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VERIFICATION OF FOREST HIGH RESOLUTION LAYERS 2015: TREE COVER DENSITY AND DOMINANT LEAF TYPE IN BULGARIA

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Abstract

The high-resolution layers (HRLs) are Pan-European land cover datasets aimed at monitoring soil sealing (imperviousness, forest, grasslands, wetness and water, and small woody features. The main purpose of this article is to present the methodology and results from verification of two Forest HRL products for the 2015 reference year for Bulgarian territory: Dominant Leaf Type (DLT) and Tree Cover Density (TCD). The verification task aims at identifying systematic classification errors and the results are supposed to be used for improvement in future product updates. Qualitative approach for assessment of the HRL quality is applied in two steps, called General overview of data quality and Look-and-feel verification. The latter is performed within dedicated strata through non-random sampling, checking HRLs for omission and commission errors. We show results from a verification at country level based on local expertise and best available in situ data. We also provide comments and recommendations concerning commission and omission strata. Several cases of both of the above types of errors are identified and analysed in the DLT and TCD high resolution layers. Despite of errors found, both DLT and TCD receive a ‘good’ mark, and the same rating prevails in the strata level evaluation.

Key words: commission error, high resolution layers, land cover, omission error, qualitative evaluation, verification.

Introduction

COPERNICUS is a European program aimed at providing Europe with Earth observation capabilities. The implementation of the pan-European and local components of the Copernicus Land Monitoring Service (CLMS) is entrusted to the European Environment Agency (EEA). The aim of CLMS is to provide users, working in the fields of environmental protection, agriculture, regional development, transport and energy, with services and information extracted from satellite data combined with data from other sources at EU level and in line with European commitments to international conventions.

Pan-European High Resolution Layers provide information on specific land cover characteristics, like the level of soil sealing (imperviousness), tree cover density and forest type, grasslands, wetness and water, and small woody features. These raster data sets are produced from satellite imagery through a combination of automatic processing and interactive rule based classification.

The practical application of the HRL technology at European level started in 2006, when the Soil Sealing layer was produced (Stoimenov et al. 2008, Maucha et al. 2011), followed by a series of high resolution imperviousness products for the 2009 and 2012 reference years. HRLs from other topics began its development in 2012 (Forest, Permanent water bodies) (Anonymous 2013) and in 2015 (Grassland, Water & Wetness and Small Woody Features). The different characteristics and especially the thematic accuracy of the products have often been the subject of interest and research by various specialists (Hurbanek et al. 2010, Dimitrov and Lubenov 2014, Congedo et al. 2016, Gallego et al. 2016).

The HRL verification task is part of the second iteration of the CLMS High Resolution Layers for the 2015 reference year. As such, it was included in the Framework Service Contracts between EEA and participating countries as a new post-production verification. The EEA developed guidelines for the verification of the HRLs, but participating countries can modify and improve the methodology, according to their specific needs and available national data sets.

Like other HRLs, the Forest layer is produced by a consortium of established European service providers. All Forest products are in the European Terrestrial Reference System 1989 (ETRS89) and in the Lambert Azimuthal Equal Area (LAEA) projection. Multitemporal satellite data in 20 m spatial resolution, mainly Sentinel-2A data from the European Space Agency (ESA) as well as Landsat 8 data from the United States Geological Survey (USGS), represent the primary input data source for the 2015 products. The two main layers (20 m spatial resolution) Dominant Leaf Type (DLT) and Tree Cover Density (TCD) provide information on the leaf type (broadleaved /coniferous) and the proportional tree cover at pixel level. Thus, users can apply a (national) definition of forest, taking into account each set of crowns that best suits their specific needs (Anonymous 2017).

The main aim of this article is the presentation of the results from verification of two Forest high-resolution layer products for the 2015 reference year for Bulgaria: Dominant Leaf Type and Tree Cover Density. Qualitative approach for assessment of the thematic quality of HRLs is applied, checking HRLs for omission and commission errors, as required by the guidelines. These results are supposed to be used for improvement in future product updates.

We show results from a verification at country level based on local expertise and best available in situ data. We also provide comments and recommendations concerning commission and omission strata.

Data and Methods

Definition of high resolution layers Forest

The following two lists present the main features and characteristics of the TCD and DLT layers, respectively:

Tree Cover Density:

- Tree Cover Density range of 0–100 %;
- Spatial resolution of 20 m;
- No Minimum Mapping Unit (MMU); pixel-based;

- Minimum Mapping Width (MMW) of 20 m;
- Includes: forests, orchards, groups of trees within urban areas (alleys, wooded parks and gardens), damaged forest parts;
- Excluded are open spaces within forests, shrub-covered areas and dwarf-pine areas.

Dominant Leaf Type (broadleaved or coniferous):

- Spatial coverage identical with that of the Tree Cover Density;
- Provides information on the dominant leaf type: broadleaved or coniferous;
- No MMU; pixel-based;
- MMW of 20 m.

The next list presents the reference data used to verify the Forest high resolution layers, including data provided centrally by the EEA and national in-situ data sets:

- GioLand Public/LUCAS2012 (EUROSTAT), Lucas Points;
- National Forest Inventory Database;
- CORINE Land Cover (CLC) 2012 database for Bulgaria;
- CLC 2018 database for Bulgaria;
- GioLand/VeryHighResolution2012 – Optical VHR2;
- GioLand/HRIM_HR_FalseColour_Cov1_2015, 20 m;
- SPOT 2.5 DWH MG2b CORE_03 VHR VNIR imagery;
- National orthophoto map 2011, 40 cm resolution;
- National orthophoto map 2013–2016 (partial coverages) 40 cm resolution;
- IMAGE2012 – Coverage 1: IRS-P6 LISS-III images;
- IMAGE2018 – Coverage 1 and 2;
- Landsat 8 Imagery: Color Infrared, ArcGIS Online, 30 m;
- ESRI world imagery basemap, 1 m or better;
- OpenStreetMap;
- Topographic maps, 1:50,000, scanned.

Verification of high resolution layers Forest

The purpose of the verification task is to identify systematic classification errors. These results are supposed to be used for improvement in future product updates. General overview of data quality and Look-and-feel analysis are applied. The latter are performed within predefined critical strata through non-random sampling and qualitative evaluation, checking HRLs for omission and commission errors.

The verification is characterized by the following principles:

- HRLs are visually inspected on in-situ data for two types of errors: commission and omission;
- Spatial stratification of the territory is applied and the check-up is performed by strata;
- Selecting proper locations requires a-priory knowledge about the country or region;
- Sample selection is not random;
- Performed at full resolution 20 m × 20 m;
- The verification procedure is carried out on three levels:
    - General overview of data quality (compulsory);
    - Visual inspection by Look-and-feel method of zones of expected errors (compulsory);
    - Quantitative verification (highly recommended);
- Result: Verification report. It contains findings and comments, as well as assessments by strata and for the HRL in general, according to a 5-grade scale (Table 1) (Anonymous 2018).

Table 1. Summarised qualitative evaluation of HRLs in five grades.

Evaluation Grade	Description
Excellent	Meaning that accuracy of the HRL is expected to reach almost 100 %; practically no errors can be found in the verified areas.
Good	Meaning that operator is confident that accuracy of the HRL is at least 85 %; only sporadic errors are encountered in the verified areas.
Acceptable	Meaning that accuracy of the HRL is estimated to reach 85 % in most of the verified areas, minor errors can be detected in the verified areas.
Insufficient	Meaning that accuracy of the HRL is not expected to reach the minimum 85 %; several errors are encountered in different regions.
Very poor	Meaning that operator is confident that accuracy of the HRL is bad and much below 85 %; majority of verified areas are wrongly mapped.

Stratification for selection of look-and-feel samples

Stratification is a common technique in sampling and for this, there are many reasons (Cochran 1977). In random selection, one of them is to divide the whole population (the territory of interest in our case) into subpopulations, which are internally homogeneous in respect to the measurements. There are also cases with a reverse focus, where the goal is to capture larger variations rather than find a common core, as in an example of stratified purposeful sampling (Patton 2002).

The verification is done in the course of the project in order to control and improve the result of the classification. Therefore, it should be done relatively quickly and with small resources. Such, for example, is the approach of obtaining qualitative assessments through systematic qualitative examinations (Global_LC2006). For the evaluation of HRLs we also apply qualitative verification, but with the following specifics: a) The main goal is to identify systematic errors in the classification; b) The visual check and the respective assessment shall be carried out by special territorial zones – critical strata; c) he positive effect of improving the products will be realized in their next update.

Based on our own observations, we can say that the stratification in the look-and-feel verification of the HRLs relies on a set of factors, including the role of anticipated and ascertained so far classification errors. In particular, stratification is based on: a) Error type (commission/omission); b) A priori knowledge of the performance of the classifier in the conditions of different land cover types and landscape elements; c) Conclusions based on accumulated data on classification errors registered so far.

The guidelines provide lists of recommended strata (Anonymous 2018). From the lists, it can be concluded that the differentiation of the territories in defining the strata is based on the following main characteristics: land cover type, classes of objects for classification (landscape elements), relevant geographical features (for example, altitude range); situational properties (e.g., areas along rivers and lakes, or areas around built-up zones).

The Tree cover density layer consists of values in the range from 0% to 100%. Previous experience has shown that the accuracy of such layers can be directly assessed only in comparison with in situ data with higher spatial resolution, using more complex and time-consuming procedures (Maucha et al. 2011). Therefore, the corresponding binary tree cover map was verified, applying a 30 % threshold to the TCD data (Anonymous 2018).

We elaborated the strata based on the vectorised versions of the two verified layers Tree cover map and Dominant leaf type, using the following databases for the territory of Bulgaria: CLC, Physical blocks of Land Parcel Identification System (LPIS) and Forest inventory database. In addition, data on hydrography and settlements were used.

At the General overview stage, we found the recurrence of commission errors in grass-shrub areas falling within the LPIS land cover class 101 polygons – Shrubs and grasslands (Anonymous 2007). This fact necessitated the allocation of this type of area as a separate stratum.

Results and Discussion

The results for each layer are presented in the form of an overview map, a description of the strata with number of samples, assigned evaluation grades and commission and omission error summaries. Discussion texts on the properties of the layer follow in the form of findings and comments. The overview map of DLT is shown in Figure 1.

Dominant leaf type

General overview of data quality of DLT

Dominant Leaf Type is generally correctly mapped. Image data from SPOT 5 (2.5 m) and Digital Orthophoto Map 2013–2016

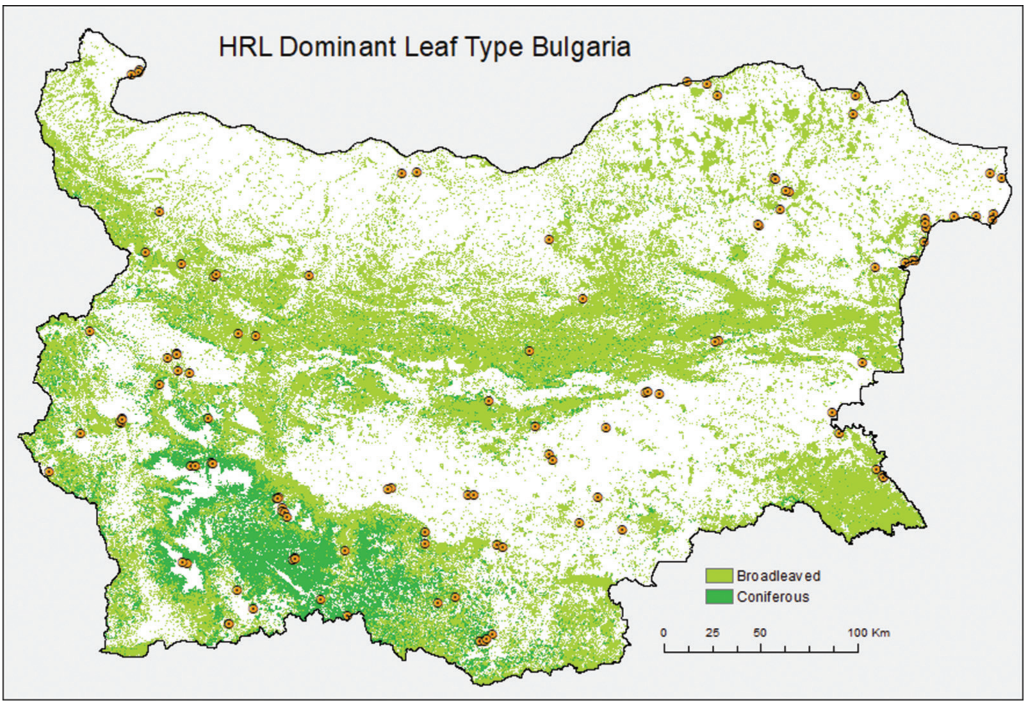

Fig. 1. Overview map of the Dominant Leaf Type layer of Bulgaria with verification locations.

showed normal quality. In some of the satellite scenes, covering the western part of the country the significant cloud cover is often an obstacle. For the general overview of the DLT product, mainly the Forest Inventory Database with its detailed attribute data is used as reference in situ data.

Frequent commission errors are broadleaved patches on shadowed slopes of deep valleys and near roads and rivers being classified as coniferous. In many cases large parts of Scots pine, spruce and fir forest stands are given as broadleaved forest. In the same time, parts of beech and oak forest stands are classified as coniferous.

Look-and-feel verification of DLT

The strata are divided into two groups, for the respective type of errors (commission and omission), as the names of the strata, the number of samples and the evaluations are presented in Table 2.

Table 2. Look-and-feel analysis of DLT.

Stratum	Name of the stratum	Number of samples verified	Results of the verification by strata
	Commission		
1	Transitional woodland-shrub	10	good
2	Moors and heathland and sclerophyllous vegetation	6	very poor
3	Shrubs and grasslands LPIS101	7	good
4	Wetland	6	acceptable
	Omission		
5	Urban vegetation	8	good
6	Trees in sport and recreation areas	8	good
7	Orchards, fruit trees	10	acceptable
8	Lowland forests, broadleaved	11	good
9	Lowland forests, coniferous	9	good
10	Mountain forests, coniferous	10	good
11	Mountain forests, broadleaved	10	good
12	Coastal forests	10	good
13	Forest along rivers & lakes	10	good
Overall evaluation			good

Dominant leaf type is generally correctly mapped. It is seen from the list of strata grades above (‘Results’ column) that most of the problems were found in the commission strata.

Most frequent commission errors found in the DLT

Transitional woodland-shrub stratum – Scots and Austrian pine plantations given as broadleaved (Fig. 2).

Wetland stratum – broadleaved given as coniferous forest. Treeless grassed and/or wet parts of wetland areas are often mapped as forest.

Moors and heathland and sclerophyllous vegetation – this stratum is totally based on the CLC class 322, for Bulgaria including only dwarf pine, which is not treated as tree cover.

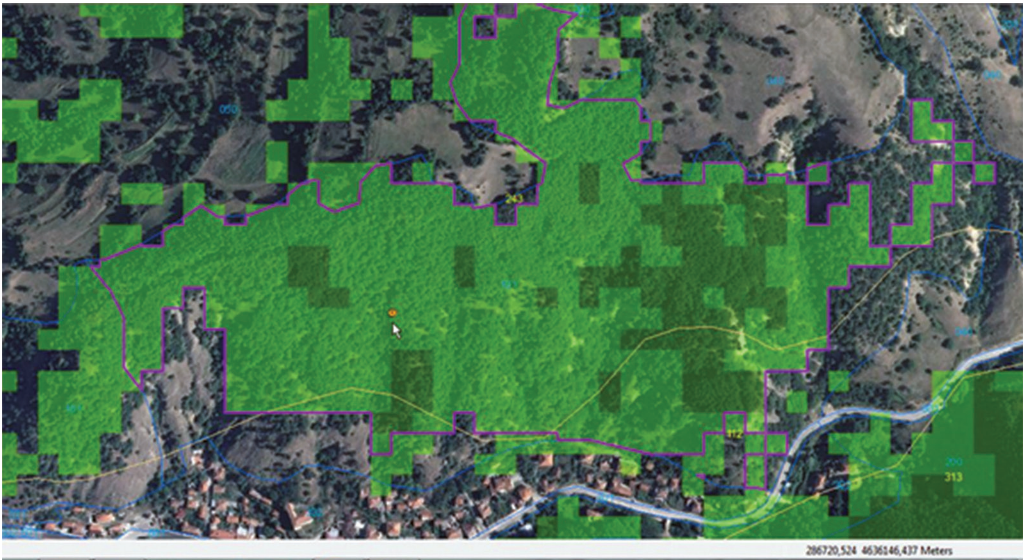

Fig. 2. Shrubs and grasslands LPIS101 – parts of broadleaved forests given as coniferous and Scots and Austrian pine plantations given as broadleaved forests.

Omission errors of DLT

The results from the verification for strata Urban vegetation and Trees in sport and recreation areas are good and in many cases excellent. Forest patches were found which are not mapped in the Dominant Leaf Type layer.

Many of CLC2018 class 222-based abandoned orchards and/or forested fruit tree plantation are not mapped in the Dominant Leaf Type layer.

Lowland forests, broadleaved – coppice broadleaved forest is not mapped in the Dominant Leaf Type layer.

Lowland forests, coniferous – Austrian and Scots pine plantations are not mapped in the Dominant Leaf Type layer.

Mountain forests, coniferous – parts of coniferous forest stands are not mapped in the Dominant Leaf Type layer.

Mountain forests, broadleaved – parts of beech and oak forest stands are not mapped in the Dominant Leaf Type layer.

Coastal forests – broadleaved and coniferous forests are not mapped in the Dominant Leaf Type layer.

Forest along rivers & lakes – parts of broadleaved forest stands and plantations – poplar, oak and locust are not mapped in the Dominant Leaf Type layer.

Tree cover density

General overview of data quality of TCD

The Tree Cover Density (Fig. 3), respectively the Tree Cover Map layer, was examined against most of the in-situ data layers listed above. Image data from SPOT 5 (2.5 m) and Digital Orthophoto Map 2013–2016 show normal quality. In some of the satellite scenes, covering the western part of the country, the significant cloud cover is often an obstacle. For the general overview of the TCD product, mainly the Forest Inventory Database with its detailed attribute data is used as reference in situ data.

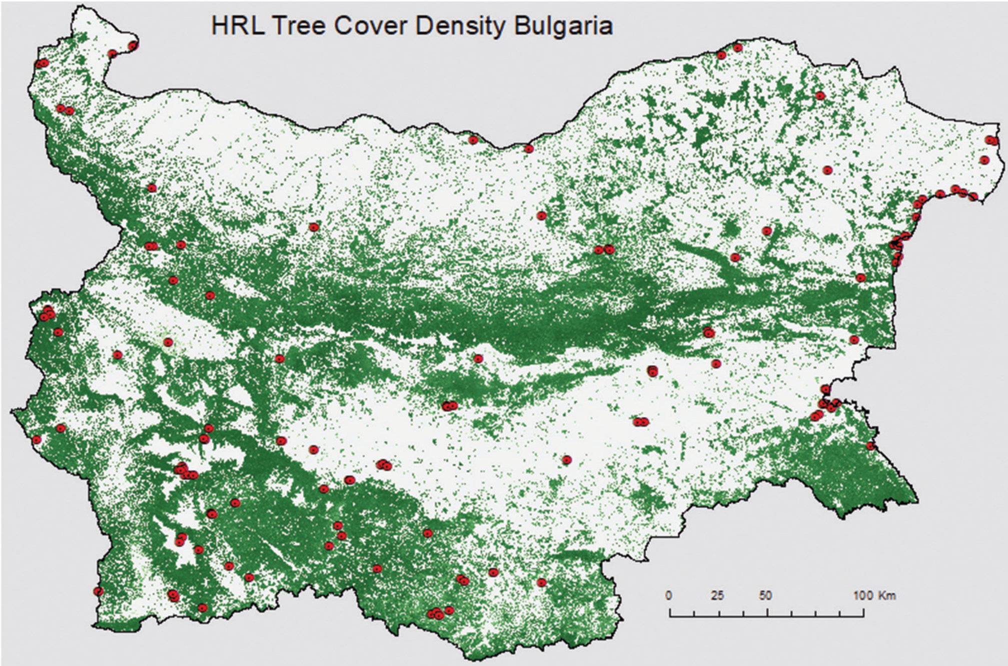

Fig. 3. Overview map of the Tree Cover Density layer of Bulgaria with verification points.

Commission errors occur with grassland patches near forest, grassland with shrubs or grass, sparsely forested areas and clear cuts in CLC classes 243, 324, 211, 231 and in permanent land use classes 040, 101, 050 of LPIS physical blocks. Glades and other open areas in forests and some coastal wetlands – inland marshes, saline and salt marshes were found mapped as tree cover.

Classifier's performance is degraded in cases when urban areas, e.g. roads, house yards and houses, are classified as tree cover. Such is the case with vineyards as well. The mostly widespread commission error is classifying dwarf pine areas as tree cover.

Look-and-feel verification of TCD

The strata, number of samples and assigned grades per stratum and overall evaluation for the TCD HRL are listed in Table 3.

The most frequent commission errors found in TCD

Transitional woodland-shrub – pasture classified as forest, bark beetle damaged forest and clear-cuts in coniferous and broadleaved forests included in the Tree Cover Density layer.

Moors and heathland and sclerophyllous vegetation– the mostly widespread commission error is classifying dwarf pine areas as tree cover (Fig. 4).

Wetland – mainly inland marshes near the Black sea and the Danube River are given as forest. In some cases part of saline and salt marshes are included in the Tree Cover Density layer.

Table 3. Look-and-feel verification of TCD.

Stratum	Name of the stratum	Number of samples verified	Results of the verification by strata
	commission		
1	Transitional woodland-shrub	12	good
2	Moors and heathland and sclerophyllous vegetation	11	insufficient
3	Shrubs and grasslands LPIS101	10	acceptable
4	Wetland	11	insufficient
	omission		
5	Urban vegetation	10	good
6	Trees in sport and recreation areas	9	good
7	Orchards, fruit trees	12	insufficient
8	Lowland forests, broadleaved	12	good
9	Lowland forests, coniferous	10	good
10	Mountain forests, coniferous	11	good
11	Mountain forests, broadleaved	10	good
12	Coastal forests	10	good
13	Forest along rivers & lakes	10	good
Overall evaluation			good

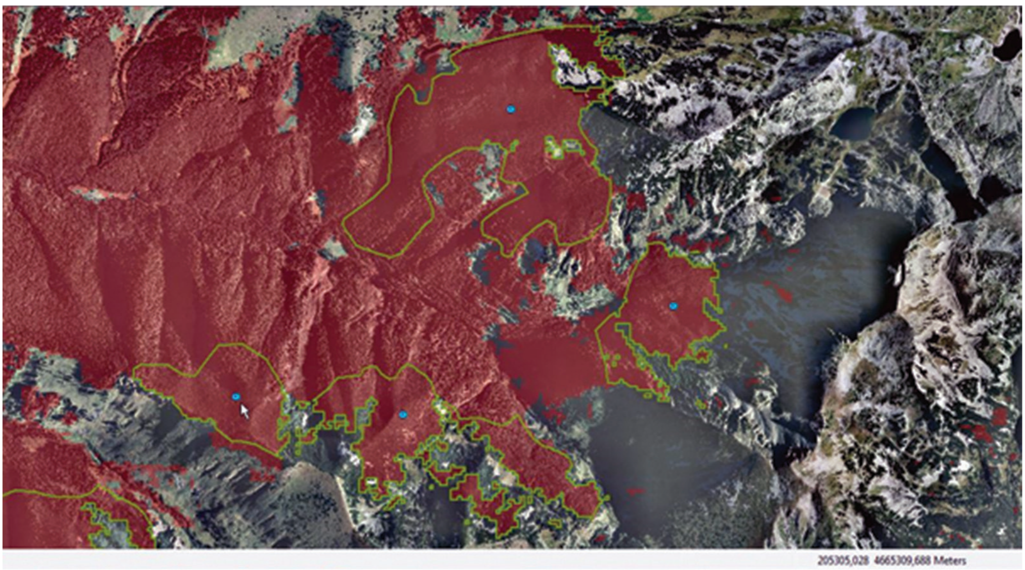

Fig. 4. The stratum Moors and heathland and sclerophyllous vegetation.

Note: This stratum (light green boundary) is totally based on the CLC class 322 for Bulgaria, including only dwarf pine, which is not treated as tree cover. Four examples are marked by blue point symbols – dwarf pine incorrectly classified as forest (semi-transparent red fill).

Omission errors in TCD

Urban vegetation and Trees in sport and recreation areas are generally correctly mapped.

Typical mistakes found are as follows:

- Urban vegetation – groups of park and urban trees;
- Trees in sport and recreation areas – groups of trees in sea, golf and skiing resorts;
- Orchards, fruit trees – missing fruit tree plantations (CLC222);
- Lowland forests, broadleaved – missing broadleaved forest stands (oak, durmast oak, locust trees);
- Lowland forests, coniferous – missing Austrian pine and Scots pine plantations;
- Mountain forests, coniferous – missing Austrian pine, Scots pine and white fir plantations (Fig. 5);
- Mountain forests, broadleaved – missing beech and durmast oak forest stands;
- Shrubs and grasslands LPIS101 – broadleaved and coniferous forest stands or group of trees are included in shrubs and grasslands;
- Coastal forests – missing both broadleaved and coniferous forests;
- Forest along rivers & lakes – missing groups of trees, broadleaved forest stands and plantations – poplar, oak, locust and aspen.

Despite of errors found, both DLT and TCD HRLs receive a 'good' mark as overall evaluation. The same rating prevails at the stratum level of evaluation.

Conclusions

We have implemented a quality assessment methodology aimed at identifying typical problems that will be useful for

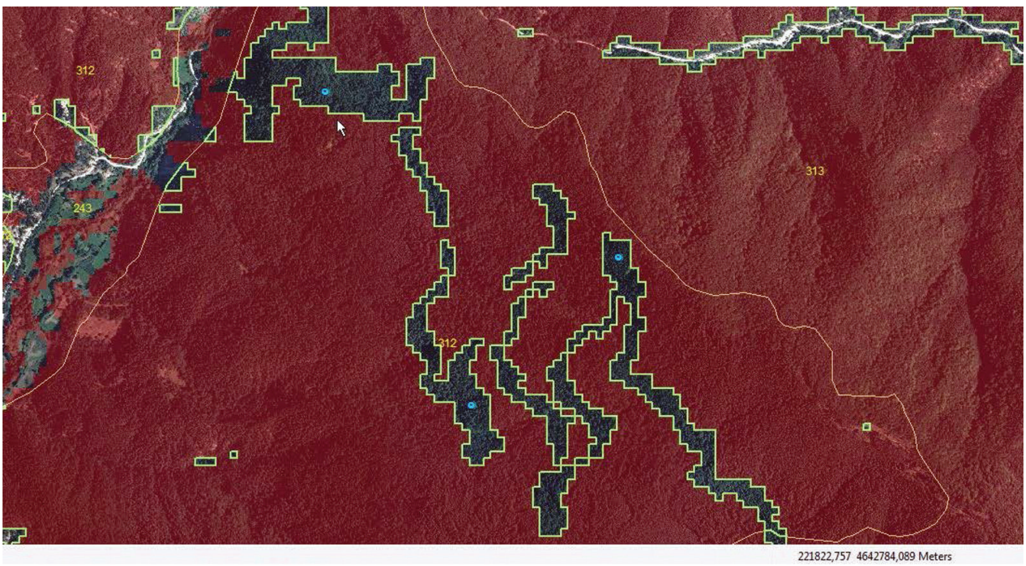

Fig. 5. White fir forest stands are not mapped in the TCD layer (semi-transparent red fill).

Note: These omission errors are identified with the help of the Forest Inventory Database with its detailed attribute table, used as reference in situ data. Three cases are marked by blue point symbols.

product improvement.

Despite the registered and described commission and omission errors, we can conclude that both Tree Cover Density and the Dominant Leaf Type high resolution layers show consistently good results. The list of evaluations by strata in five grades both for the TCD and the DLT are dominated by 'good' evaluations. Overall evaluations are 'good' for both HRLs.

High resolution layers data sets provide a valuable and special view on several important land cover characteristics. Overall results of HRL verification task demonstrate a good general ability of automated analysis of multi-temporal satellite imagery to extract certain land cover types.

It would be useful if, in addition to the status products, change products are provided for verification by countries.

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