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VERIFICATION OF THE NATURA 2000 LOCAL COMPONENT DATASET IN BULGARIA

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Abstract

The thematic accuracy is an important data quality element of land cover databases. For this reason it has been paid a considerable attention by researchers over years. The main aim of this article is the presentation of the results from verification of the Natura 2000 (N2K) local component dataset for Bulgaria, which is a part of a project, managed by the European Environmental Agency (EEA). Following the methodology proposed by EE, we apply a quantitative approach based on probability sampling at polygon level. Thus, we obtain scientifically rigorous estimate of the thematic accuracy of N2K layer and of some geometric characteristics as well. Based on local expertise and in situ data, an evaluation of the quality of this product is made and statistical results are obtained, comparable to the results in other countries. The results of the verification show that the overall thematic accuracy is higher than the 85 % level expected at Pan-European scale.

Key words: sampling, semi-automatic classification, thematic accuracy, VHR satellite image, visual interpretation.

Introduction

Image classification is a widely used technique for producing thematic maps of various resources. To make these maps useful it is necessary to have information about their accuracy. Assessment of the thematic accuracy of land cover databases is an important element of spatial data quality and therefore over years it has been paid a considerable attention by researchers (e.g., Congalton 1991), and for practical applications (Olofsson 2014). Proven approach for obtaining scientifically rigorous estimate of thematic accuracy is based on probability sampling (Cochran 1977). This is a sampling design in which: (1) Each potential sampling location receives its own non-zero probability of selection; (2) These so called inclusion probabilities are known in advance from the design; (3) The method for computing a unique estimate from every sample is stated.

Under the Land monitoring service of the Copernicus programme of the European Union, several land cover/land use (LC/LU) products have been produced (Anonymous 2017) within the frames of its Pan-European and Local components. Accuracy characteristics of the High Resolution Layers 2012 have recently been assessed applying qualitative (Dimitrov and Lubenov 2014) and quantitative (Congedo et al. 2015, Dimitrov 2016)

methodologies.

The main aim of this article is the presentation of the results from verification of the Natura 2000 (N2K) local component dataset for Bulgaria. The verification task is managed by EEA and is supported by Copernicus funds. All EEA member and cooperating countries are invited to participate. The EEA developed guidelines for the verification of the Local Component (Maucha et al. 2017), but member states are free to modify and improve the proposed methodology.

We apply a quantitative approach at polygon level to evaluate the thematic accuracy of N2K layer and of some geometric characteristics as well. Our goals are to provide statistical results comparable to the results in other countries and to make a quality evaluation based on local expertise and in situ data. Typical mistakes found by local teams could be used for technology improvements. Another goal is to raise the awareness on the local component products in this country to help in identifying potential use cases. The results of the verification show that the overall thematic accuracy is higher than the 85 % level expected at Pan-European scale. We also provide remarks and recommendations concerning LC/LU polygon content and delineation quality.

Overview of Natura 2000 Network

Natura 2000 protects about 18 % of the land in the EU countries (787,767 km^2) and is considered almost complete in the EU terrestrial environment. 251,564 km^2 have been designated as Natura 2000 in the marine environment.

Natura 2000 sites can vary considerably in character. They are not strictly protected in terms of how they are allowed to be used by people. Many sites are farmed, forested and located in urban areas. The other areas are wild and natural.

The European ecological network Natura 2000 is of the highest importance for the preservation of the natural habitats. It is a Pan-European system of protected areas and ecological corridors which identification is based on scientific criteria, thus putting into force the EU Directives 79/409 for the protection of birds and 92/43 for the conservation of the natural habitats and the habitats of the wild flora and fauna.

The establishment of the Natura 2000 network in Bulgaria is postulated by the Biodiversity Act, where the sites of this network are called “protected zones”. The process began in 2002 together with the accession of Bulgaria to the EU and finished in 2008 when the protected sites were accepted by the EC after the biogeographic seminar for Bulgaria and Romania. According to the two EU Directives 335 protected sites constitute the European Ecological Network Natura 2000 in Bulgaria (114 according to the Birds Directive and 231 according to the Habitats Directive). The total area is 3,901,084 ha that constitutes 34.3 % of the country’s territory (Gussev and Tzonev 2015).

The Bulgarian part of the European Ecological Network Natura 2000 encompass 90 habitat types, or 38.86 % of all 231 habitat types presently identified and designated in the EU Annex I of Directive 92/43/EEC.

LC/LU Product Description

Unlike the products of the Pan-European component, Copernicus’s local component only covers selected areas that are

particularly sensitive to environmental challenges or spatial management problems. Examples include Natura 2000 protected areas, riparian zones along the hydrographic or coastal areas, cities above a certain number of inhabitants, etc.

While the Pan-European component is hindered by relatively coarse spatial resolution (Corine land cover (CLC) – 25 ha Minimum Mapping Unit (MMU), High Resolution Layers (HRLs) – 1 ha grid) for national, regional or local applications, the local component provides a different level of spatial and thematic detail reducing the MMU from 1 ha to 0.25 ha. However, these products are mapped only for specific areas of interest from an environmental point of view.

The Natura 2000 product has been produced by a consortium of companies under a specific contract with EEA (Anonymous 2015b). They used a semi-automatic classification of very high resolution (VHR) satellite image data set with subsequently computer-assisted visual refinement. It offers a detailed LC/LU dataset for a selection of Natura 2000 sites and a surrounding 2 km buffer zone. The sites cover endangered semi-natural and species rich grassland habitats which will be assessed in order to investigate the effectiveness of the N2K network in halting the decline of certain grassland habitats (Richter et al. 2015). The LC/LU monitoring is implemented for a total of 160,444 km² of Natura 2000 area in 524 (buffered) sites at the two time steps 2006 and 2012 (Fig. 1).

The MAES (Mapping and Assessment of Ecosystems and their Services) nomenclature is LC/LU nomenclature which ensures compatibility to other European established LC/LU products such as CLC (Bossard et al. 2000, Büttner and Kosztra 2007), Urban Atlas (Anonymous 2016) and Riparian Zones (Anonymous 2015a). Detailed product specifications are presented in Table 1.

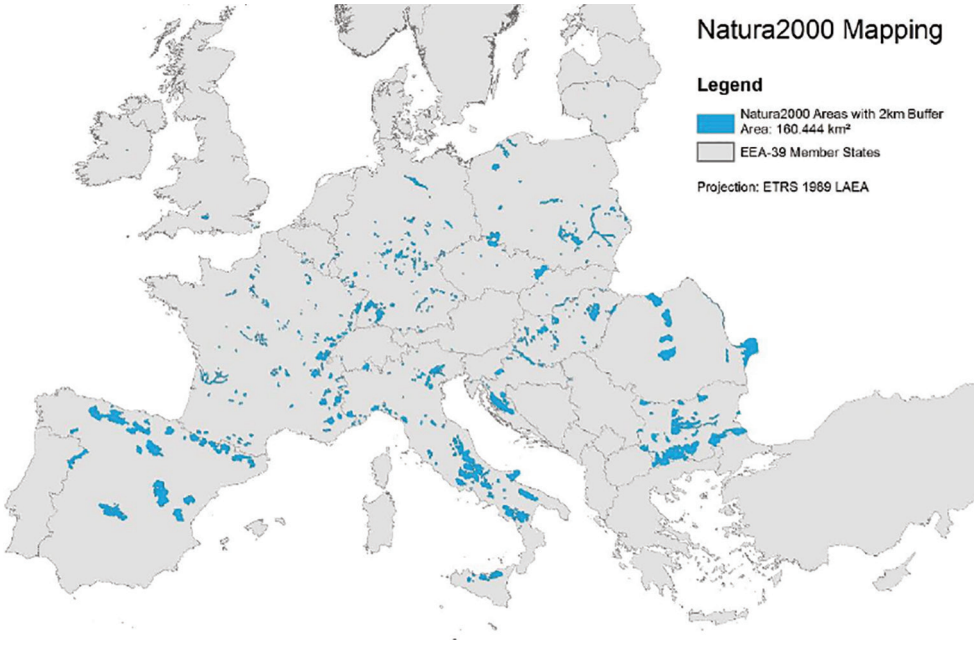

Fig. 1. Natura 2000 sites in Europe with 2 km buffer (Richter et al. 2015).

Table 1. Product Specifications of LC/LU Product (Richter et al. 2015).

Product Title / Content
Natura 2000: LC/LU mapping of a selection of N2K sites
Product Short Name
LCLU
Product Definition
The Natura 2000 product is providing a detailed LC/LU dataset for areas within buffer zone that comprises grassland habitats covering EEA28
Input Data Sources:
1) Selected Natura 2000 sites AOI with manual amendments: N2K_2kmBuff_2006_2012_80PcentCover_clipEU_ALL.shp
2) DWH_MG2b_CORE_03 / D2_MG2b_LOLA_011b – Optical VHR2 coverage over EU 2011–2013 and N2K Sites:
• 1045 SPOT-5 HRG (2.5 m); 71 SPOT-6 (1.5 m), 6 Pléiades (2.0 m)
3) DAP_MG2b_01 / N2K_data_procurement: Optical VHR2 coverage over EU 2004–2008 and N2K Sites:
• 476 SPOT-5 HRG (2.5 m)
Additional data:
• CLC 2006/2012
• Urban Atlas 2006/2012
• GIO HR Layer Forest
• DWH_MG2_CORE_01 – RapidEye (5 m)
• DAP_MG2b_CORE_02 – Image2006 (IRS / SPOT – 25 m)
• USGS – Landsat-8
• Numerous additional reference and in situ data sources

Natura 2000 LC/LU Product – Bulgaria

Summary statistics of Natura 2000 LC/LU product – Bulgaria is presented in Table 2. The total area for the country is 2,203,278 ha, i.e., 19.87 % of country's territory (Fig. 2).

Characterization of the dataset:

- Reference data provided centrally: IMAGE2012 VHR satellite image mosaic, Google Earth Imagery, Bing imagery and OpenStreetMap.
- In situ data used: National Orthophoto Map with spatial resolution 0.4 m, Land Parcel Identification System Land Cover data (LPIS LC), Forest management plans and a hydrography database.
- Reference years: 2009–2012 (partial coverages).
- MMU: 0.5 ha.
- Software used for verification: LACO-Wiki (Anonymous 2016a), Google Earth, ArcGIS 10.3, QGIS 2.18, etc.

Table 2. Summary statistics of Natura 2000 LC/LU product – Bulgaria.

N2K Class	Number of polygons	Area, ha	Share, %
1.1.1.1	3,400	39,763.09	1.80
1.1.1.3	2,349	9,663.99	0.44
1.2.1.1	253	3,320.11	0.15
1.2.1.2	55	612.39	0.03
1.2.1.3	2	16.22	0.00
1.2.1.4	5	211.81	0.01
1.3.1.1	464	1,951.44	0.09
1.3.2.1	31	103.01	0.00
1.4.1.1	528	2,673.46	0.12
2.1.1.1	5,403	260,438.21	11.82
2.1.2.1	92	220.60	0.01
2.2.1.1	531	11,523.72	0.52
2.2.2.1	1,034	14,076.94	0.64
2.3.1.1	3	14.70	0.00
2.3.2.1	945	14,044.72	0.64
2.3.3.1	658	7,478.35	0.34
3.1.2.1	2	6.77	0.00
3.1.3.1	13,084	768,140.55	34.86
3.1.4.1	1	4.60	0.00
3.1.5.1	1	5.10	0.00
3.2.2.1	2	2.06	0.00
3.2.3.1	13,243	394,401.54	17.90
3.3.3.1	3,949	96,005.80	4.36
3.4.1.1	14,733	90,423.27	4.10
3.4.1.2	273	344.62	0.02
3.5.1.1	8	98.24	0.00
4.1.1.1	7,558	123,191.24	5.59
4.2.1.1	9,301	68,838.43	3.12
4.2.1.2	21,763	238,961.06	10.85
4.2.2.1	92	16,507.59	0.75
5.1.1.1	1,091	6,832.22	0.31
5.1.1.2	90	4,138.15	0.19
5.2.1.1	136	2,694.59	0.12
6.1.1.1	2,168	8,151.33	0.37
6.2.1.1	33	107.99	0.00
6.2.1.3	329	811.69	0.04
6.2.2.1	742	2,749.75	0.12
6.2.2.2	4	40.51	0.00
7.1.1.1	134	713.62	0.03
9.1.1.1	375	4,027.21	0.18
9.1.1.3	25	120.73	0.01
9.1.2.1	17	42.99	0.00
9.2.1.1	903	9,232.63	0.42
9.2.1.3	18	215.21	0.01
9.2.1.4	16	94.09	0.00
9.2.1.5	33	196.57	0.01
1.0.1.1.1	5	65.19	0.00
Count 47	**Count 105,882**	**Sum 2,203,278.05**	**Sum 100.00**

Verification Methodology and Data Sets

The verification methodology we apply generally follows the methodology guidelines (Maucha et al. 2017) and consists in visual inspection of a stratified sample at polygon level against reference imagery of higher spatial resolution than the N2K layer. Several other in situ databases are involved in the decision making process as well. The stratification before sampling is based on the mapped classes. The reference data provided centrally and the in situ ones are described in the previous section.

The verification process includes the following steps:

- Preparation of input and reference data;

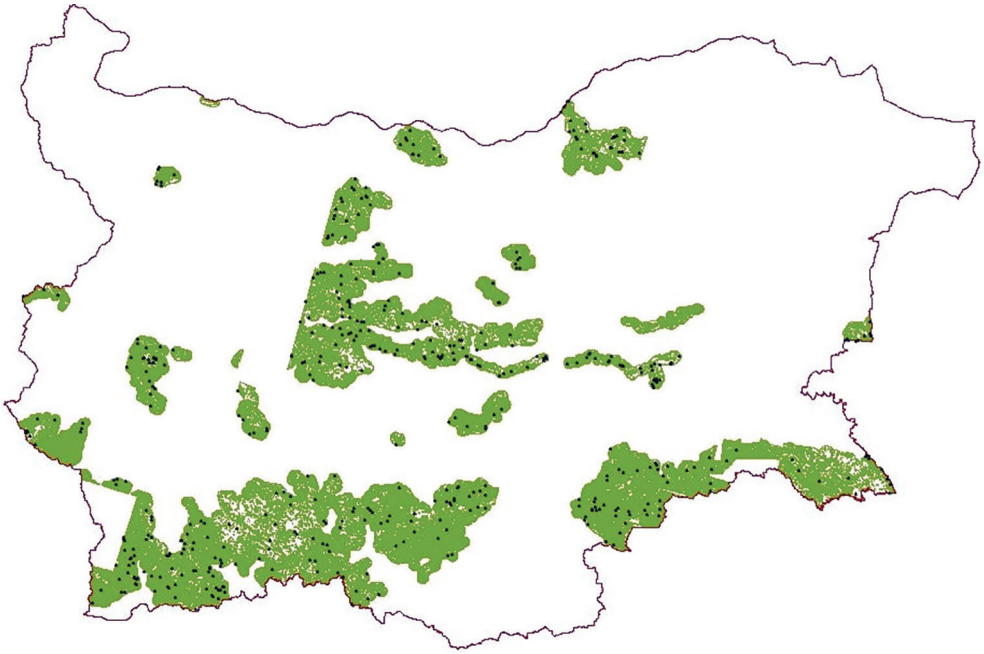

Fig. 2. Natura 2000 LC/LU product – Bulgaria.

- Creation of the sample set of LC/LU polygons;
- Visual interpretation of selected samples;
- Evaluation of results.

Preparation of input and reference data

The N2K data set is a single Pan-European layer of polygons in the EPSG: 3035 (ETRS89, LAEA) coordinate reference system. From the Pan-European LC / LU product, the part covering the territory of the country was clipped in order to serve as input for the verification. A total of 106,017 polygons along the border of Bulgaria were affected by the above operation. Of these, 136 polygons turned out to be smaller than MMU and were therefore eliminated by joining larger ones. The in situ image data are provided through a wms service and together with the vector ones organized in a local GIS working environment.

Creation of the sample set of LC/LU polygons

The number of samples is a trade-off between the minimum sample size requirements from a statistical point of view and the workload resources. Generally, the larger sample size ensures a better confidence of the assessment. One recommendation for stratified random sampling is to provide between 20 and 100 samples per stratum (Congalton and Green 2008). From the uncertainty of measurement point of view the lowest limit of number of measurements is accepted to be at least 10 (Anonymous 1999).

Here we have to mention that the N2K product currently is focused on several

valuable grassland types (Anonymous 2017). Thus, considering the goal of this study stated previously, we decide to provide at least 12 samples for each of non-grassland classes and 15 samples for the four grassland ones: 4.1.1.1, 4.2.1.1, 4.2.1.2 and 4.2.2.1. Taking also into account that several classes have less than 12 polygons the total number of samples is set to 500. The sample data set was generated within LACO-Wiki environment.

Visual interpretation of selected samples

The interpretation of LC/LU classes is performed according to the MAES nomenclature, levels 1 – 4. The polygons are displayed over LACO-Wiki reference imagery and the shown LC/LU class code of each sample is evaluated for correctness. In the LACO-Wiki tool this "not blind" approach is called "enhanced plausibility". For large polygons, that can be heterogeneous, the LC/LU class code is checked around a sample point, rendering an account of MMU size. These points have been generated in advance for all sample polygons as a separate layer. Other three characteristics can be set for the polygon evaluating its delineation and positional status: content of polygon's area, detail of delineation and positional accuracy. Finally, the expert can add a comment as a free text. In parallel to the work in the LACO-Wiki tool the expert carries out additional inspection of the same sample polygons in a local GIS environment using in situ image and vector databases. On-line open spatial databases like GoogleEarth and OpenStreetMap are intensively involved in the process as well.

Results and Discussion

As a result from the verification of LC/LU N2K product 465 sample polygons out of 500 have been assigned to the correct class. Therefore, the overall accuracy of 93.0 % is a result which is higher than the required 85 % level.

For 24 of the 47 classes typical for Natura 2000 sites in Bulgaria it was found that the code of all validated LC/LU samples was 100 % true (Table 3). For the most part, these are linear objects to which another code of the MAES nomenclature can hardly be attributed: Road networks and associated land, Railways and associated land, Lines of trees and scrub, River banks, Interconnected running water courses and Highly modified natural water courses and canals. This group also includes objects which have specific for the respective class interpretation features that cannot be found in another class of the nomenclature: Port areas, Airports, Green urban areas and leisure facilities, Greenhouses, Vineyards, Fruit trees and berry plantations and Marine (other).

Table 3. 100 % correctly interpreted samples.

N2K Class	Description	Number of samples
1.2.1.1	Road networks and associated land	12
1.2.1.2	Railways and associated land	12
1.2.1.3	Port areas	2
1.2.1.4	Airports	5
1.4.1.1	Green urban areas and leisure facilities	12
2.1.1.1	Non-irrigated arable land	13
2.1.2.1	Greenhouses	12
2.2.1.1	Vineyards	13

N2K Class	Description	Number of samples
2.2.2.1	Fruit trees and berry plantations	12
3.1.2.1	Broadleaved swamp forest	2
3.1.3.1	Other natural & semi-natural broad-leaved forest	13
3.4.1.1	Transitional woodland and scrub	13
3.4.1.2	Lines of trees and scrub	12
3.5.1.1	Damaged forest	8
4.2.2.1	Alpine and sub-alpine natural grassland	15
5.1.1.1	Heathland and Moorland	12
5.1.1.2	Other scrub land	12
5.2.1.1	Sclerophyllous vegetation	12
6.2.1.3	River banks	12
9.1.1.1	Interconnected running water courses	12
9.1.1.2	Highly modified natural water courses and canals	12
9.1.2.1	Separated water bodies belonging to the river system (dead side-arms, flood ponds)	12
9.2.1.1	Natural water bodies	13
10.1.1.1	Marine (other)	5
Count 24		

Typical Mistakes

Some typical and often recurrent errors have been detected in the validation process:

Incorrect classification

Twenty four erroneously classified polygons were found during the validation. The following examples are selected: Figure 3 shows the wrong code 6.2.2.1 Bare rocks and rock debris. In fact, the land cover in this polygon is no different from the surrounding forests. In situ data used – the stand characteristics from the forest management plan indicate that the outlined polygon includes coppice stands, Scots pine stands and coniferous plantations. Correct code has been proposed – 3.3.3.1 Other natural & semi-natural mixed forests.

In Figure 4 the code for polygon is 3.2.3.1 Other natural & semi-natural coniferous forest. After a careful review of the satellite and the ortho-images, of the retrospective images in Google Earth, as well as of the stand characteristics in the forest management plan, it was found that these are pure coniferous plantations and the code proposed by the interpreter is 3.2.4.1 Highly artificial coniferous plantations.

In Figure 5 the outlined polygon is classified as 3.1.4.1 Broadleaved evergreen forest. According to the forest inventory, these are coppice Turkey oak stands. The proposed code is 3.1.3.1 Other natural & semi-natural broadleaved forest.

In the following Figure 6 for the Eco-area Belite Skali, located in the Slavyanka reserve, the code 6.1.1.1 Sparsely vegetated areas is given. Perhaps the reason is that by 2006 this territory was a career. Because the area is rich in mineral springs it was decided the marble extraction to be terminated and this beautiful place to be created. By the reference year 2012, the correct code is 1.4.1.1 Green urban areas and leisure facilities.

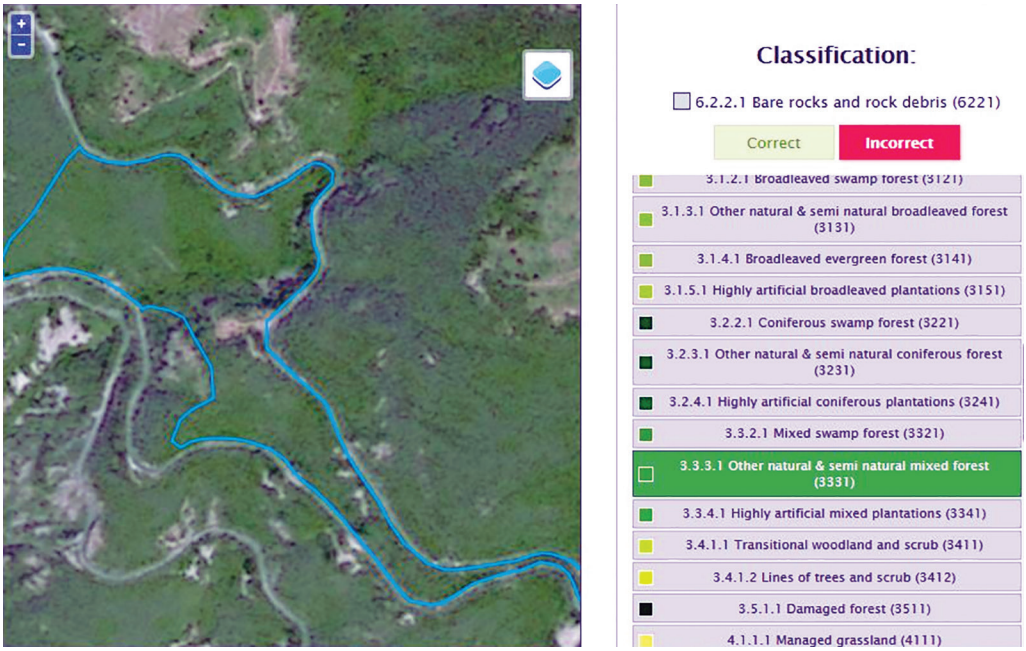

Fig. 3. Incorrect classification 6.2.2.1 Bare rocks and rock debris – Correct is 3.3.3.1 Other natural & semi-natural mixed forest.

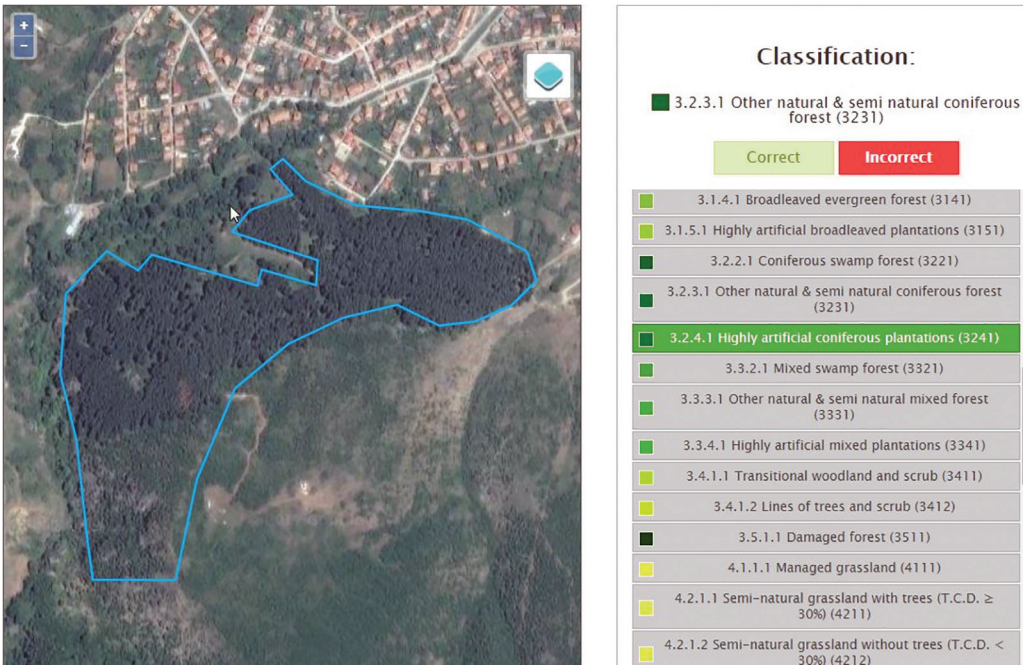

Fig. 4. Incorrect classification 3.2.3.1 Other natural & semi-natural coniferous forest – Correct is 3.2.4.1 Highly artificial coniferous plantations.

Fig. 5. Incorrect classification 3.1.4.1 Broadleaved evergreen forest – Correct is 3.1.3.1 Other natural & semi-natural broadleaved forest.

Fig. 6. Incorrect classification 6.1.1.1 Sparsely vegetated areas – Correct is 1.4.1.1 Green urban areas and leisure facilities – Eco-area BeliteSkali.

Incorrectly delineated areas

In many cases, the boundaries of the polygons are outlined too roughly; include unnecessary parts or there are missing parts, and often both. In other cases the boundaries have been shifted (Fig. 7).

Fig. 7. Delineation too coarse, missing and unnecessary parts, shifted borders.

Forest in Natura 2000 LC/LU Product

Over half of the Natura 2000 LC/LU products – Bulgaria areas (57.12 %) are occupied by forests. These are large-area polygons, and the overall impression is that in most cases the boundaries are delineated too roughly, with redundant or missing parts. Provided the MMU is 0.5 ha, separate polygons can be delineated in mixed forests – 3.1.3.1 Other natural & semi-natural broadleaved forest, 3.2.3.1 Other natural & semi-natural coniferous forest, 3.2.4.1 Highly artificial coniferous plantations, 3.1.5.1 Highly artificial broadleaved plantations, and in some cases also 3.4.1.1 Transitional woodland and scrub. Such is the example in Figure 8. The classification is correct – 3.3.3.1 Oth-

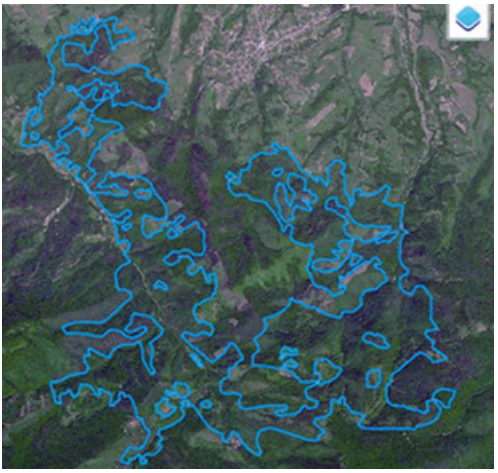

Fig. 8. Correct classification 3.3.3.1 Other natural & semi-natural mixed forest large polygons of 3.1.3.1, 3.2.3.1 and 3.2.4.1 should be separated.

er natural & semi-natural mixed forest, but large polygons of 3.1.3.1, 3.2.3.1 and 3.2.4.1 should be separated.

Damaged forest

Class 3.5.1.1 Damaged forest includes forest damaged by fire, storm, tornado or snow events as long as trees are lying on the ground and also forest damaged by pests like e.g. bark beetle as long as the damage is visible due to discoloration. In Figure 9 two examples are shown of forest stands affected by bark beetle in the Vitosha Nature Park.

Fig. 9. Damaged forest – forest stands affected by bark beetle in the Vitosha Nature Park.

Evaluation of Results of Verification

As a final step of the verification, the LACO-Wiki tool generates a report in the form of MS Excel file. It contains several sheets including a contingency matrix with user and producer accuracies and confidence intervals per class. As a whole, accuracies are good with user accuracies varying between 50 % and 100 % and producer accuracies falling into the range 76.47 % – 100 %. The overall accuracy is 93 % with confidence interval ±2.06 %. Favourable approaches applied, namely the polygon level of sampling and the plausibility interpretation probably have also given their contribution to these high results. Several summary accuracy characteristics taken from the report are shown in Table 4.

Table 4. Estimated accuracy characteristics.

Accuracy estimates	Value
Overall Accuracy	0.93
Overall Accuracy (CI)	**± 0.0206**
Kappa	0.928246
Kappa (CI)	**± 0.0229**
Geometric Agreement	
Delineated area	0.69
Detail of delineation	0.854
Positional accuracy	0.974

In the lower half of the table three geometric indicators are presented, calculated from the corresponding geometry attributes set up during the verification.

Using more detailed scores the geometric agreement indicators, describing the correctness of delineation can be presented as follows:

- Detail of delineation – 85.4 %;

Correct: 427; Too coarse: 73; Too detailed: 0;

- Correctness of delineated area – 69.0 %;

Correct: 345; Missing and unnecessary parts: 51; Unnecessary parts included: 62; Missing parts: 42;

- Positional accuracy – 97.4 %;

Correct: 487; Shifted: 13.

Conclusions

A quantitative approach to assessing the thematic accuracy of the LC/LU N2K product is applied that is statistically endorsed in view of the objectives pursued. It provides comparability of results between countries. The resulting 93.0 % overall accuracy, is higher than the required 85 % in the product specifications. Producer's accuracies for 24 out of 47 classes available in Bulgaria equal 100 %. Principally these are linear objects to which another code of the MAES nomenclature can hardly be attributed and also objects with typical and unique interpretation features.

The assessment of the quality of delineation shows that the boundaries of many polygons are outlined too roughly or shifted; include unnecessary parts or there are missing parts, and often both. In other cases the delineation is correct, but polygons can be separated into other MAES polygons with an area larger than the MMU of 0.5 ha.

The verification of the Natura 2000 local component dataset for Bulgaria provides statistical results and quality evaluation based on local expertise, reference data and in situ data used.

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