.01	5
511	Water courses	32,537	0.29	33
512	Water bodies	64,848	0.58	425
521	Coastal lagoons	734	0.01	7
	Total:	11,099,180	100.00	53,572

From the data provided, it can be seen that two types of land cover: Non-irrigated arable land (3,821,699 ha) and Forests (3,475,979 ha) cover almost 2/3 (65.75 %) of the territory of Bulgaria.

The distribution of major land cover classes at level 1 of the CLC nomenclature is shown in Table 4.

Table 4. Area of main classes (level 1) for CLC2018.

Code class	CLC level 1 classes	Area		Count
		ha	%	
1xx	Artificial surfaces	532,460	4.80	5,843
2xx	Agricultural areas	5,734,700	51.67	23,598
3xx	Forests and semi-natural areas	4,722,855	42.55	23,217
4xx	Wetlands	11,331	0.10	46
5xx	Water bodies	98,119	0.88	452
	Total:	11,099,180	100.00	53,572

In Figure 7 a diagram can be seen, showing the areas and their percentage of the total area of the 5 classes of land cover (level 3 of the CLC nomenclature) covering more than 3/4 of the territory of Bulgaria in 2018 reference year.

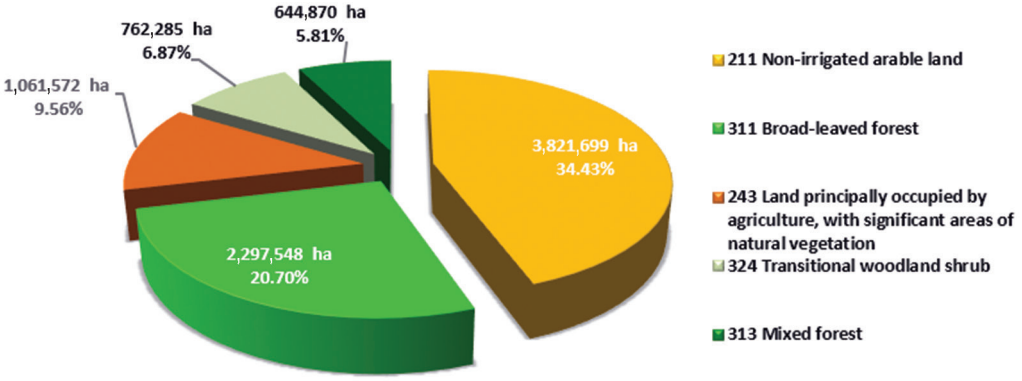

Fig. 7. The five land cover classes, forming more than 3/4 of the territory of the country in 2018.

Land cover changes in the period 2012–2018

For the period 2012–2018 4,751 change polygons have been found and mapped with a total area of 100,235 ha. In terms of number and area this is more than twice compared to the previous three periods of CLC mapping. In Table 5 the areas (ha) are given of the detected land cover changes at level 1 of the CLC nomenclature for the survey period, as well as their percentage of the area of changes and their number.

Traditionally, the largest in number (2720), the largest as area (53,558 ha) and with the highest percentage (53.54 %) of the total area of the changes are the changes occurring in class 3 'Forests and semi-natural areas'. Six types of changes prevail, forming over 3/4 of the area of all changes (see Table 6 and Fig. 8).

Table 5. Land cover changes at level 1 of the CLC nomenclature for the survey period.

Code class	Changes in level 1 classes	Area		Count
		ha	%	
1xx	Artificial surfaces	940	0.94%	48
2xx	Agricultural areas	45,429	45.41%	1,978
3xx	Forests and semi-natural areas	53,558	53.54%	2,720
4xx	Wetlands	87	0.09%	2
5xx	Water bodies	21	0.02%	3
	Total:	100,035	100.00%	4,751

Table 6. The largest in terms of area and number changes for the period 2012–2018.

Type of change	Description of the change	Area		Count
		ha	%	
312-324	Loss of coniferous forests	23,392	23	867
311-324	Loss of broad-leaved forests	18,389	18	1242
231-211	Pastures into non-irrigated arable land	14,534	14	765
221-211	Vineyards into non-irrigated arable land	9451	9	341
222-211	Fruit trees and berry plantations into non-irrigated arable land	6051	6	220
324-311	Restored broad-leaved forests	4865	5	275
	Total:	76,682	77	3710

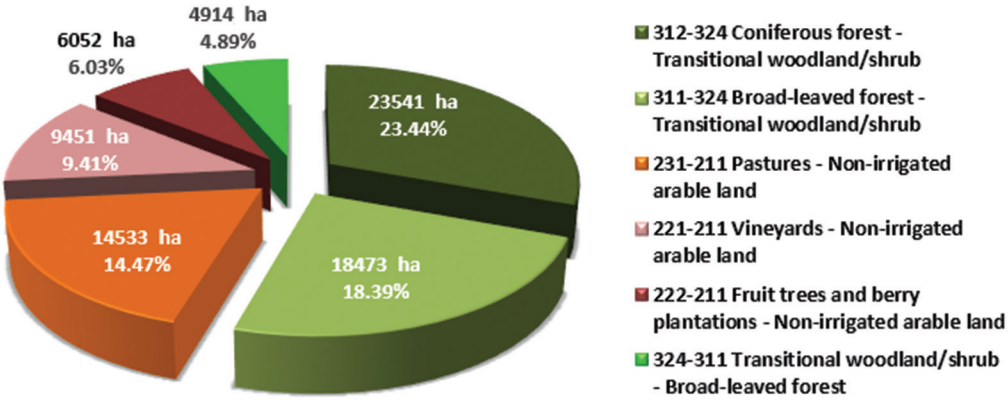

Fig. 8. The types of changes with the highest number and percentage of the total area.

The forest loss of both types (coniferous and broad-leaved) is much more considerable against the restored one. The area of recovered broad-leaved forests (change 324-311) is 4865 ha, which is almost 4 times less than the broad-leaved forest loss (18,389 ha).

It can be seen from Figure 9 that the largest in terms of area and number are losses of coniferous (312-324) and broad-leaved (311-324) forests. The main reason for this is the intensive invasion of bark beetle in the coniferous forests on both the western border with Serbia and the Republic of Northern Macedonia (Fig. 9) and on a smaller scale on the border with

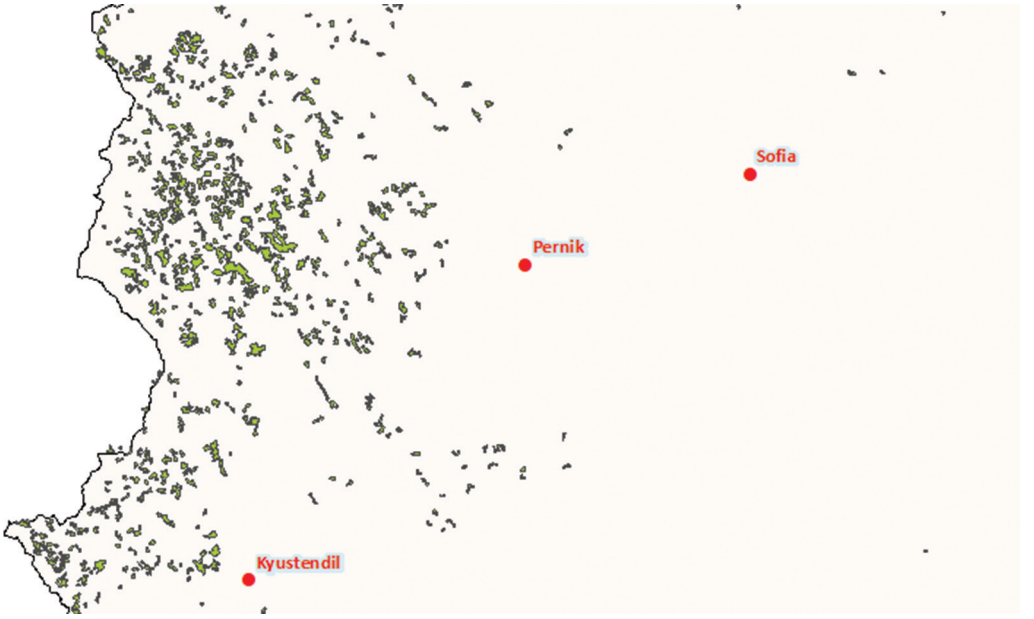

Fig. 9. Large number of changes 312-324 on our western border – North of Kyustendil.

Greece. This explains the above marked increase in the number of changes in Bulgaria for the period. The phenomenon is of a transient nature and the expected adequate measures by the competent authorities should limit it and liquidate it. This allows diverse and in-depth statistics to be produced for a quarter of a century and comparisons with the other 38 countries.

As is well known, land cover changes can be considered the relevant information source about processes (flows) in the landscape (Feranec et al. 2010). and various types of land cover transformation to different categories of land use change. In relation to agriculture, from Fig. 9 the some specific processes can be marked. Along with an intensification course (change of pastures (231) to non-irrigated arable land (211), extensification processes are avalable – conversion of vineyards (221) and orchards (222) to non-irrigated arable land (211).

Conclusions

The article presents the methodology and main results of the CORINE Land Cover 2018 Bulgaria. The status of the CLC as a part of Land Monitoring Service of the Copernicus programme is indicated. The most importand deliveries of the project are described, namely geospatial databases CLC2012revised, CLC-Change2012–2018 and CLC2018. The applied methodology ensured consistency between these three databases. As a result of a statistical analysis facts and figures, derived from CLC databases, are presented. Major land cover transformations, like deforestation, forestation, extensification and intensification are exposed.

All the project results are freely available from the ExEA website for further and more detailed analises and applications.

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References

Anonymous 2007. Technical Guidelines. EEA Technical report No 17. Available at: http://www.eea.europa.eu/publications/technical_report_2007_17

Anonymous 2012. Support Package. Available at: http://CLC2012.taracsak.hu

Anonymous 2017a. Copernicus – Pan-European. Available at: https://land.copernicus.eu/pan-european

Anonymous 2017b. CORINE Land Cover. Available at: https://land.copernicus.eu/pan-european/corine-land-cover

Anonymous 2019. Member and cooperating countries. Available at: https://www.eea.europa.eu/about-us/countries-and-eionet/intro (Accessed on 3 June 2019)

Bossard M., Feranec J., Oťaheľ J. 2000. CORINE Land Cover technical guide – Addendum 2000. Technical report. 40 p. European Environment Agency. Available at: https://www.eea.europa.eu/publications/tech40add

Büttner G, Kosztra B. 2017. CLC2018 Technical Guidelines final. Based on CLC2006 Technical guidelines (EEA Technical report No 17/2007). Wien. 61 p.

Büttner G., Soukup T., Kosztra B. 2014. CLC2012 Addendum to the CLC2006 Technical Guidelines (ETC / SIA report). 35 p.

Feranec J., Jaffrain G., Soukup T., Hazeu G. 2010. Determining changes and flows in European landscapes 1990–2000 using CORINE land cover data. Applied Geography 30(1): 19–35.

Feranec J., Soukup T., Hazeu G., Jaffrain G., eds. 2016. European landscape dynamics: CORINE land cover data. Boca Raton: CRC Press. 367 p.

Heymann Y., Steenmans Ch., Croisille G., Bossard M. 1994. CORINE Land Cover. Technical Guide. Luxembourg (Office for Official Publications of European Communities). Available at: http://las.physik.uni-oldenburg.de/eProceedings/vol03_3/03_3_buttner2.pdf

Kosztra B., Büttner G., Hazeu G., Arnold S. 2017. Updated CLC illustrated nomenclature guidelines. Wien. 124 p.

Stoimenov A, Koleva R., Dimitrov V., Tepeliev Y., Lubenov T., Kroumova J. 2014. Satellite mapping of Bulgarian land cover – CORINE 2012 project. Forestry Ideas 20(2): 189–196.