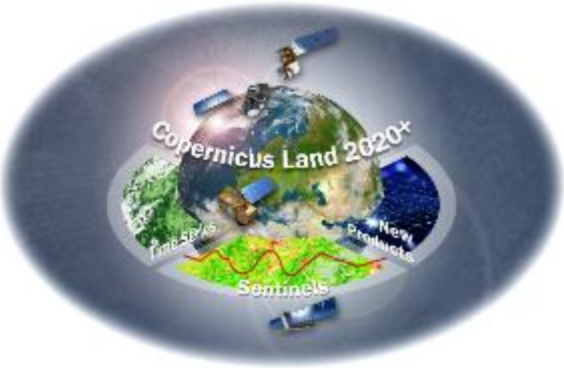
Horizon 2020

Space Call - Earth Observation: EO-3-2016: Evolution of Copernicus services

Grant Agreement No. 730008

ECoLaSS

Evolution of Copernicus Land Services based on Sentinel data



D10.2

"D35.1b – Time Series Consistency for HRL Product (incremental) Updates"

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SIRS

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submitted to:

European Commission – Research Executive Agency

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Applicable Documents

ID	Document Name / Issue Date
AD01	Horizon 2020 Work Programme 2016 – 2017, 5 iii. Leadership in Enabling and Industrial Technologies – Space. Call: EO-3-2016: Evolution of Copernicus services. Issued: 13.10.2015
AD02	Guidance Document: Research Needs Of Copernicus Operational Services. Final Version issued: 30.10.2015
AD03	Proposal: Evolution of Copernicus Land Services based on Sentinel data. Proposal acronym: ECoLaSS, Proposal number: 730008. Submitted: 03.03.2016
AD04	Grant Agreement – ECoLaSS. Grant Agreement number: 730008 – ECoLaSS – H2020-EO-2016/H2020-EO-2016, Issued: 18.10.2016
AD05	D4.2: D22.1b - Assessment of EO and other Data Requirements (Issue 2), Issued:

	December 2019
AD06	D8.2: D33.1b - Methods Compendium: Time Series Analysis for Thematic Classification (Issue 2), Issued: December 2019
AD07	D9.2: D34.1b - Methods Compendium: Time Series Analysis for Change Detection, Issued: 04.12.2019
AD08	D12.2: D42.1b - Prototype Report: Consistent HR Layer Time Series/Incremental Updates, Issued: December 2019
AD09	D13.2: D43.1b - Prototype Report: Improved Permanent Grassland, Issued: December 2019

EXECUTIVE SUMMARY

The Horizon 2020 (H2020) project, "Evolution of Copernicus Land Services based on Sentinel data" (ECoLaSS) addresses the H2020 Work Programme 5 iii. Leadership in Enabling and Industrial technologies - Space, specifically the Topic EO-3-2016: Evolution of Copernicus services. ECoLaSS is being conducted from 2017–2019 and aims at developing and prototypically demonstrating selected innovative products and methods as candidates for future next-generation operational Copernicus Land Monitoring Service (CLMS) products of the pan-European and Global Components. ECoLaSS assesses the operational readiness of such candidate products and eventually suggests some of these for implementation. This shall enable the key CLMS stakeholders (i.e. mainly the Entrusted European Entities (EEE) EEA and JRC) to take informed decisions on potential procurement as (part of) the next generation of Copernicus Land services from 2020 onwards.

To achieve this goal, ECoLaSS makes full use of dense time series of High-Resolution (HR) Sentinel-2 optical and Sentinel-1 Synthetic Aperture Radar (SAR) data, complemented by Medium-Resolution (MR) Sentinel-3 optical data if needed and feasible. Rapidly evolving scientific developments as well as user requirements are continuously analysed in a close stakeholder interaction process, targeting a future pan-European roll-out of new/improved CLMS products, and assessing the potential transferability to global applications.

This Deliverable "**D35.1a – Time Series Consistency for HRL Product (incremental) Updates**" lays out the feasibility of a higher update frequency for several products – namely, the imperviousness, forest and grassland layers – of the Copernicus Land Monitoring Service of the continental and global component, for mid-term (2018) and long-term (2020+) evolution.

Following the conclusions on EO availability drawn from WP 22 "Assessment of EO and other Data Requirements" [AD05] as well as the conclusions from phase 1 and phase 2 Tasks 3 and 4, an increased update frequency for HRL products is proposed. The outputs of those tasks are used as a ground to achieve the objectives of this WP:

- To propose a different incremental update frequency for each of the previously mentioned products, tailored to the HRL specific change characteristics;
- To test new methods to correctly identify the automated changes detected in WP34;
- To test new methods to ensure the spatial and temporal coherence of those changes along the time series;
- To test new methods to assess the accuracy of the thematic label associated with the detected changes in WP34.

This report represents the final issue of the WP35 deliverable at the end of month 34 of the project, considering the outcomes of phase 1 and phase 2, when tasks are interlinked more clearly. In the first issue, preliminary outcomes of WP22, 33 and 34 in terms of data availability and change detection methodologies were considered. Issue 2 considers the first implementation of the services envisaged over the demonstration sites in Task 4 and should allow for a clearer definition of the update frequencies and the various tested methods.

Recommendations are made for update frequencies, based on the evaluation and assessment of the prototype creation for those HRLs in the phase 1 and phase 2. Frequencies suggested in the first iteration are refined in this final report.

Based solely on parameters, like EO data availability and magnitude of change, it is difficult to draw any conclusions on whether the frequency of updates should be increased or decreased. The real question, whose answer will be provided by the feasibility examination of all prototypes, is more on the ability to improve the accuracy of the detected changes and their labels, i.e. provide an estimate with a greater degree of confidence, and reduce the bias, i.e. ensure that the level of omission and commission errors are equivalent.

A post-classification procedure was developed for the Imperviousness layer, and has been improved in the phase 2, based on a dedicated calibration sample dataset and a reclassification procedure. It will also be applied to the FOR HRL 2018 production. Other cases that call for dedicated approaches are the agriculture, phenology and indicators thematic topics. Updates and change detection in these subjects have been briefly addressed in WP34 and discussed in the prototypes implementation reports. The feasible timings, closer to near real time monitoring, and technical constraints for such products at large scales and the proper match with specific requirements are out of scope in the ECoLaSS project. Recent ITT calls are addressing such topics.

For the topics at hand within ECoLaSS, shorter updates have proven to be feasible during this project – thanks to the coherence and the density of Sentinel datasets – but yet remained tricky to produce. However, it should be noted that those two-year to yearly incremental updates will mainly focus on:

- Gain in impervious surface for the IMP layers;
- Clear cuts for FOR layers;
- Loss of grasslands area for the GRA layers.

Other types of change will demand lengthier time series to be detected, and will certainly be integrated later in the new version of status layers.

Table of Contents

List of Figures and Tables

Abbreviations

AT	Austria
BE	Belgium
BG	Bosnia and Herzegovina
CEE	Communauté Economique Européenne/European Economic Community
CLC	Corine Land Cover
CLCC	Corine Land Cover Change
CLMS	Copernicus Land Monitoring Services
CORINE	Coordination of Information on the Environment
CY	Cyprus
CZ	Czech Republic
DAP	Data Access Portfolio/Differential Attribute Profiles
DE	Germany
DEM	Digital Elevation Model
DK	Denmark
DLT	Dominant Leaf Type
DOM-TOM	Département d'Outre-Mer/Territoire d'Outre-Mer
DWH	Data Warehouse
EC	European Commission
ECoLaSS	Evolution of Copernicus Land Services based on Sentinel data
EE	Estonia
EEA	European Environment Agency
EEE	Entrusted European Entities
EIONET	European Environment Information and Observation Network
EL	Greece
EO	Earth Observation
ES	Spain
ESA	European Space Agency
EU	European Union
EU-DEM	European Union Digital Elevation Model over Europe
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organisation Corporate Statistical Database
FI	Finland
FR	France
FUA	Functional Urban Area
GFRA	Global Forest Resources Assessment
GRA	Grassland
HR	High Resolution
HRL	High Resolution Layer
HU	Hungary
ICP	International Co-operative Program
IE	Ireland
IMD	Imperviousness Degree
IMP	Imperviousness
IRS	Indian Remote-Sensing Satellite
IT	Italy

JRC	Joint Research Centre
LC	Land cover
LT	Lithuania
LU	Luxembourg
LU	Land Use
LUCAS	Land Use/Cover Area frame statistical Survey
LV	Latvia
MGRS	Military Grid Reference System
MMU	Minimum Mapping Unit
MT	Malta
NL	Netherlands
NRC	National Reference Centers
OLI	Operational Land Imager
PL	Poland
PT	Portugal
RO	Romania
S-1	Sentinel-1
S-2	Sentinel-2
S-3	Sentinel-3
SAR	Synthetic Aperture Radar
SE	Sweden
SI	Slovenia
SK	Slovakia
SoEF	State of Europe's Forests
SPOT	Satellite Pour l'Observation de la Terre/Satellite for observation of Earth
SRTM	Shuttle Radar Topography Mission
SVM	Support Vector Machine
TCD	Tree Cover Density
UA	Urban Atlas
UAA	Utilized Agricultural Area
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
WHO	World Health Organisation

1 Introduction

The Horizon 2020 (H2020) project, "Evolution of Copernicus Land Services based on Sentinel data" (ECoLaSS) addresses the H2020 Work Programme 5 iii. Leadership in Enabling and Industrial technologies - Space, specifically the Topic EO-3-2016: Evolution of Copernicus services. ECoLaSS is being conducted from 2017–2019 and aims at developing and prototypically demonstrating selected innovative products and methods as candidates for future next-generation operational Copernicus Land Monitoring Service (CLMS) products of the pan-European and Global Components. ECoLaSS assesses the operational readiness of such candidate products and eventually suggests some of these for implementation. This shall enable the key CLMS stakeholders (i.e. mainly the Entrusted European Entities (EEE) EEA and JRC) to take informed decisions on potential procurement as (part of) the next generation of Copernicus Land services from 2020 onwards.

To achieve this goal, ECoLaSS makes full use of dense time series of High-Resolution (HR) Sentinel-2 optical and Sentinel-1 Synthetic Aperture Radar (SAR) data, complemented by Medium-Resolution (MR) Sentinel-3 optical data if needed and feasible. Rapidly evolving scientific developments as well as user requirements are continuously analysed in a close stakeholder interaction process, targeting a future pan-European roll-out of new/improved CLMS products, and assessing the potential transferability to global applications.

This report "**D35.1b – Time Series Consistency for HRL Product (incremental) Updates**" aims at linking the data availability and the user requirements to define higher update frequencies, while testing methods to detect changes in land cover / land use (LC/LU), quantify the accuracy of those outputs and create a new layer by combining the older layer and the detected changes. The objective of this WP35 is to investigate the incremental updates of High-Resolution Layers (HRL) where "incremental" is defined as the combination of full coverage inventories with incremental spatially partial updates. The report focuses more specifically on the Imperviousness, Forest and Grassland products with regards to the envisaged evolution of Copernicus Land Services addressed in ECoLaSS.

1.1 Purpose and objective of this WP

Building on the results from WP34, in which methodologies on change and signal anomaly detection are explored, the objectives of the WP35 are:

- Determine an appropriate incremental update frequency suitable for specific HRL requirements: Imperviousness, Forest and Grassland;
- Develop a suitable method to characterize outputs from automated change detection (WP34) into relevant themes;
- Develop a suitable method to calibrate detected thematic changes to ensure spatial and temporal consistency;
- Identify a relevant method for the assessment of thematic accuracy, focused particularly on the accuracy change detection, and in agreement with the guidelines introduced for benchmarking in the report D33 [AD06].

The conclusions have been used as inputs for the WP42 "Incremental Updates of HR Layers" [AD08].

1.2 Document structure

Chapter 1 of this document is the introduction. Chapter 2 is focused on the search for an appropriate update frequency for the different HRLs: Imperviousness, Forest, Grassland. Those proposed frequencies must be designed to find balance between the data availability and user requirements for a tighter LC/LU monitoring. Chapter 3 describes the testing of the identified methodologies to characterize and refine the outputs of the candidate methods tested in WP 34 [AD07], to ensure a spatial and temporal coherence. The last section provides the conclusions and outlooks.

2 Determination of appropriate incremental update frequency

For reporting purposes, policy decision makers such as the EEA need regular and consistent map updates in order to provide a synoptic status of the environment or several lands monitoring information. The update frequency of HRL products is described (section 2.1), followed by a compilation of the temporal coverage of EO data used for the 2015 production (section 2.2), an analysis of the expected magnitude of changes based on other datasets and existing HRLs (section 2.3), and an elaboration of a potential definition for future most appropriate updates frequencies (sections 2.4 and 2.5), which take into account the dynamics/stability of EO data and eventual political requirements.

2.1 Update frequency of current products

The update cycle for producing maps – currently 3 years for HR Layers or 6 years for CORINE Land Cover (CLC) and CORINE Land Cover Change (CLCC) – is not anymore compatible with the long-term EEA requirements. Monitoring the implementation of policies requires more frequent updates particularly for the HR Layers which were initially designed to provide more frequent updates as compared with CLC. It could also be noted that those characteristics were established on older, yet state-of-the-art at the time, technologies and kept in place to enforce the temporal consistency of such time series datasets. The objective of this work package is to investigate a methodology for incremental updates of the Copernicus Land HRLs based on the improvement brought by the Sentinel constellations. There is an important need for providing coherent incremental thematic updates for progressive map updates with reduced time frames.

So far, the HR Imperviousness layer is the only HR Layer for which several map updates already exist and have been validated. During the HRL2015 production process it has become apparent that there is a need to reprocess these maps to get a reliable and consistent characterisation of changes over time. Currently, because of the magnitude of change and the spatial coverage of some of the HRL themes in the landscape, it appears difficult to obtain reliable change estimates from the HRL alone because even though the technical specifications requirements are met, the amount of errors present (which should be less than 15% for both, commission and omission) is typically above the rate of change observed in several products. Therefore, in the 2015 implementation of the HRL production, there was a need to reprocess the Imperviousness time series to obtain a more consistent dataset and accurate estimation of change. However, such a re-processing exercise should be minimised in the future and an appropriate method is required to accurately identify changes from one period to the next even though the changes are expected to be below the overall level of accuracy of the individual status layers.

The HRL2018 production is still in the given 3 years update cycle, but timeliness is a crucial factor and service providers are forced to deliver the requested status layers within a 12-month time period. Growing user requirements and policy needs generally point in the direction of shorter update frequencies.

2.2 Temporal coverage of EO Data used for current production

The identification of a suitable update frequency is a combination of several factors including (i) the magnitude of changes that are to be expected, (ii) the expected accuracy of the change detection and (iii) the availability of suitable imagery. There is a trade-off between each of these factors, the longer the period between two updates, the more accurate the detection of changes will be because both the magnitude of changes and the number of cloud-free satellite observations will be increased. Therefore, the availability of suitable cloud-free observations is often the main limiting factor in determining a suitable update frequency particularly when the accuracy of change detection is increased by using dense time series, as illustrated in Figure 2-1 for the image data used for the HRL2015 production. A useful starting point is to assess the situation during the HRL2015 production in terms of satellite image availability considering that this was the first time that denser time series were used in operational production of the HRLs. In total, more than 56,000 optical HR scenes have been processed, covering the time period 2014-2017, accompanied by more than 80,000 SAR scenes (ENVISAT-ASAR & Sentinel-1).

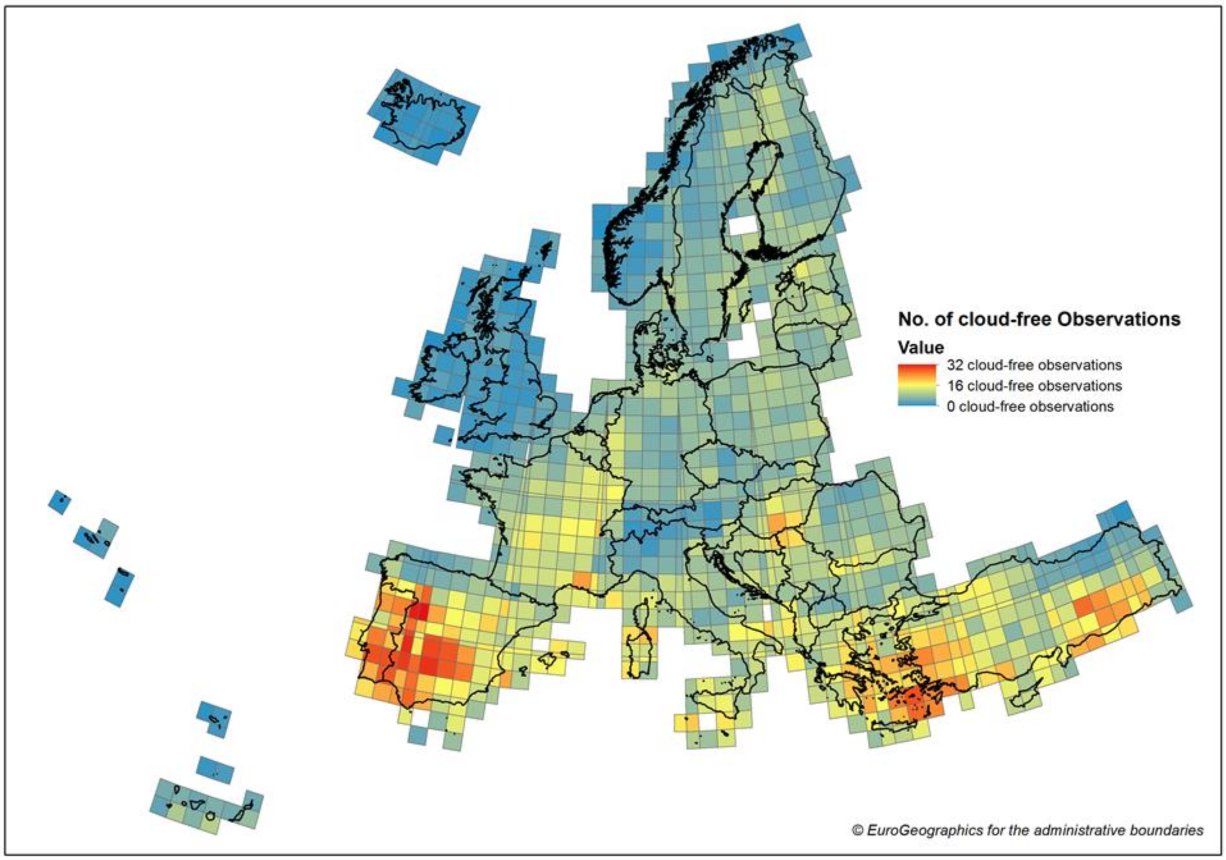


Figure 2-1 – Number of cloud free observations for HRL2015 production per MGRS tile (incl. ResourceSat-2, SPOT-5, Landsat 8 and S-2) over the 2014-2017 period

The HRL2018 production is currently benefiting from the full availability of the Sentinel-2A and B satellites. It is intended to make use of the full time series 2018 (2017, 2019) with a maximum cloud cover up to 80%. The thereof resulting scene count is much higher than it was in the HRL2015 production in which a dedicated scene selection has been applied. In total, it is expected that the number of Sentinel-2 scenes will be 25x higher than in the HRL2015 production. With respect to SAR data, it is assumed that the number of Sentinel-1 scenes to be used in the HRL2018 production will be almost double. Figure 2-1 provides an overview of the estimated Sentinel-1 and Sentinel-2 scenes for the HRL2015 and HRL2018 production.

With such an amount of data, the implementation of current HRLs might be fully based on the Sentinel satellites, and focussing on a single reference year (2018). From this perspective, higher update frequencies seems to be feasible in general, but might still be difficult over cloud prone regions for which the number of cloud free observations may remain limited despite the increased number of scenes processed and also due to existing issues with the quality of the Sentinel-2 Level-2A cloudmasks - that still await to be fully addressed through the algorithm Sen2Cor at the writing time of this final report, as pointed out in the final report of WP22 [AD 05]. This is especially the case for products, which largely or fully depend on optical satellite data.

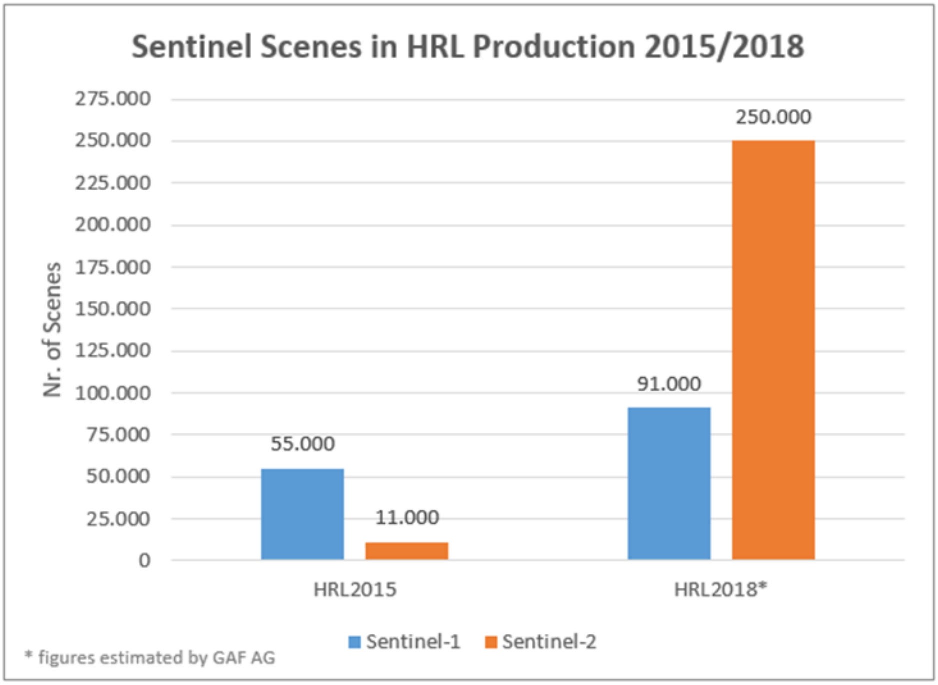


Figure 2-2 – Number of Sentinel scenes used in HRL2015 production and estimated figures for HRL2018 production

2.2.1 Imperviousness Layer

As already stated, imperviousness is the HRL for which the longer time series is available. The HRL Imperviousness degree consists of a series of 20m and 100m thematic raster status and change products derived from EO data at 20m spatial resolution for the 2006, 2009, 2012 and 2015 reference years. Up until 2015, the production of HRL Imperviousness degree was based primarily on a combination of SPOT4 and 5 and IRS LISS-III with a RapidEye coverage introduced in 2012. The aim was to organise the acquisition around two separate coverages at least 6 weeks apart during the vegetation growing season. The data are often referred to IMAGE20XX and can be accessed from the ESA DWH (Data Warehouse) and documented in the ESA Data Access Portfolio (DAP) document (ESA, 2014). These coverages were aimed to be multi-purposes serving the production of CLC as well as the Imperviousness degree layers for 2006 and for all the other HRLs from 2012. However, the acquisition of a complete cloud-free coverage based on these two complete coverages always was problematic with having to rely on gap filling exercise at a final stage to ensure a near complete coverage. Therefore, the target to achieve complete coverage (+/- 1 year) was always difficult to achieve. Further details on the characteristics of the IMAGE2012 dataset is provided below for the description of the Forest layer.

For 2015, the HR_MAGE_2015 dataset was also produced based on IRS LISS-III and SPOT-5 data still coordinated by ESA, but the 2015 production of the Imperviousness degree represented a major change with the production workflow shifting from a centralised approach for the acquisition of input EO data coordinated by ESA based on commercial third-party satellite missions to an HRL specific EO data acquisition approach controlled by the service providers in charge focusing on open data sources. For HRL imperviousness degree, the main data source used was Landsat 8 OLI with some Landsat 7 ETM+ data and HR_IMAGE_2015 used only as an additional data source for gap filling in persistent cloud covered areas. The main reason for this approach was to ensure a better control on the input data acquisition and reduce the dependencies with the ESA DWH with a view to reduce the overall timeframe needed to finalise the HRL Imperviousness degree production. S-2 was not considered for the 2015 reference year because the satellite had just been launched and the use of an additional data stream would have made the time series analysis more complex particularly for the calculation of the imperviousness degree which relies on the integration of multiple NDVI observations requiring a good intercalibration between Landsat 8 and S-2 which was not available at the time. However, the acquisition timeframe was still focused within +/- 1 year of the reference year from 4/12/2013 until 28/11/2016 with data acquired in mostly three periods during Spring, Summer and Autumn of 2014, 2015 and 2016. The data is more or less equally spread over the three years (only 5 scenes were acquired in December 2013) as shown in Figure 2-3. In itself, this means that reducing the update frequency of HRL Imperviousness below the current 3-year period would not be possible if the current level of accuracy/completeness in terms of change detection is maintained. A total of over 7,000 Landsat scenes were acquired and processed over more than 600 Landsat path and row combinations to cover the whole of Europe, thus representing an average of 12 scenes per path and row. However, there is considerable spatial variability in terms of successful cloud-free acquisition as shown in Figure 2-1 and purely from a satellite image acquisition, the image acquisition window could potentially be reduced to the just the reference year in some areas (mostly in southern European regions) increasing to a yearly update frequency for these regions based on the 2015 EO data acquisition strategy.

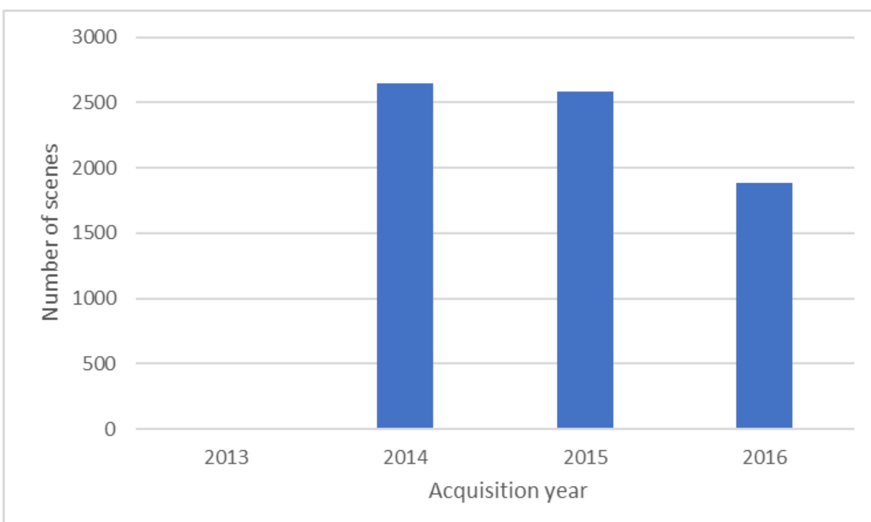


Figure 2-3 – Number of Landsat scene acquisition per year for the 2015 production of the HRL IMP (Imperviousness)

For the HR Layer IMD 2018, the production is now almost exclusively based on S-2 imagery with S-1 being used for cloud prone areas. Considering the production is still ongoing, there are no final statistics on the imagery used, but as mentioned above, it can be expected that a larger proportion if image scenes will be acquired from the reference year with less images used from 2017 and 2019. Another major change is that the resolution of the HR Layer is now 10m to match the resolution of S-2 VNIR spectral bands and no longer 20m in previous years. As some early tests showed this is likely to cause some issues in relation to the detection of changes with potentially a lot of smaller objects now detected which was not the case previously.

2.2.2 Forest Layer

The HRL Forest consists of a series of 20m and 100m thematic raster products derived from EO data in 20m spatial resolution for the two reference years 2012 and 2015. The 2012 reference year (+/- 1 year) production relied almost fully on the Coverage_1 of the ESA DWH (Data Warehouse) dataset DWH_MG2_CORE_01, also referred to as HR_IMAGE_2012. More detailed data on this dataset is provided by the ESA Data Access Portfolio (DAP) document (ESA, 2014). Generally, the dataset provides two seasonal pan-European coverages of optical HR EO data, composed during specific acquisition windows in 2011, 2012 – extended in 2013, for the continuation of CLC like exercises and for the generation of the HRLs. Coverage_1 consists of more than 1,700 multispectral satellite scenes from the satellites IRS-p6, ResourceSat-2, SPOT-4 and SPOT-5 with a temporal coverage of 21.01.2011 to 08.09.2013. Almost 50% of the EO data has been acquired in 2011 and more than 50% of the data are represented by IRS-p6 scenes (see **Figure 2-4**).

As also shown in **Figure 2-4**, the HRL2015 production with reference year 2015 (+/- 1 year) could strongly benefit from a drastically increased EO data situation due to the availability and accessibility of Sentinel-2A and Landsat 8 data. Both satellites formed the primary data source for the HRL Forest 2015 production within the limits of the given reference period, covering the time span from 04.02.2014 to 23.11.2016. Almost 82% of the EO data has been acquired in 2016 and more than 60% of the data are Sentinel-2 scenes.

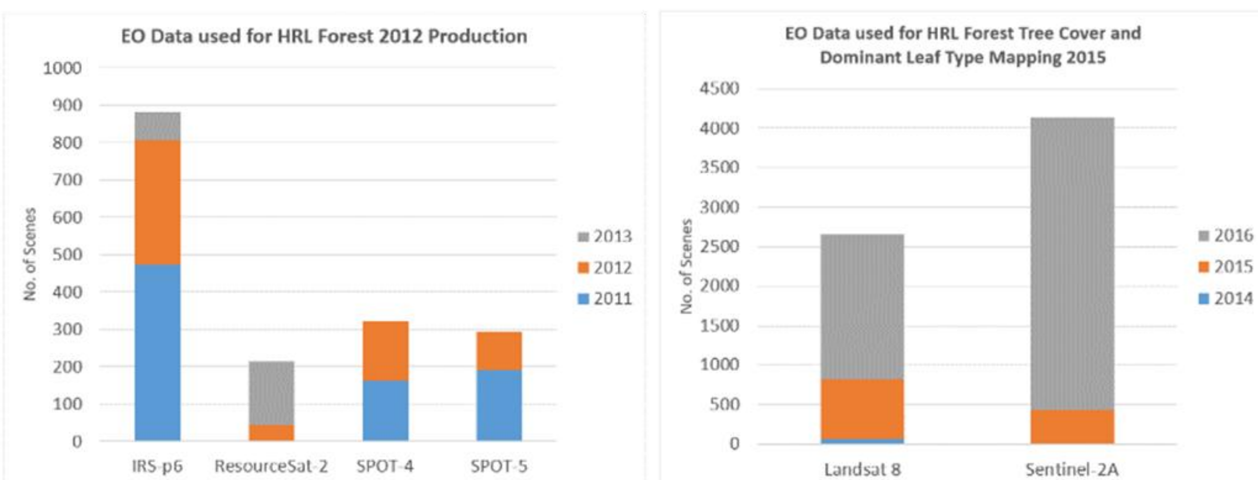


Figure 2-4 – Earth Observation data used in HRL Forest production 2012 and 2015

From the 2018 reference year onwards, the HRL Forest will provide the primary products Dominant Leaf Type (DLT) and Tree Cover Density (TCD) in 10m spatial resolution. The HRL2018 production is currently focussing on data from the acquisition year 2018 (+/- 1 year) and is making use of Sentinel-2A+B time series data, covering the vegetation period. In addition to that, the HRL Forest is incorporating timely consistent SAR data from Sentinel-1A+B for the first time. As most of the data from the 2015 production has been acquired in 2016 (82%), the update frequency of the current HRL Forest might be effectively in the range of 2 years.

2.2.3 Grassland

The selection of suitable data (EO data, ancillary data) was a cornerstone step in the production process. The acquisition of EO data was done to meet the classification requirements, such as amount of cloud/haze cover and dates. The best available images that were afterwards processed, derive from satellites S-2 and Landsat 8. Since S-2 represented the main input data source, the Military Grid Reference System (MGRS) has been defined as production unit system. The HRL Grassland 2015 used a multi-temporal and multi-sensor approach for creation of the Grassland mask, as seen on Figure 2-1.

Multi-temporal in this context means a time series of classifications using EO data of the specified reference year 2015 +/-1 year. However, the largest part of satellite data is from 2016 (~71%). The temporal series include images from 2015 (~18%), 2014 (~10%) and 2013 (~0.5%), respectively.

Multi-sensor implies the use of several optical sensors in order to fill data gaps and to increase the number of data coverages per MGRS tile, namely S-2 (~59%) and Landsat 8 OLI (~41%), respectively. In addition to the optical also radar data (S-1) were part of the production.
On average, about 3-4 multi-temporal scene coverages (S-2, Landsat 8) have been used for the per-pixel analysis per MGRS tile. An initial land cover classification has been performed for each MGRS tile using Support Vector Machines (SVM). The GRA 2015 mask been derived by classifying nearly 4225 single satellite images (S-2, Landsat 8 OLI) from the 2015 reference year.

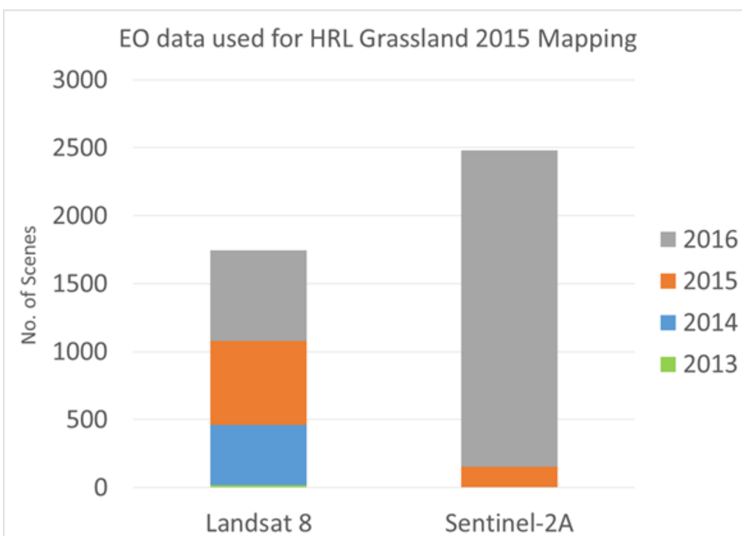


Figure 2-5 – Summary of the total amount of images used for the production of the GRA 2015 mask, per year and satellite.

Subsequently, an integration of the optical classification with a SAR classification was made to obtain the final Grassland Mask. Approximately 20,530 SAR images from S-1 from year 2016 were pre-processed and used for elaboration of the SAR classification. The pre-processing enabled the extraction of thematic information using a highly automated processing chain. It included: download, ingestion of data and metadata, geometric correction, coherence estimation and geocoding using ETRS89 LAEA projection to 20m spatial resolution. These steps have been performed using SRTM DEM where available. In Northern

Europe (above 60° North latitude) EU-DEM 25m has been used. The SAR classification included a removal of all pixels that are not grassland, i.e. no-data values, urban mask and pixels with a value over a threshold of 0.45 long term coherence along the time series. Finally, these where used an input and together with the optical segments and training samples elaborated on the S-2/Landsat 8 images for an enhancement of the optical grassland classification results.

For the 2018 reference year it is planned to use the full S1A and S1B time series as well as the full S2A and S2B time series. The S-1 and S-2 time series of the year 2017 will be used to fill possible data gaps caused by cloud or snow cover, for example. The optical and SAR data is used to drive temporal features as input for the production of the status and additional products. In Figure 2-6 the overall amount of available Sentinel-2 L1C scenes for the 2018 reference year can be seen in comparison to 2015, 2016 (used for HRL2015) and 2017 (used for gap filling).

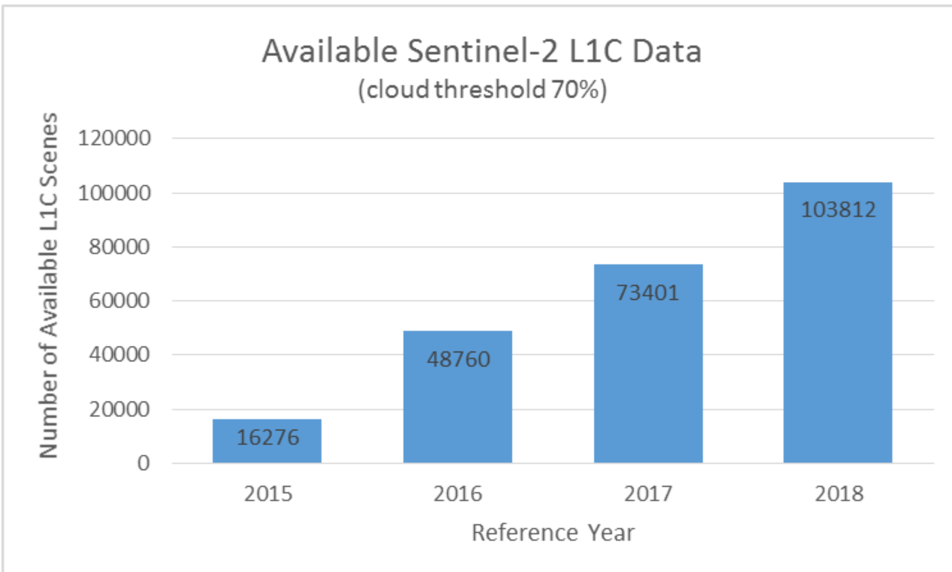


Figure 2-6 – Available Sentinel-2 L1C data per reference year.

2.3 Expected magnitude of changes based on existing layers and/or related data sources

From the HRL product portfolio, the HRL Imperviousness provides the longest time series ranging from 2006 to 2015. This period is being extended to the reference year 2018 by the ongoing HRL 2018 production. For the HRL Forest, an experimental change product has been created for the period 2012-2015 for the first time and simplified change products 2015-2018 will be produced as part of the HRL2018 production. Besides, a Grassland change product 2015-2018 will be derived for the first time as part of the ongoing HRL2018.

It is proposed in this section to estimate the percentage of variation (gain or loss in surface for a given class of land cover, regarding the overall European or national area) that can be expected from one year to the other. Ancillary data and their temporal variability, such as CORINE Land Cover (CLC) change layers or Land Use/Cover Area frame statistical Survey (LUCAS) database, are being used to draw a comparison and eventually sketch a trend for the years to come.

2.3.1 Imperviousness Layer

Urban areas, as opposed to rural ones, are used to define human settlement presenting a high population density, as well as a dense tissue of infrastructure and built-up environment. The urban population in 2014 represented 54% of the overall population, and is expecting to keep rising (WHO; UN Habitat, 2016). According to the World Health Organisation (WHO), the global urban population should grow approximately 1.84% per year from 2015 to 2020; this percentage slowly decreasing over the years to reach 1.44% per year between 2025 and 2030.

Despise the impression that the temporal change in urban area does not appear to be significant at the global scale, its impact on the neighbouring forests, agriculture, water systems, through consumption rise, can turned out to be critical (Lambin, et al., 2001). A close monitoring of the urban growth is necessary to ensure a sustainable development (Wilson & Chakraborty, 2013). In most developing countries, urban growth is mainly driven by population growth. However, in Europe, population growth no longer increases substantially, but urban areas continue to expand, this phenomenon is known as urban sprawl (EEA, 2006). Datasets such as the HRL Imperviousness degree are key to better inform policy makers on the spatial distribution and extent of urban sprawl.

2.3.1.1 Expected magnitude of changes based on CLC data:

For a better accuracy, the CLC change layers are used, since differences between the status layers are based on a 25 ha MMU whereas the change layers are mapped with a 5ha MMU.

2.3.1.1.1 Change analysis

The CLC products were generated for 28 countries for the 1990 layer then for 39 countries (33 EEA members and 6 cooperating nations) in the following years. There are 2 sets of products that will be used in this analysis:

- CLC change layer (CLCC) from 1990 to 2000, the one from 2000 to 2006, the one from 2006 to 2012 and the one from 2012 to 2018;
- CLC status layer from 1990, and the others from 2000, 2006, 2012 and 2018.

The CLC layers (change and status) have been generated by each country, without potentially different methodologies, even though the results have been harmonized – this is why some country results can be set apart in this analysis, due to known technical issues:

- Albania, Bosnia-Herzegovina, Macedonia, Switzerland: those countries were not covered in 2000, hence a sharper increase between 1990 and 2006;
- Iceland: there is no data in 1990 and in 2000;
- Norway: there is no data in 1990 and the products for 2000 were created from existing maps;
- Turkey: backdating was used too for the creation of the products for 1990 and 2000;
- French DOM-TOMs were added between 2000 and 2006 in separate databases;
- Faroe Islands (Denmark) has been added between 2012 and 2018.

To highlight urban area changes, all classes related to the Imperviousness Layer have been singled out from one layer to the next:

- Continuous urban fabric (code 111);
- Discontinuous urban fabric (code 112);
- Industrial or commercial units (code 121);
- Port areas (code 123);
- Airports (code 124);
- Roads (code 122).

In the CLC nomenclature, several classes are added to the urban area, such as mineral extraction sites (code 131), dump sites (code 132), construction sites (code 133), green urban sites (code 141) and sport and leisure facilities (code 142), but they are not included here to follow as closely as possible the definition of imperviousness for the HRL products.

2.3.1.1.2 Results

For 1990, CLC only covered EU countries. From 2000, this was increased to cover all EEA-39 countries. Therefore the 1990-2000 CLC change layer only cover the EU countries whereas subsequent CLCC layers cover the whole of EEA-39 countries. Therefore, the total urban area increased, but, the ratio (of the urban areas related to the total surface of all countries) in 2000 was smaller than in 1990, meaning that the new countries added were less urbanized that the historical ones. The countries added afterward 1990 then presented a smaller proportion of urban areas, hence the small variation from 2.98% of urban areas in 1990 to 2.85% in 2000.

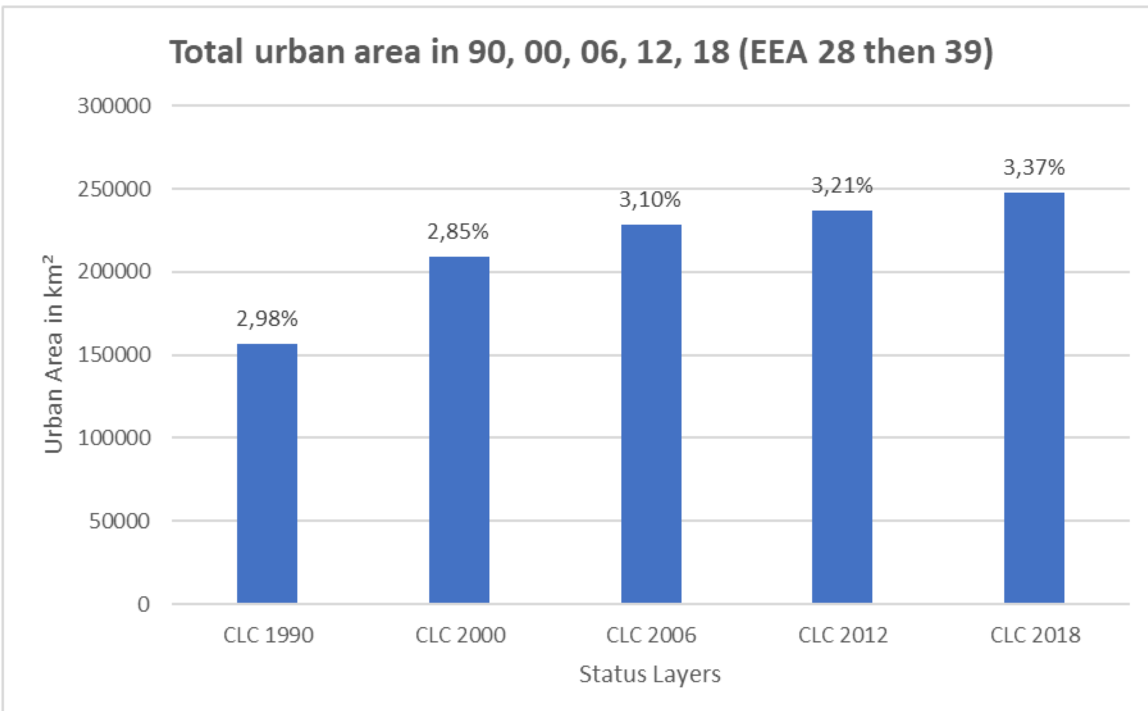


Figure 2-7 - CLC total urban area in 1990, 2000, 2006, 2012 and 2018 in km² for the EEA-39 countries (EEA, 2018c).

Figure 2-7 shows that urban areas tend to expand in time – but at a slower rate with each new CLC release. The 2008 financial crisis has changed the different European housing markets, calling for stricter regulations – which have tightened the credit markets and left fewer options on the mortgage markets – leading to less and less new built-up opportunities. Between 2000 and 2006 the urban areas had a growth rate of 1.46% per year, while between 2006 and 2012, this rate fell to 0.62% per year, which is closely related to the financial crisis of 2007-2008.

The Figure 2-8 and Figure 2-9 display the urban area gain for each selected country from the 39 members. Increase from 1990 to 2000 is shown in blue, increase from 2000 to 2006 in orange, increase from 2006 to 2012 in gray and increase from 2012 to 2018 in yellow.

Spain, as well as France, Germany, Italy, Turkey, UK and the Netherlands exhibit the strongest increases in urban area in km^2, between 1990 and 2018. Most of the change for those countries appeared between 1990 and 2000, and later slowed down their increase rate.

On the other hand, some countries show an increasing amount of new built-up areas (Cyprus, Estonia, Hungary, Kosovo, Latvia, Lithuania, Montenegro, Sweden and Switzerland). Other countries clearly show a slowing down in the expansion of urban areas (Austria, Belgium, Bosnia, Finland, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain).

With a few exceptions (mainly due to political instabilities, such as in Kosovo), a clear divide can be made between the Western-Southern countries (Spain, Portugal, France, Italy, Germany, United Kingdom, Ireland, Belgium, Netherlands, …) whose new built-up rates are slowing down or experiencing very little increase, and the Eastern-Northern countries (Bulgaria, Estonia, Hungary, Kosovo, Latvia, …) whose urban area are expanding at an increasing rate.

However, for each country, the percentage of new built-up areas remains extremely small compared to the overall surface even within a 6-year window, usually less than one percent of the total country area.

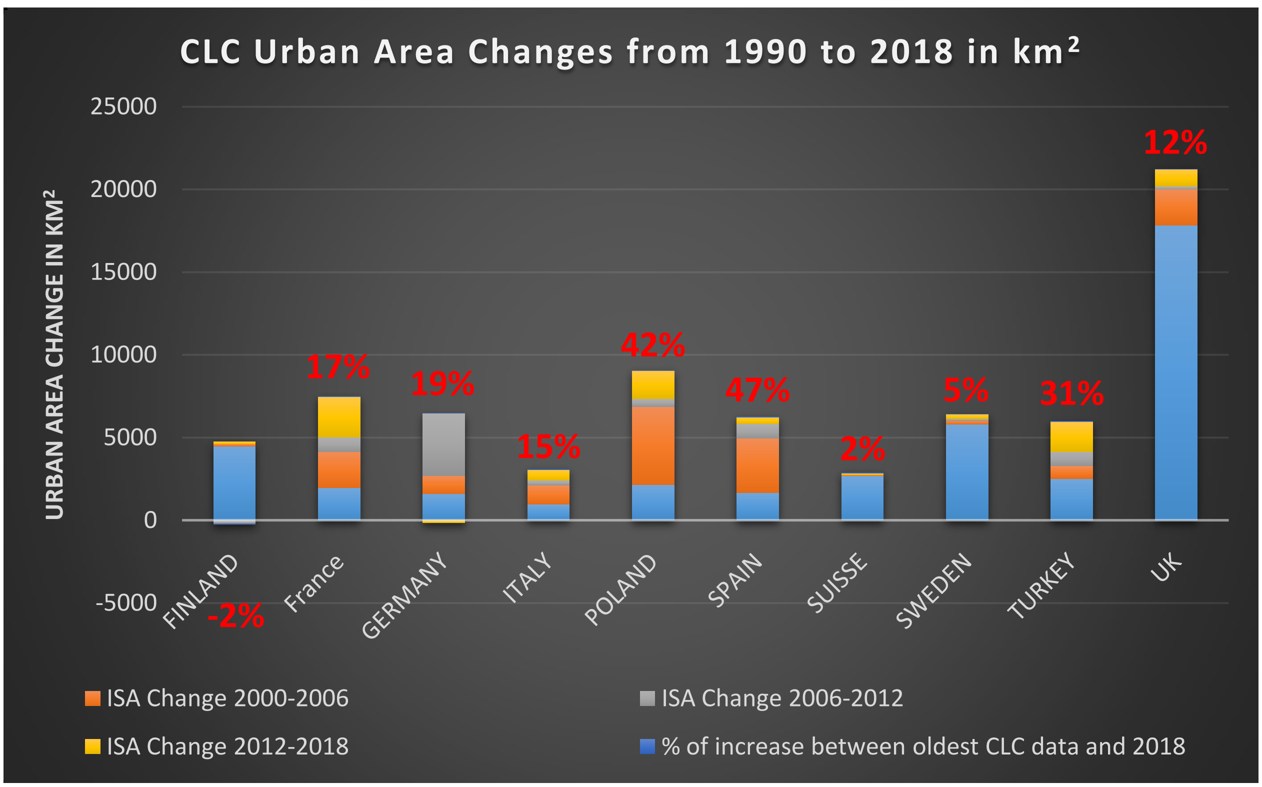


Figure 2-8 - Changes in impervious surface area (ISA) from 1990 to 2018 based on CLC, showing the biggest increases in km^2 – and in red, the global percentage of increase between 1990 (or 2000, depending on the country) and 2018.

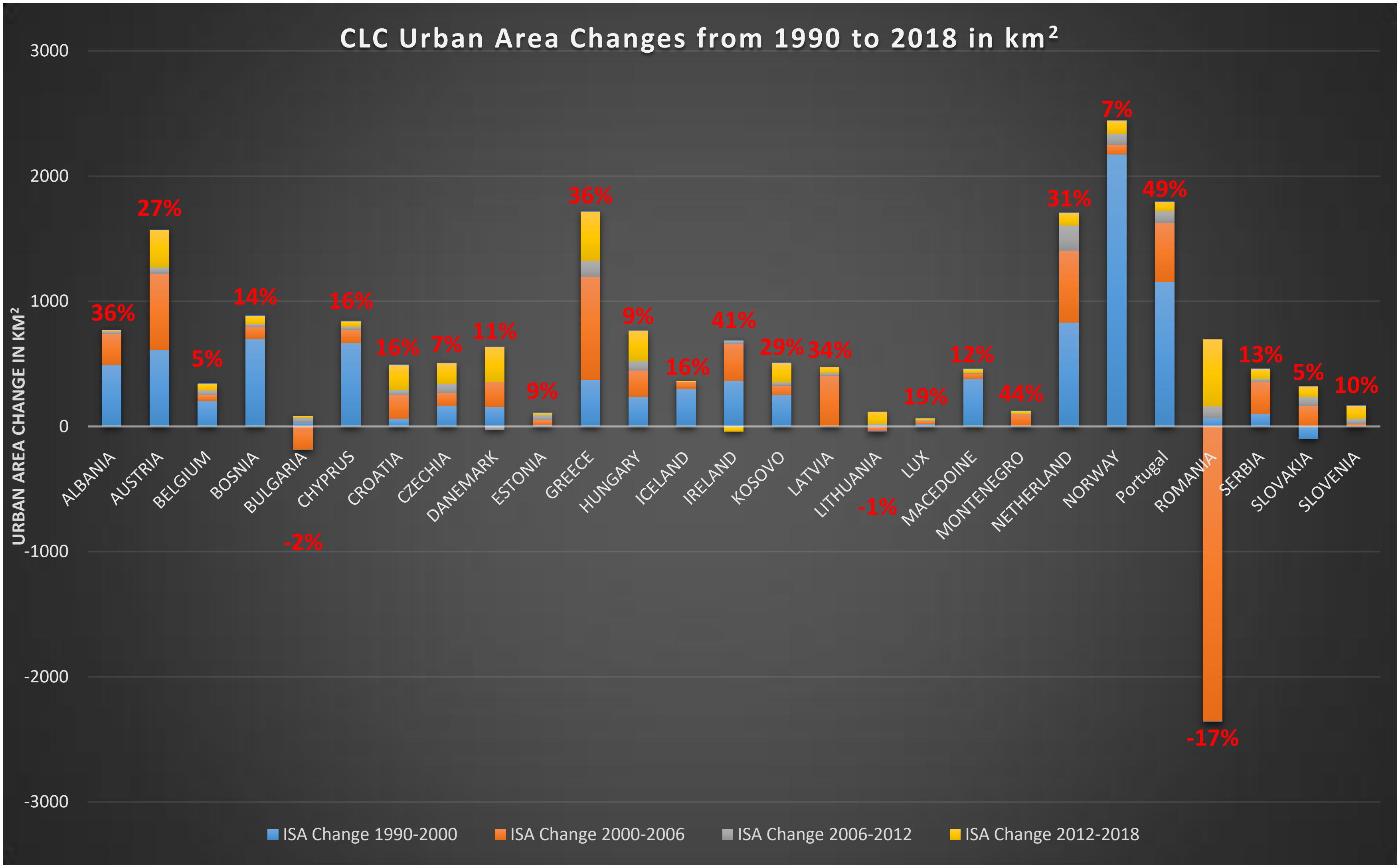


Figure 2-9 - Changes in impervious surface area (ISA) from 1990 to 2018 based on CLC, showing other increases or decreases in km^2– and in red, the global percentage of increase between 1990 (or 2000, depending on the country) and 2018.

Using the status layer, the results of the comparison between two layers can be found in Table 2-1. The percentage of increase is less accurate than the results given by the change layers, which is mostly due to the addition of new countries in the coverage, as well as to commission and omission errors that were not corrected on the older status layer, but on the newest. A slight increase is to be noted between 2012 and 2018, which comes probably comes from a rebound in construction after the financial crisis of 2007-2008.

Table 2-1 – Raw difference between status layers for CLC database on a selection of polygons related to urban areas for 1990, 2000, 2006 and 2012.

	CLC 1990	CLC 2000	CLC 2006	CLC 2012	CLC 2018
Pixel count on a selection of CLC classes (111, 112, 121, 123, 124)	14145471	18457983	19951054	20588432	21985476
% of increase of the urban areas compared to the urban area of the previous year		30,49%*	8,09%	3,19%	6,79%

*due to the increase of European coverage.

2.3.1.2 Expected magnitude of changes based on LUCAS data:

The LUCAS survey is being updated on a three-year basis since 2006 with in-situ measurements, photographs and soil samplings if possible. 27 countries were covered in 2012, generating around 270,000 observations for different types of LCLU. The database is often used as a validation database to assess the accuracy of national or global products and maps (Karydas, et al., 2015).

2.3.1.2.1 Change analysis

For the impervious layer, only the category A for Artificial land is of interest in this analysis – it comprises two sub-categories (A10 for built-up areas and A20 for artificial non-built-up areas) and the following sub-divisions:

- Buildings with one to three floors (code A11);
- Buildings with more than three floors (code A12);
- Greenhouses (code A13) that doubled as a crop land cover;
- Non-built-up area features (code A21) such as yards, cemeteries, parking areas, any soil covered with artificial impervious materials;

Non-built-up linear features (code A22) label artificial covered soils whose width exceeds 3m, that are assimilated to roads.

However, it should be noted that for visual validation, observations falling into the A13 and A20 categories are studied individually and eventually excluded from the selected points. In this analysis, only indisputable categories (A11 and A12) are retained.

2.3.1.2.2 Results

At a pan-European level, the LUCAS database is coherent with an increase of the surface occupied by urban tissue, as seen in Table 2-2.

Table 2-2 – Observations regarding built-up areas in LUCAS database

	2006	2009	2012	2015
Numbers of countries	10	23	28	28
Total numbers of points	168402	234534	270120	339555
Number of A11 and A12 observations	1387	3119	4004	4151
Percentage of built-up points	0.82%	1.33%	1.48%	1.22%

However, at a national level, the database is not representative of the urban areas in each country – too few points are available to characterize the impervious surface (see Annex). In addition, the LUCAS stratification should be taken into account considering the sampling intensity may be different from one period to the next. This would require applying a weighting factor which further makes the analysis more complex and was not available here. Finally, the enumerators carrying out the LUCAS survey did not have the information from the previous survey for most of the time period which means that most of the time the survey was performed 'blindly' with respect to change detection which means that some changes may actually be a different interpretation of the land cover/use rather than an actual change and renders the change analysis less reliable particularly for this particular theme which was sampled with low intensity.

2.3.1.3 Example of one urban area: Nantes

SIRS regularly produce LCLU maps for local authorities. The example of Nantes in France is particularly interesting as it was done over several decades with data spanning from the 1950s to the 2010s thus providing insights on long term changes.

2.3.1.3.1 Change analysis

The classes selected to compute the total urban areas are:
- Urban fabric (map label 11);
- Industrial, commercial units with sport and leisure facilities (map label 12).

2.3.1.3.2 Results

As can be seen in Table 2-3, the expansion rate of the city is slowly decreasing over the years, as it is expected in the Southern/Western countries of the EU. Since 2008, the rate has almost stabilized at 0.6-0.7% of new urban areas created per year, compared to the overall occupied land.

Table 2-3 – Urban area expansion for Nantes and its suburbs, from 1951 to 2014

Year	Total of urban area in km^2	Percentage of increase of the total area compared to the previous year	Temporal Step (in years)	Average percentage of increase of urban area per year
1951	55.5273661	-		-
1981	121.28	118%	30	1.81%
1999	157.6	30%	18	1.28%
2004	165.64	5.1%	5	0.97%
2008	170.14	2.7%	4	0.66%
2009	171.43	0.7582%	1	0.75%
2012	174.41	1.7383%	3	0.60%
2014	176.93	1.4449%	2	0.71%

2.3.1.4 Expected magnitude of changes based on Urban Atlas data

The analysis in this section will compare the Urban Atlas data from 2006 and 2012 to confirm the trends sketched by the analysis done on the CLC change layers.

The Urban Atlas (UA) 2006 provides European, comparable and detailed 20-class LU/LC map data for the main Functional Urban Areas (FUAs) and covers most of all EU urban areas with more than 100,000 inhabitants and all EU27 member state capital cities as defined by the Urban Audit.

The UA 2012 update and extension covers in addition to the cities mapped in 2006 also all urban areas with a population above 50,000 inhabitants corresponding to a total of 695 FUAs. An extension of the FUAs mapped in 2012 was also recently performed for the West Balkan and Turkey with a total of 800 FUAs now mapped for 2012. However, the 2006-2012 change product is only available for the original 305 FUAs mapped in 2006. For the 2018 update, the 2012-2018 change product will be available for all

800 FUAs. The Minimum Mapping Unit (MMU) of the Urban Atlas is 2,500m² in urban areas and 1ha in rural areas with some exception: some polygons with a MMU as small as 500m² can be included if they are part of a greater unit cut by the transport network (e.g. forest or residential area). This is a much finer resolution compared to that of CLC which is particularly relevant to urban expansion which tends to occur over small dispersed areas thus potentially underestimated by CLC.

2.3.1.4.1 Change analysis

First, the changes in sealed areas between 2006 and 2012 are provided at different levels of aggregation:

- At a pan-European scale, for all EEA-39 members;
- At a national scale, for each country,
- At a biogeographical scale, for aggregated countries, exhibiting the similar characteristics in terms of climate and expected LC.

The impervious areas at different scales are determined by combining information of the UA classes related to the imperviousness topic for both years. It is important to note that the statistics are available but not directly comparable. Indeed, the global extent of the products changed from one period to another with an extension for some FUAs and new ones. The classes used in the UA 2012 databases are listed in the Table 2-4, and the selection of classes singled out for this study is displayed on a green background.

Table 2-4 – Nomenclature of classes in UA 2012

UA CODE	UA CLASS NAME	Built-up (c1) vs non Built-up areas (c2)
11000	Continuous Urban Fabric (including all types of sealing)	c1
11300	Isolated Structures	c1
12100	Industrial, commercial, public, military and private units	c1
12210	Fast transit roads and associated land	c1
12220	Other roads and associated land	c1
12230	Railways and associated land	c1
12300	Port areas	c1
12400	Airports	c1
13100	Mineral extraction and dump sites	c2
13300	Construction sites	c2
13400	Land without current use	c2
14100	Green urban areas	c2
14200	Sports and leisure facilities	c1
21000	Arable land (annual crops)	c2
22000	Permanent crops	c2
23000	Pastures	c2
24000	Complex and mixed cultivation patterns	c2
25000	Orchards	c2
31000	Forests	c2
32000	Herbaceous vegetation associations	c2
33000	Open spaces with little or no vegetations	c2
40000	Wetlands	c2
50000	Water	c2

Table 2-5 – Nomenclature of classes in UA 2006

CODE	CLASS NAME	Built-up (c1) vs non Built-up areas (c2)
11000	Continuous Urban Fabric (including all types of sealing)	c1
11300	Isolated Structures	c1
12100	Industrial, commercial, public, military and private units	c1
12210	Fast transit roads and associated land	c1
12220	Other roads and associated land	c1
12230	Railways and associated land	c1
12300	Port areas	c1
12400	Airports	c1
13100	Mineral extraction and dump sites	c1
13300	Construction sites	c1
13400	Land without current use	c1
14100	Green urban areas	c1
14200	Sports and leisure facilities	c1
20000	Agricultural and natural areas (including annual and permanent crops, pastures, herbaceous vegetation associations, open spaces with little or no vegetation, wetlands)	c2
30000	Forests	c2
50000	Water	c2

The same selection is reproduced on the nomenclature of classes listed in Table 2-5 from the UA 2006 database, which is slightly different from the more recent version of 2012.

2.3.1.4.2 Results

Hereafter the results obtained at pan-European level, based on FUAs in common between 2006 and 2012, which is a partial snapshot of the global LCLU, can be seen in Table 2-6. The growth rate of the urban areas covered by the UA in 2006 and 2012 is at 3.03% for 6 years, which means a yearly growth rate of 0.51% - close to the growth rate found for the CLC change layer between 2006 and 2012, which amounts to 0.53%, but focuses on the entire area whereas the Urban Atlas only covers larger cities.

Table 2-6 – Pan-European comparison between the UA 2006 and UA 2012 classification results.

	2006 (km²)			2012 (km²)			2006-2012
Level of Reporting	Non Built-up Area	Built-up Area	Total Area	Non Built-up Area	Built-up Area	Total Area	% increase
Pan-European	378 465	60 411	438 876	376 635	62 241	438 876	3,03%

The results for built-up areas in km^2 at national level are displayed in Table 2-7. Since the FUAs target very specific regions, whose urban areas are more prominent, it is expected that the growth rate of impervious surfaces must be higher than on a CLCC layer.

Table 2-7 – Comparison between the UA 2006 and the UA 2012 database at country level.

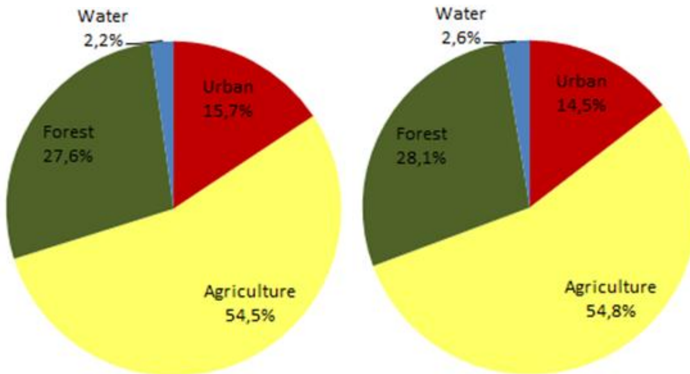
	2006 (km²)			2012 (km²)			2006-2012
Level of Reporting	Non Built-up Area	Built-up Area	Total Area	Non Built-up Area	Built-up Area	Total Area	% increase
AT	17 135	1 982	19 117	17 036	2 081	19 117	**4,99%**
BE	5 748	2 061	7 809	5 709	2 100	7 809	**1,89%**
BG	13 195	1 088	14 283	13 176	1 107	14 283	**1,75%**
CY	2 498	215	2 713	2 486	227	2 713	**5,58%**
CZ	25 313	2 994	28 307	25 192	3 115	28 307	**4,04%**
DE	73 374	13 801	87 175	73 134	14 041	87 175	**1,74%**
DK	14 516	2 454	16 970	14 470	2 500	16 970	**1,87%**
EE	6 905	430	7 335	6 875	460	7 335	**6,98%**
EL	6 744	1 197	7 941	6 716	1 225	7 941	**2,34%**
ES	11 023	1 547	12 570	10 918	1 652	12 570	**6,79%**
FI	10 122	1 010	11 132	10 070	1 062	11 132	**5,15%**
FR	46 685	8 425	55 110	46 416	8 694	55 110	**3,19%**
HU	11 736	1 675	13 411	11 683	1 728	13 411	**3,16%**
IE	6 956	1 007	7 963	6 947	1 016	7 963	**0,89%**
IT	9 839	2 991	12 830	9 720	3 110	12 830	**3,98%**
LT	7 470	625	8 095	7 437	658	8 095	**5,28%**
LU	2 318	278	2 596	2 308	288	2 596	**3,60%**
LV	3 720	236	3 956	3 717	239	3 956	**1,27%**
MT	164	82	246	163	83	246	**1,22%**
NL	5 846	1 590	7 436	5 784	1 652	7 436	**3,90%**
PL	30 115	3 943	34 058	29 845	4 213	34 058	**6,85%**
PT	3 672	756	4 428	3 621	807	4 428	**6,75%**
RO	3 546	785	4 331	3 487	844	4 331	**7,52%**
SE	23 819	2 270	26 089	23 797	2 292	26 089	**0,97%**
SI	4 252	474	4 726	4 241	485	4 726	**2,32%**
SK	7 873	800	8 673	7 844	829	8 673	**3,63%**
UK	23 881	5 695	29 576	23 843	5 733	29 576	**0,67%**

2.3.1.5 Comparison of the magnitude of change from the data sources analyzed

The overall magnitude of change in percentages is very similar for the Urban Atlas to that obtained with CLC and CLCC analysis at least at pan-European level despite the finer resolution of the Urban Atlas and the fact the CLC cover the whole of EEA-39 whereas the Urban Atlas 2006-2012 change layer only cover cities over 100,000 inhabitants within the EU27. In fact, it is possible that some of these differences compensate each other as one would expect that CLC would underestimate artificial areas due to the large MMU. In fact, when comparing the land use class proportion of the FUAs mapped for the Urban Atlas, CLC slightly underestimate the proportion of artificial areas as compared with the Urban Atlas (see Figure 2-10).

The results from the city of Nantes are interesting because of the long-term time series and the fact that urban expansion tend to have stabilised in recent years. In addition, the magnitude of change is similar to that observed with the pan-European analysis based on a different far more detailed data set even compared with the Urban Atlas.

The analysis of LUCAS for change is problematic particularly for the artificial land theme and would require more in-depth analysis beyond the scope of this deliverable.



(a) (b)

Figure 2-10 – Comparison of level 1 land use class proportion for UA2006 LUZ from (a) UA2006 and (b) CLC2006

Although the Urban Atlas analysis only focuses on the larger cities, it provides a more detailed characterisation of urban expansion which exhibits considerable variability between EU countries as illustrated in Table 2-7.

The overall magnitude of changes based on UA is approximately 3% between 2006 and 2012 but regional differences exist, as previously sketched in the CLCC layers analysis:

- Eastern countries present high percentages of changes (up to 6 or 7%) which can be related to the economic growth in the past years for these countries;
- Mediterranean countries exhibit the same pattern – a well-known behaviour for Spain and Portugal with high increase of constructions after 2006, for example;
- The British Islands, some Nordic and Western-Central countries present very low rates of change.

This geographical pattern, as seen in Figure 2-11, may be considered for the incremental update of the imperviousness layer with countries where the urban expansion is very high, updated more frequently than countries for which there is little change.

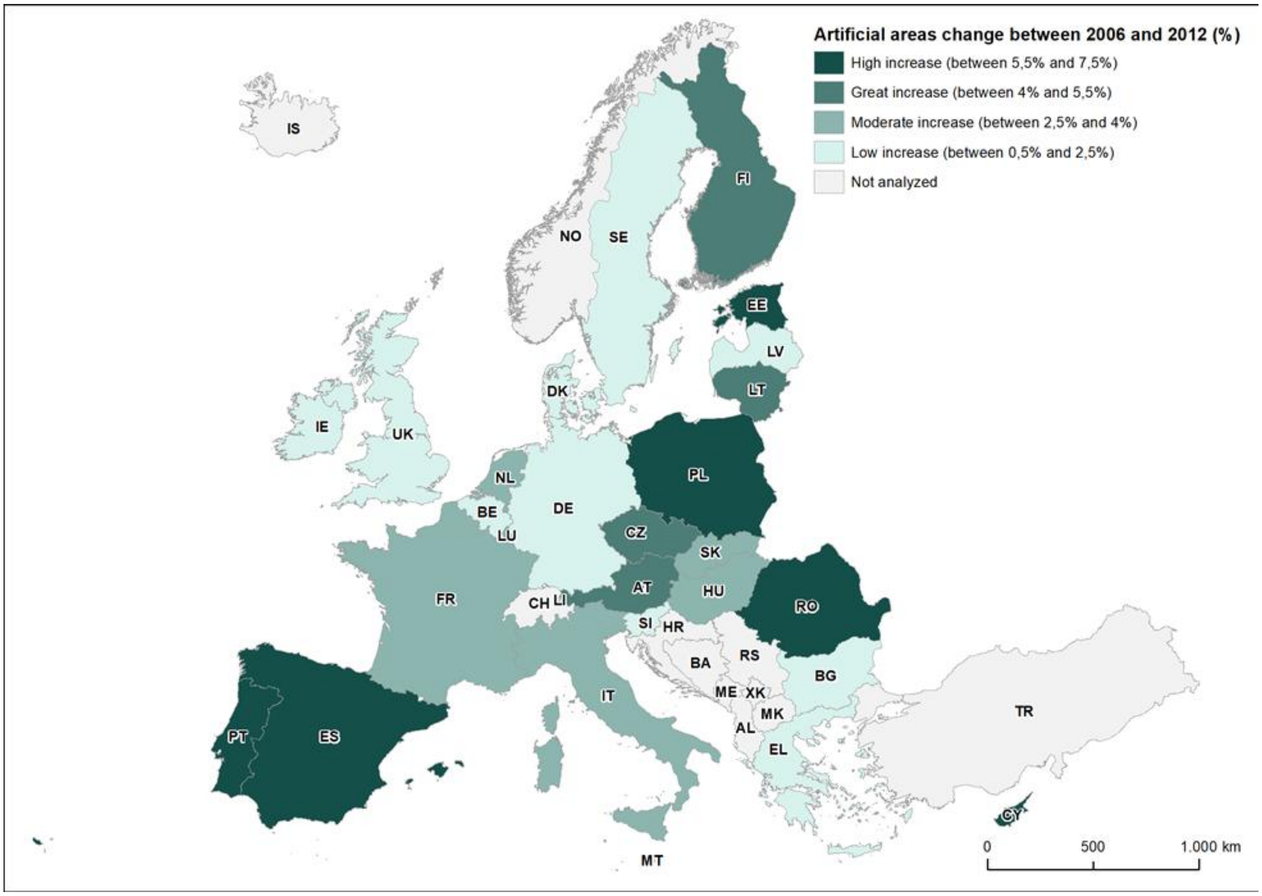


Figure 2-11 – Expansion of artificial areas from the Urban Atlas between 2006 and 2012.

2.3.2 Forest Layer

As people all over the world are highly dependent on intact ecosystems, it gets more and more important to understand how valuable ecosystem services are for humankind. Especially the socio-economic value of forest ecosystem services, e.g. in terms of climate regulation and air quality, carbon sequestration, watershed services and flood mitigation, soil stabilization and erosion control (Krieger, 2001), is of particular importance. Estimates assume a reduction of the global number of trees by 46 % since the beginning of human civilization, and 15 billion trees are being cut down every year (Crowther et al., 2015). While the global forest area decreased in the period 1990–2015 (FAO, 2015a), forest areas in Europe were found stable or slightly increasing, and covered about one-third of the entire European land area (FAO, 2016). Since Europe generally gained forest area over the last 25 years (FAO, 2015b), it would be of great importance to know the quantity of forest area gains and losses, in a more spatially explicit manner, and at finer temporal resolution.

Therefore, the ECoLaSS project aims to determine an appropriate future incremental update frequency for the HRL Forest. For this purpose, information about tree-covered areas in the EEA-39 countries from the HRL Forest reference years 2012, 2015 2018, and other sources can initially serve as an update indicator. In this chapter, related data from the EEA-39 countries are examined, comprising the 33 EEA member countries and 6 cooperating countries of the West Balkan (EEA, 2018a).

2.3.2.1 Expected magnitude of changes based on CORINE Land Cover data

The CORINE Land Cover (CLC) data are mapped by the EEA-39 countries or derived from their national land cover/land use (LC/LU) databases, and collected, coordinated and harmonized by the European Environment Agency (EEA) on European level. The data comprise information on LC/LU in 44 classes, with a relatively coarse Minimum Mapping Unit (MMU) of 25 ha (5 ha for changes) and a Minimum Mapping Width (MMW) of 100 m. Generated from high spatial resolution satellite images and specific in-situ data, the development of the first data set began in 1985 and resulted in the "CLC 1990" product, which was updated after 10 years. Whereas the first CLC data of 1990 include LC/LU information of 27 countries, the subsequent data sets of 2000, 2006, 2012 and 2018 comprise consistent information for the EEA-39 countries (recent version 20) in Europe (EEA, 2018b; EEA, 2018c) and are therefore used in this analysis. The Tender for the next generation of CORINE Land Cover (CLC+) with reference year 2018 and a MMU of 0.5ha was published in summer 2019.

2.3.2.1.1 Change Analysis

First, to quantify the changes in forest area between the different reference years, the forest area per country is determined using the CLC status layers. These have been used in the analysis, as some inconsistencies between CLCC and CLC data have been detected, which extent could not be properly assessed yet. Combined information of the CLC-classes broadleaved forest (Code 311), coniferous forest (Code 312) and mixed forest (Code 313) is used to estimate the magnitude of forest area changes both for the pan-European area and for the individual countries in Europe. For those three CLC-classes, a threshold of > 30% crown cover is a requirement (ETC/ULS 2017).

2.3.2.1.2 Results

The forest area within the CLC datasets of the years 2000, 2006, 2012 and 2018 makes a proportion of ca. 29 % of the total EEA-39 land area. According to the CLC data (Figure 2-12), the change amounts to a gain in forest area between 2000/2006 (0.8 %) and a significantly higher gain between 2006/2012 (1.8 %), whereas it amounts to a slight forest loss (0.1%) in 2018.
In summary, the overall change between 2000 and 2018, means a gain in forest area of 2.5 % within the EEA-39 countries (Figure 2-13), with absolute annual change rates of +0.1 % in the period 2000 to 2006, +0.3 % in the period 2006 to 2012 and -0.016% for 2012 to 2018. However, the calculated change rates based on CLC data seem to overestimate the gain in forest area due to the coarse specifications of the CLC status layers. CLCC data 2006 to 2012 indicates at least for some countries significant lower change rates (e.g. for Germany = 0.05 %, France = 0.14 %, Poland = 0.002 %).
In the period 2012 to 2018 a slight loss (-0.1%) can be observed in the absolute forest area, mainly caused by dramatic forest fires in the mediterranean countries in 2017, specifically within Portugal and Spain. Sweden shows also a strong loss in the forest area, but it is unclear, to which extent the figures of the forest fires in summer 2018 already entered in the CLC 2018 update. However, the overall pan-European trend of forest gain has been stopped.

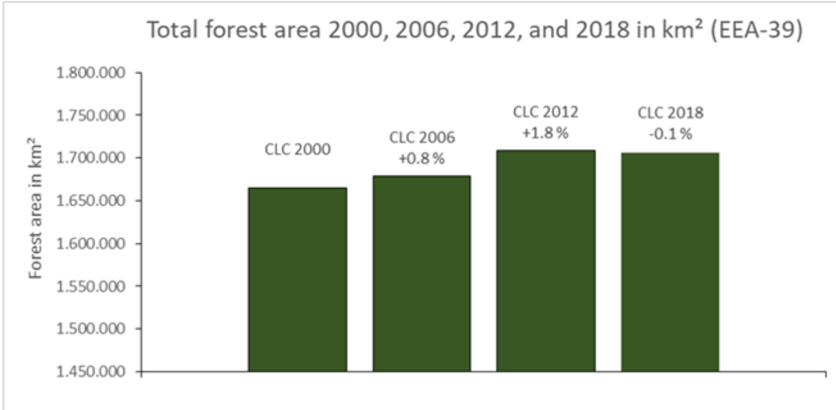


Figure 2-12 – CLC total forest area 2000, 2006, 2012 and 2018 in km² for the EEA-39 countries (EEA, 2018c).

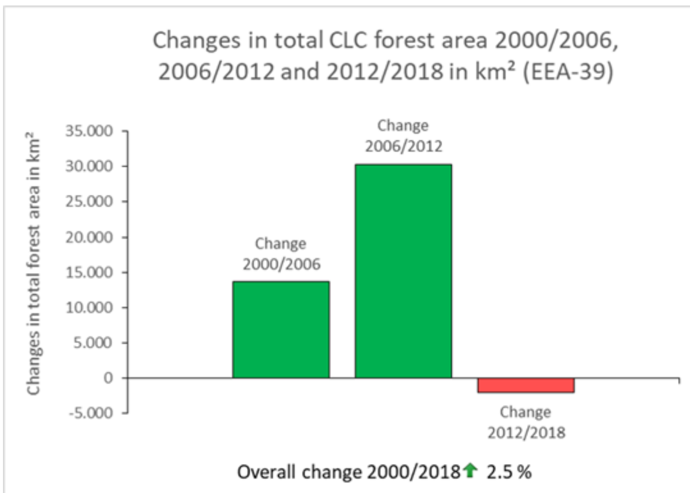


Figure 2-13 – CLC, Changes in total forest area in the EEA-39 countries. Changes 2000/2006, 2006/2012 and 2012/2018 in km² (EEA, 2018c).

Figure 2-14 and Figure 2-15 provide the area statistics of forest loss and forest gain per country. The biggest area changes in terms of km² don't necessarily reflect the biggest changes in terms of relative percentages of the overall forest areas of countries. Iceland for example, was the country with the highest relative gain in forest area of 70.7 %, but due to the generally low overall coverage of forests in Iceland, the increase in absolute numbers amounts to only 222 km², which is compared to the previous CLC inventory 2000-2012 a doubling in the forest area. Iceland was followed by Ireland with a gain of 55.7 % (1,627 km²) and Liechtenstein with 19.5 % (11 km²). Finland is the country where the absolute forest area in km² increased the most between 2000 and 2018, with a gain of over 19,000 km² (9.7 %), followed by Spain (>16,000 km², 17.5 %) and Sweden (> 6,000 km², 2.6 %).

However, the notable absolute gains in forest area for some countries (e.g. Spain, Sweden) have to be treated with caution, as they appear disproportionately high. A change in the prevailing methodology of interpreting satellite images, from Computer Assisted Photointerpretation (CAPI) to a semi-automatic methodology, took place in the CLC 2012 update (EEA, 2017) and may have contributed to this. In addition, there have been revealed some topological errors within the geospatial data (e.g. for Spain). This issue has been reported to the entrusted entity and will be addressed by the EEA. For more detailed change rates between the different years please consult the Annex.

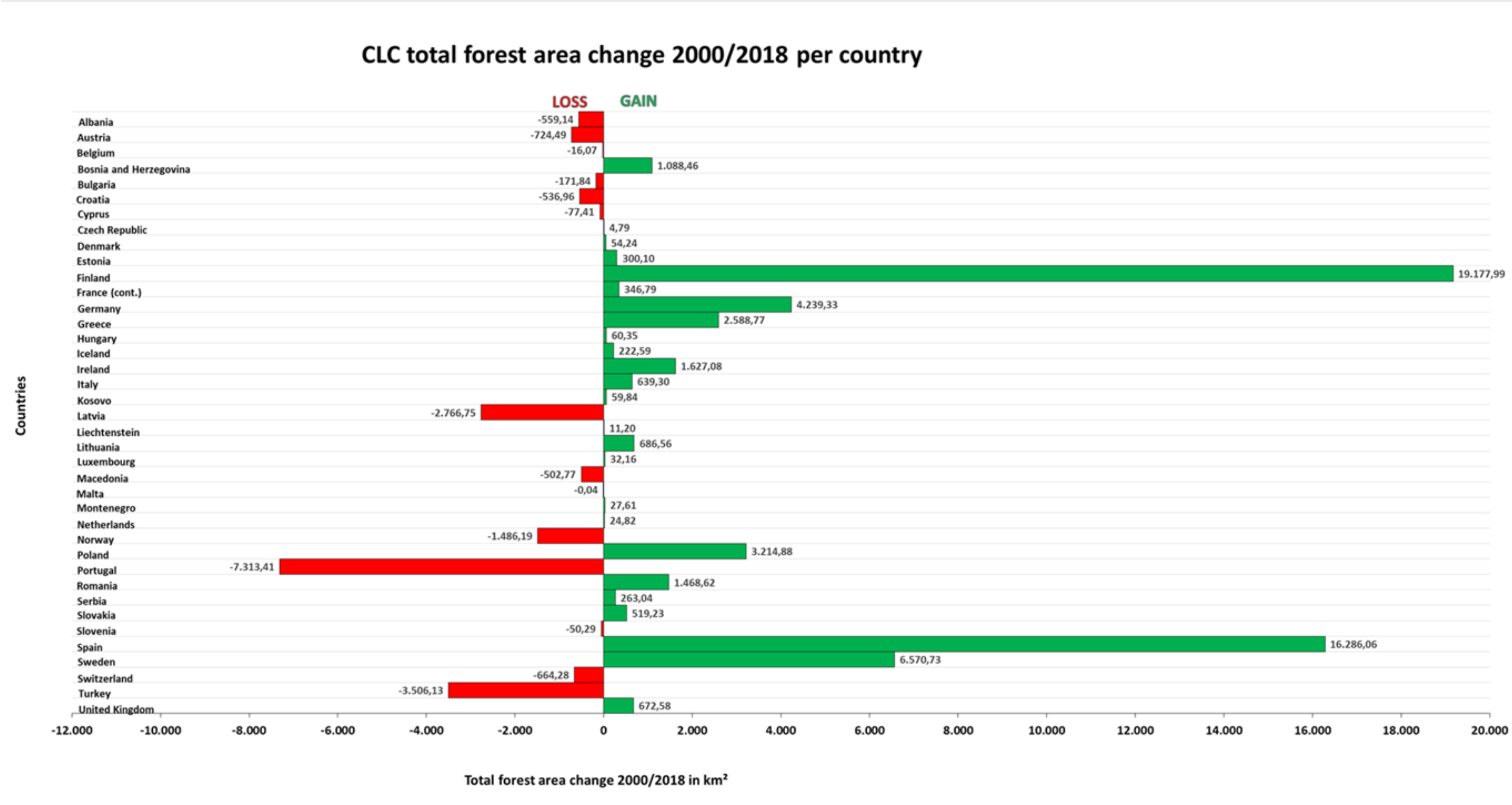


Figure 2-14 – CLC total forest area change 2000/2018 per country in km². Changes, greater or equal 1 % are given in percent (EEA, 2018c).

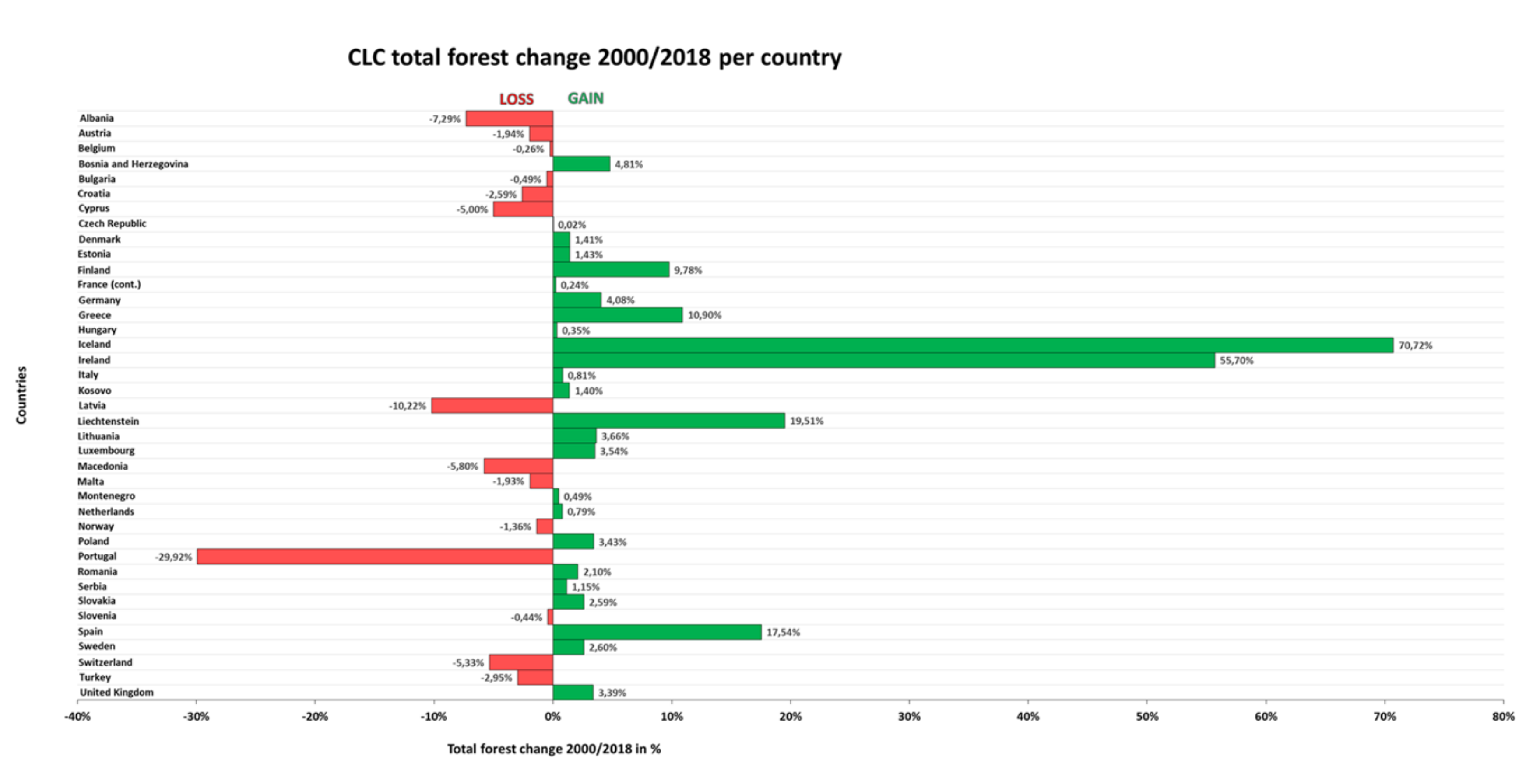


Figure 2-15 – CLC total forest area change 2000/2018 per country in percent (EEA, 2018c).

2.3.2.2 Expected magnitude of changes based on data of the Food and Agriculture Organization of the United Nations

As defined by FAO, forests are areas with trees ≥ 5 m height at maturity in situ, a spatial extent of > 0.5 ha and with a tree canopy cover of > 10 %, as well as regrowth or temporarily unstocked areas expected to revert to forest. Moreover, there are "other wooded land" areas with different specifications, which could be an additional indicator of change in forest area. Those areas have a tree canopy cover between 5-10 % or a coverage with smaller trees, shrubs and bushes with a tree canopy cover of > 10 % (FAO, 2000). This definition is largely in line with the HRL Forest definition, but different to the one used by CLC with 30 % canopy cover and 25 ha MMU. In this chapter, the FAO data of the State of Europe's Forests Reports 2011 and 2015, as well as of the Global Forest Resources Assessments 2010 and 2015 are examined. On the one hand, the data for forest areas are analyzed (for 25 countries in Europe[1]), on the other hand, also combined information with other wooded land (EEA-39) is examined here. Due to the given data base, however, information on other wooded land is only available for 2010 and 2015.

2.3.2.2.1 State of Europe's Forests

The State of Europe's Forests (SoEF) Report 2015, of the Food and Agriculture Organization of the United Nations (FAO), deals with the status and trends in Europe's forests and their management. Its information ranges from 1990-2015, thus it covers a period of 25 years. Especially the chapters about quantitative indicators (e.g. forest area) and the corresponding tables, are of particular importance, to assess the magnitude of the changes in forest area in Europe over time (FAO, 2015b), not the least because 200 national experts have contributed their knowledge. Although most of the data basis comes from the governments of the individual countries, also international data providers like UNECE, EUROSTAT or ICP-Forests provided additional information (UNECE/FAO 2015).

2.3.2.2.1.1 Change Analysis

First, to quantify the changes in forest area between the different years, the forest area (without wooded land) per country are determined from the data (see chapter 2.3.2.2.1.2). This information of the forested area in 25 countries in Europe is used to estimate the magnitude of forest area changes in those countries since 1990 (FAO, 2015b) and in Europe (see Annex). Moreover, also the change in other wooded land between 2010 and 2015 is examined here (see chapter 2.3.2.2.1.3).

[1] Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Estonia, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Luxembourg, Malta, Norway, Romania, Slovakia, Slovenia, Sweden, Switzerland and Turkey.

2.3.2.2.1.2 Results - Forest area

The forest area in the observed 25 European countries changed from a proportion of 33 % of the total land area in 1990, to 34 % in 2000 and 2005, and further increased to 35 % in 2010 and 37 % in 2015. The overall change in forest area from 1990 to 2015 amounts to a relative gain of 10.8 % with absolute change rates of 0.2 % (1990/2000), 0.3 % (2000/2005), 0.2 % (2005/2010) and 1.1 % (2010/2015) per annum. The change rate between the years 1990 and 2010 was decreasing (see Figure 2-16), whereas the observed changes between 2010 and 2015 are by far the largest, with a relative gain in forest area of over 5.8 % (70,000 km²) in the considered 25 countries in Europe (see Figure 2-17). It can be assumed that in case of such large fluctuations in forest area coverage, there might either be a change in the definition of forested area or that different survey methods influenced the data basis between the survey points in time. For more detailed change rates between the different years (see Annex).

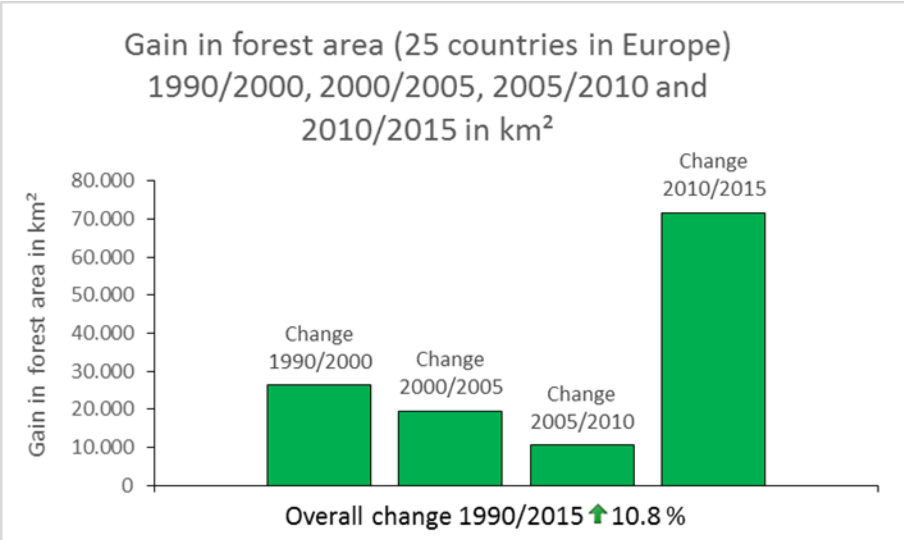
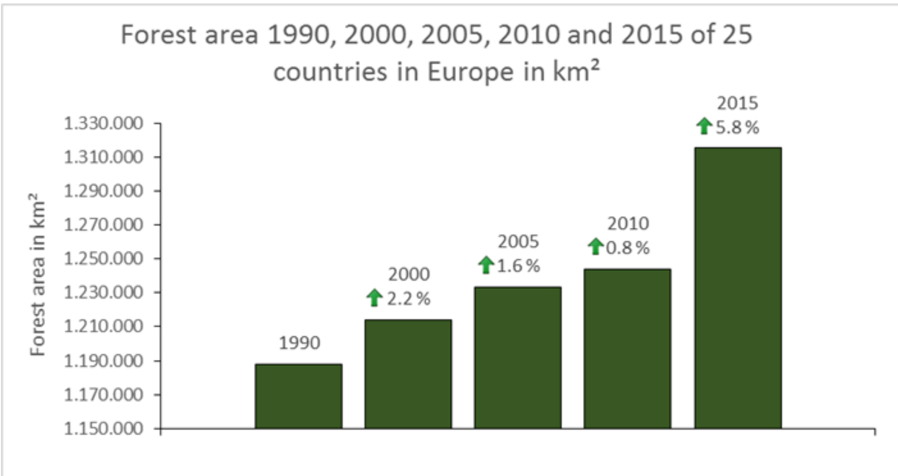


Figure 2-16 – Gain in forest area in 25 countries of Europe. Changes 1990/2000, 2000/2005, 2005/2010 and



2010/2015 in km² (FAO, 2015c).

Figure 2-17 – Forest area 1990, 2000, 2005, 2010 and 2015 of 25 countries in Europe (FAO, 2015c).

2.3.2.2.1.3 Results - Forest area and other wooded Land

The combined information on the development of forest area and other wooded land between 2010 and 2015 is shown in Figure 2-19, providing information on the gains and losses for each of the EEA-39 countries. The data exhibit an overall gain in forest area and wooded land (2010/2015) of 2.1 % (> 45,000 km², see Figure 2-18), resulting in an annual change rate of 0.5 %, which seems to be a representative value for assessing forest area changes in Europe.

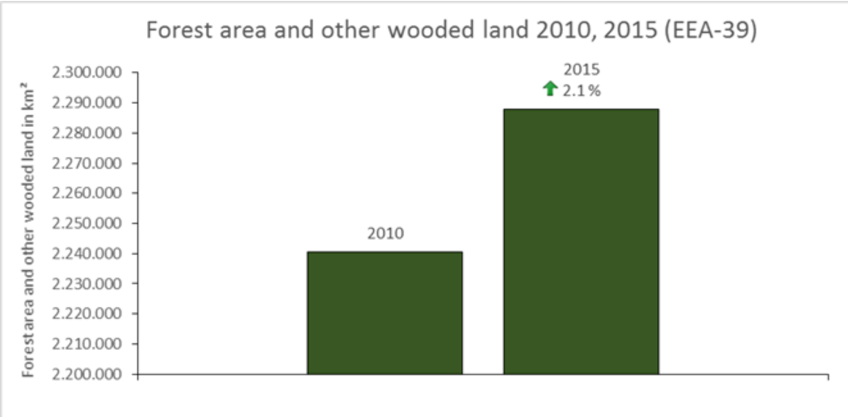


Figure 2-18 – Forest area and other wooded land 2010, 2015 in km² (EEA-39), (FAO, 2015d).

Just four countries show recorded losses of over 1 % (Bosnia and Herzegovina, Liechtenstein, Malta and Bulgaria) across the EEA-39. Whereas the “loss” areas in Malta (0.5 km²) and Liechtenstein (13 km²) are just marginal in terms of absolute areas, the losses in Bosnia and Herzegovina amount to over 2,000 km². The largest absolute gains (in km²) are observed in Norway (17,400 km², 14.1 %), Portugal (13,000 km², 35.9 %) and Germany (3,400 km², 3.1 %). Especially such large and exceptional fluctuations as reported for Norway and Portugal suggests that there might be either a change in the (national) forest definition or that different survey methods and/or statistical corrections influencing the data basis have been applied between the two reporting dates. The European average of 2.1 % gain in forest area, however, seems to be a more representative value in terms of forest change assessment. For more detailed change rates between the different years, see Annex.

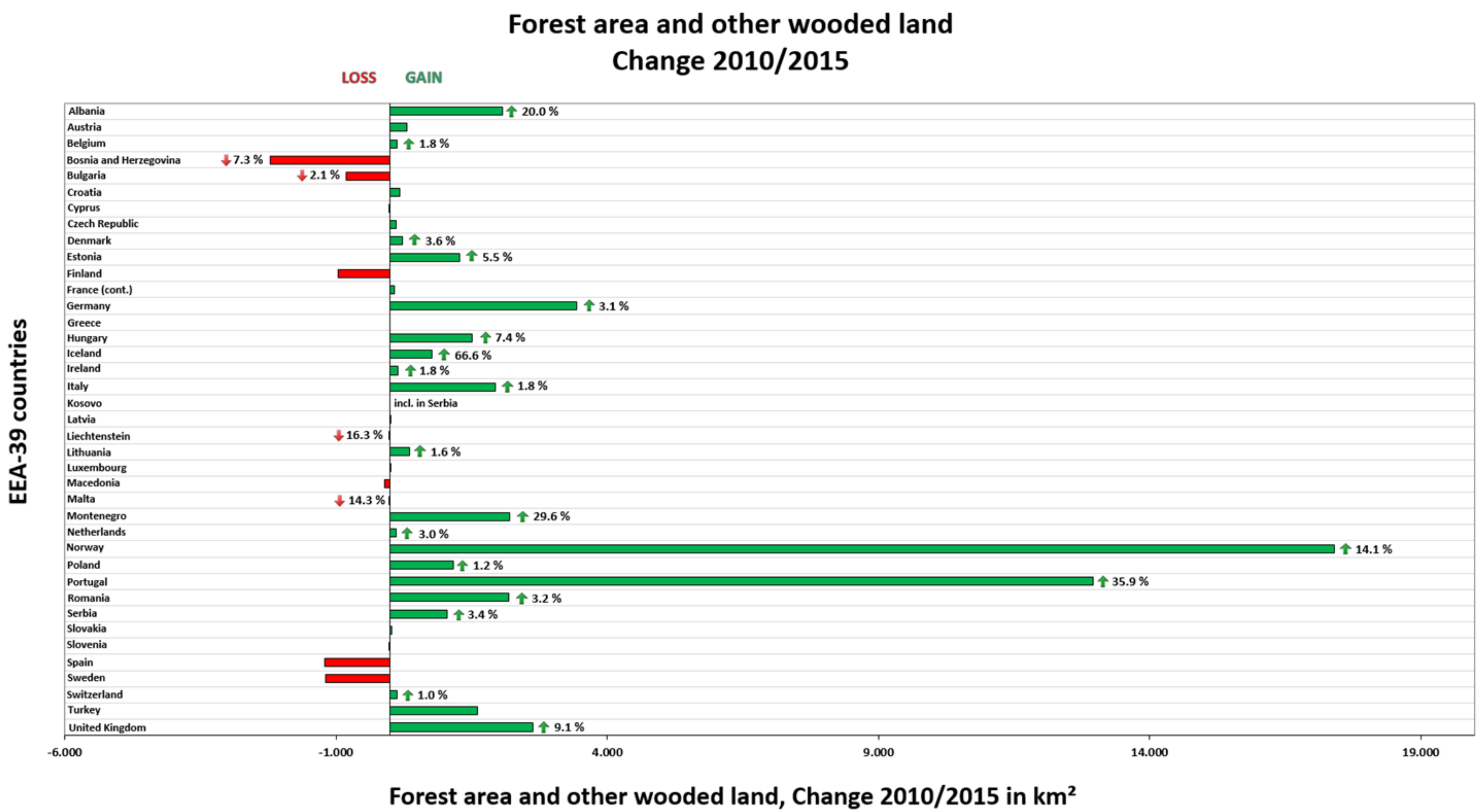


Figure 2-19 – Forest area and other wooded land, change 2010/2015 per country in km². Changes, greater or equal then 1 % are given in percent (FAO, 2011 and FAO, 2015d).

2.3.2.2.2 Global Forest Resources Assessment

The Global Forest Resources Assessment is also provided by the Food and Agriculture Organization of the United Nations (FAO), but it deals with the status and trends in forests and their management at a global scale. Its information ranges from 1990-2015, thus it covers a period of 25 years, too (FAO, 2015e). Data were collected by the countries, with their specific survey methods, but with agreed definitions of the investigation object (Keenan et al., 2015). In this chapter, only information on forests and other wooded land is examined, thus data with other wooded land, only available for 2010 and 2015, is used here.

2.3.2.2.2.1 Results - Forest area and other wooded Land

According to the Global Forest Resources Assessment data of 2010 and 2015, the forest area changed from a proportion of 38 % of the land area to 39 % in 2015, in 36 of the EEA-39 countries. The data suggest that there is an overall gain in forest area of 1.6 % (> 35,000 km²) from 2010 to 2015 (see Figure 2-16), which is slightly lower (annual change rate of 0.3 %) than the data of the State of Europe's Forests Reports, is as well in a representative range for assessing forest area changes in Europe.

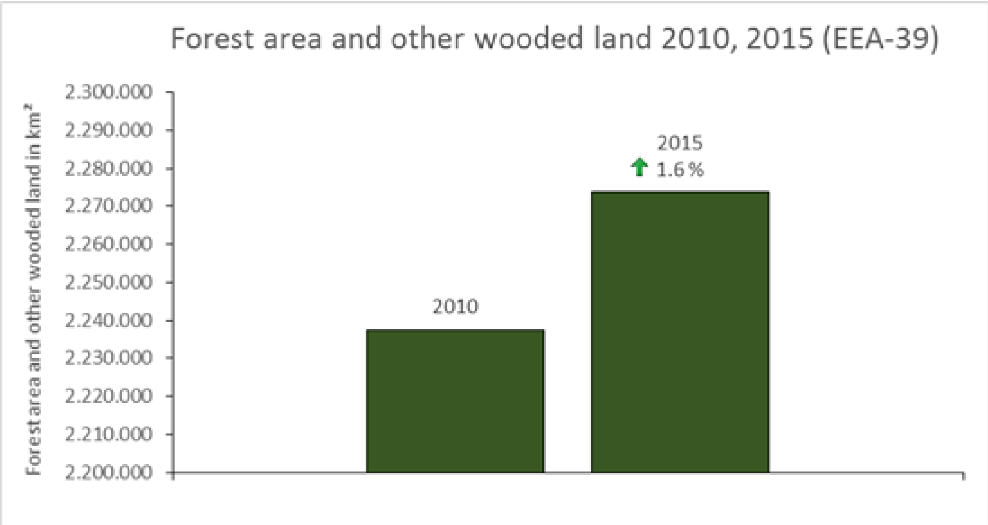


Figure 2-20 – Forest area and other wooded land 2010, 2015 in km² (EEA-39), (FAO, 2015e).

The relative changes in the individual countries exhibit that particularly Sweden is confronted with a loss in forest area of 7,400 km² (2.4 %), followed by Finland with (2,500 km², 1.1 %) and Spain (1,200 km², 0.4 %). Nevertheless, the huge amount of gains in forest area in e.g. Norway (10.6 %) or Portugal (35.9 %) of each about 13,000 km² and Germany (3,400 km², 3.1 %), lead to an overall gain in forest area. Especially such large and exceptional fluctuations as reported for Norway and Portugal suggests that there might be either a change in the (national) forest definition or that different survey methods and/or statistical corrections influencing the data basis have been applied between the two reporting dates. For more detailed change rates between the different years (see Annex).

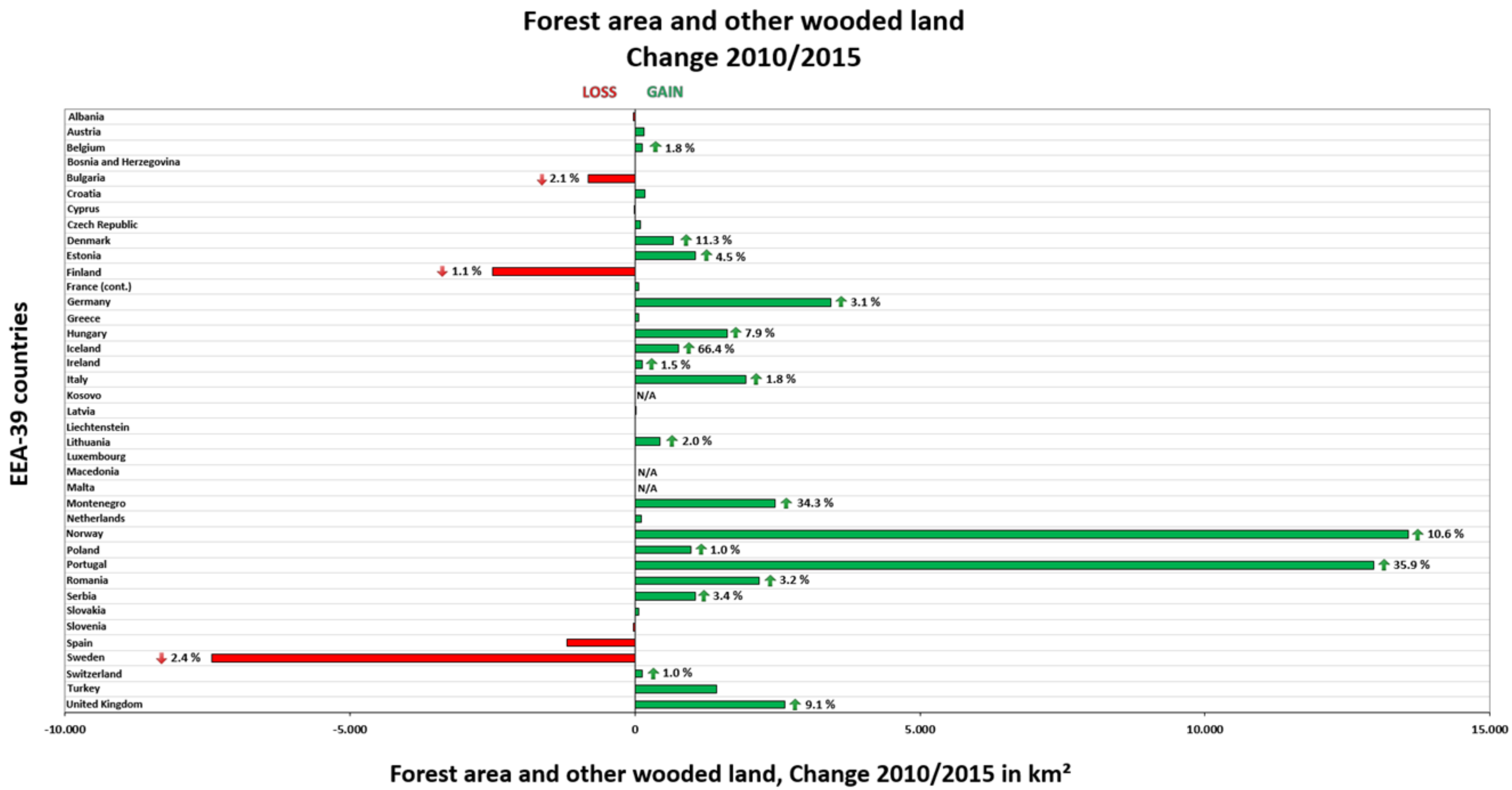


Figure 2-21 – Forest area and other wooded land, change 2010/2015 per country in km². Changes, greater or equal then 1 % are given in percent (FAO, 2010 and FAO, 2015e).

2.3.2.3 Conclusion

In synopsis, the investigated data on forested areas in Europe all agree in showing an overall gain in forest area until 2012/2015, however at different magnitudes. Whereas CLC data show an overall gain in forest area of 1.8 % from 2000 to 2012, the data of the Global Forest Resources Assessment (GFRA) Report 2015 display the same increase in forest area of 1.6 %, but within the time interval 2010 to 2015. The State of Europe's Forests (SoEF) Report 2015 indicates a gain in combined forest area and other wooded land of 2.1 % between 2010 and 2015. Although GFRA and SoEF reports have been both published by the FAO, the reported figures differ at least partially significantly per country, which indicates that there might be different forest definitions taken into account.

Nevertheless, an increase of the forest area across Europe in the order of magnitude of 1-2 % in 5-10 years seems to have taken place. Considering the related overall areas, these are significant gains in forest cover. However, breaking the figures down to smaller time intervals, e.g. to one year, it becomes obvious that the extent of annual net increase of forest area is rather small on European extent, i.e. presumably < 0.5% per year. The trend shows an accelerating increase rate in the recent years until 2015.

With the latest available CLC 2018 database, a source beyond the reference year 2015 could be taken into account, which indicates a turnaround in the overall forest increase for the period 2012 to 2018. For the first time since beginning of the CLC inventory, a slight loss of the European forest area in the magnitude of 0.1 % can be observed. Even though most of the EEA-39 countries still show an increase in their overall forest area, the observed loss sums up to more of 15,000 km² with the largest part (>75 %) in well-wooded countries like Sweden, Portugal and Spain. The observed loss seems to be associated with extensive forest fires which have taken place in the recent years, specifically in 2017 and 2018. The thereof overall resulting annual change rate is lower than -0.02 %, but with the ongoing process of climate change, an increase in the frequency and extent of such extreme events has to be expected in future.

At this point, it should be mentioned that the investigated overall change rates show only the net result over all regional increases and decreases, whereas spatially explicit change patterns (e. g. forest fires in the Mediterranean) do frequently show higher rates of changes, as also indicated by individual member state figures above. Furthermore, the changes in forested or tree-covered areas do not reflect changes in quality or properties of these areas, such as (long-term) changes in the dominant leaf type composition (broadleaved vs. coniferous) or (mid-term) in tree cover density, etc. Thus, the overall extent of all "changes" in forested and tree-covered areas will be higher than the indicated figure of forest area change. Anyway, for the ECoLaSS goal to identify the optimal incremental HRL Forest update frequency, the changes in forest/tree cover extent are considered more relevant, since any incremental update methodology will have to primarily focus on this, potentially rather short-term changing features, whereas the very slow changes in the forest properties will have to be captured in longer cycles.

2.3.3 Grassland

As the largest biome of the planet, grassland – comprising both soil and plants – houses a variety of ecosystems, counters soil erosion, stimulates remineralisation and accumulation of humus, protects groundwater and has – similar to forest – high potential of long-term storage of CO_2 (Ciais et al. 2010). The wide geographic spread of grasslands across different climatic, topographic and geological conditions within the European countries reflects their adaptiveness and resilience. However, human impact and climate change will have strong implications on the dissemination of grasslands, their biological diversity and their biomass production potential (Chang et al. 2017).

Studies at national and European level identify a loss of grassland areas in the EEA countries as well as a considerable degradation of grassland ecosystems within the last decades (Velthoff et al. 2014; FAOSTAT 2017; CLC 2017; EUROSTAT 2017; CORINE Land Cover Data 1990-2018; BfN: Agrarreport 2017; Gang et al. 2014; European Commission: Environment Directorate-General 2008).

The decrease in grassland areas – in a pan-European as well as in global context – results on the one hand from growing demands for crop and fodder production and a general intensification in industrial crop and livestock farming in favourable areas which fosters the conversion of highly valuable grassland areas into cropland; on the other hand, it is the consequence of abandoning vast grassland in marginal areas leading to widespread bush encroachment due to the reduced practice of extensive management system (Landau et al. 2000; Bernuès et al. 2000; Ates et al. 2012). As part of natural as well as cultivated landscape, it is of great importance to have detailed knowledge about distribution and expansion of grasslands as well as to have a reliable basis for change detection in the future in order to preserve natural grasslands and to adopt management schemes for cultivated grasslands.

Data sources concerning grassland in a pan-European context are Corine Land Cover, LUCAS data from Eurostat or Land cover data from FAOSTAT. The CORINE inventories have been produced since 1990 and are updated in 2000 continuing with a 6 years update cycle (the latest status layer available was produced for the reference year 2018). The layer of CLCC is produced since 2000. The data sets provide a broad overview of grassland changes at European level (European Union, 2019). The LUCAS points are available with an update rate of every 3 years since 2006 to identify changes in land use and land cover in the European Union. The previous published LUCAS survey is from 2012 and then covered all 27 EU countries including observations at more than 270,000 points. A following LUCAS survey was carried out in 2015 over 28 members states with 273 401 points followed by the most recent LUCAS survey that was published in April 2018, including 1,090,863 points distributed over the same area as in 2015 (Eurostat 2019). These data cannot provide an adequate basis for direct comparison and change detection due to their individual data acquisition methods, updating different coverage, diverse categories regarding land cover classes and/or differing definitions on grassland vegetation. However, an analysis of available time series of these data sources could give a basic indication of potential change, its amount and temporal and spatial dynamic and thus supports a definition of possible update frequencies of the HRL grassland.

2.3.3.1 Expected magnitude of changes based on land cover data from FAOSTAT

The Food and Agriculture Organization of the United Nations (FAO) collects annual data on land cover and land use from all EEA countries. Concerning the grassland status in the EEA countries the FAO provides a data basis which allows grassland dynamic analysis and the identification of trends. For most EEA countries the annual data collection of the FAO starts in 1961. Within the first decades, data were either provided by “manual estimation” or “FAO estimate”, later on by “Official data reported on FAO Questionnaires from countries” or by “Data reported on country official publications or web sites (Official) or trade country files”.

2.3.3.1.1 Change Analysis

In order to get representative figures, data from 2000 onwards are used for the following analyses. Since then most of the todays EEA countries provided statistical data concerning land cover.
FAOSTAT specifies several land cover categories forest, agricultural and other; the category agriculture is subdivided into arable land, permanent crops and permanent meadows and pastures. The defining approach for permanent meadows and pastures is not completely identical to the definition of the HRL Grassland 2015

(AD07), however it could support an estimating concerning the magnitude of expected grassland changes and their spatial and temporal dynamic.

Definitions of the FAO

Permanent meadows & pastures – cultivated:
Permanent meadows and pastures are the land used permanently (for a period of five years or more) for herbaceous forage crops that are managed and cultivated.

Permanent meadows & pastures - naturally growing:
Permanent meadows and pastures - Naturally growing is the land used permanently (for a period of five years or more) for herbaceous forage crops that is naturally growing.

Permanent meadows & pastures cultivated, non-irrigated:
Permanent meadows and pastures - Cultivated and non- irrigated, area of the "Cultivated Permanent meadows and pastures" which development relies on rainfed irrigation in a given year.

Permanent meadows and pastures - cultivated & actually irrigated:
Permanent meadows and pastures - Cultivated and irrigated, area of the "Cultivated Permanent meadows and pastures" which is actually irrigated in a given year.

2.3.3.1.2 Results

The analysis of the data for permanent pastures in the EEA countries reveals a decrease of 62.800 km²of grassland between the years 2000 and 2017. Figure 2-22 presents the analogous surface changes between the years 2000 and 2017. Countries like Spain, Poland and France show the greatest decrease of grassland between the years 2000 and 2017, whereas in Croatia Lithuania, Portugal and Turkey are showing an increase in grasslands (2000-2017).

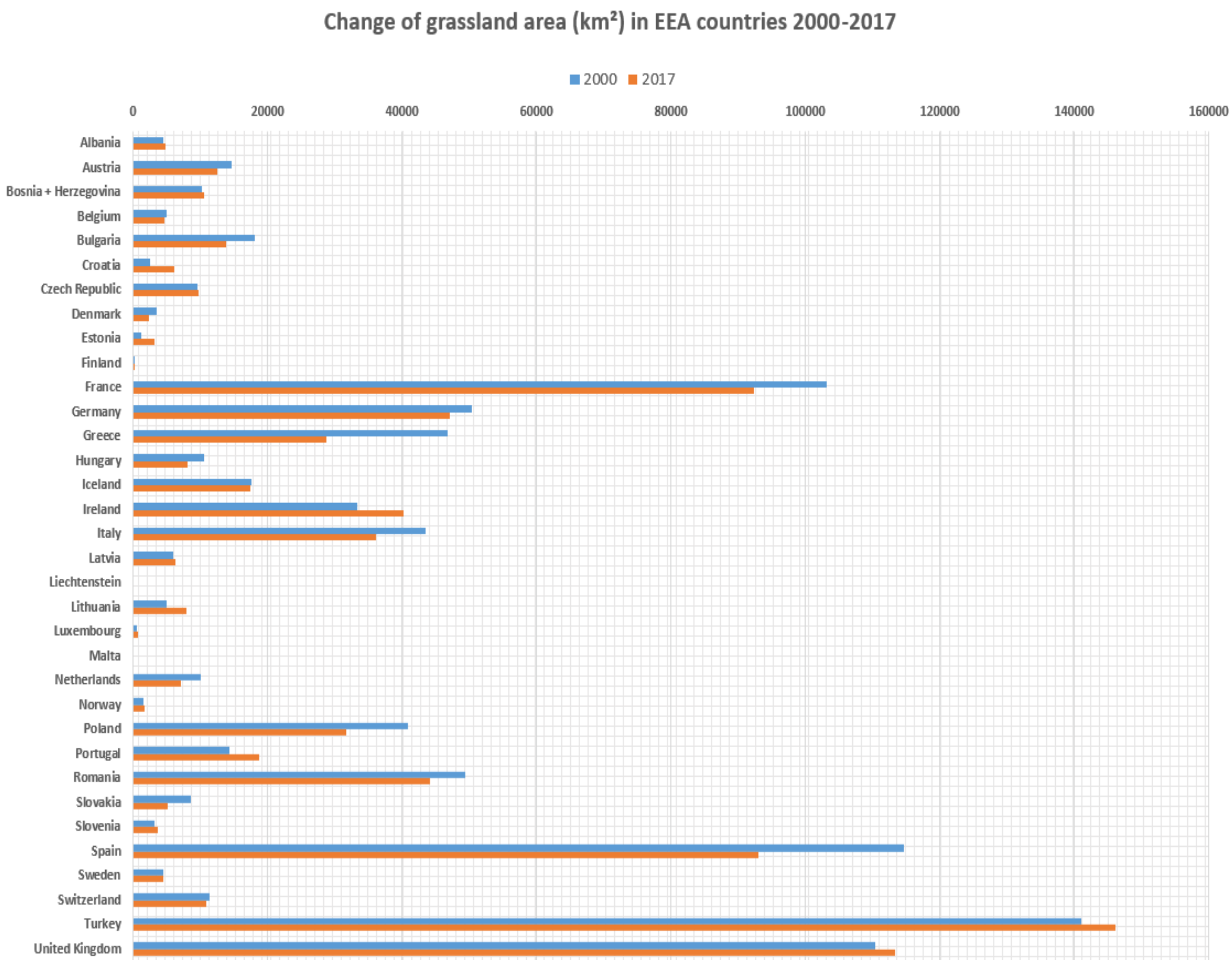


Figure 2-22 – Comparison of the change in permanent pastures for selected EEA countries for the years 2000 - 2015 (FAOSTAT 2017); excluded are those countries having joined the EU later.

Although the dynamic of the pastures differs a lot regarding amount of area and spatial dynamic (increase/decrease) over the years (there are countries revealing strong increase of pasture area) as shown in Figure 2-23, the tendency for a general decrease in permanent pastures in the pan-European area continued through the years until 2015. Afterwards it slightly increased and stagnated from 2016 to 2017 (see Table 5-10 in the Annex). In order not to tamper the outcome, those countries having joined the EU after the year 2000 or providing no data have been excluded (such as Cyprus, Kosovo, Macedonia, Montenegro or Serbia).

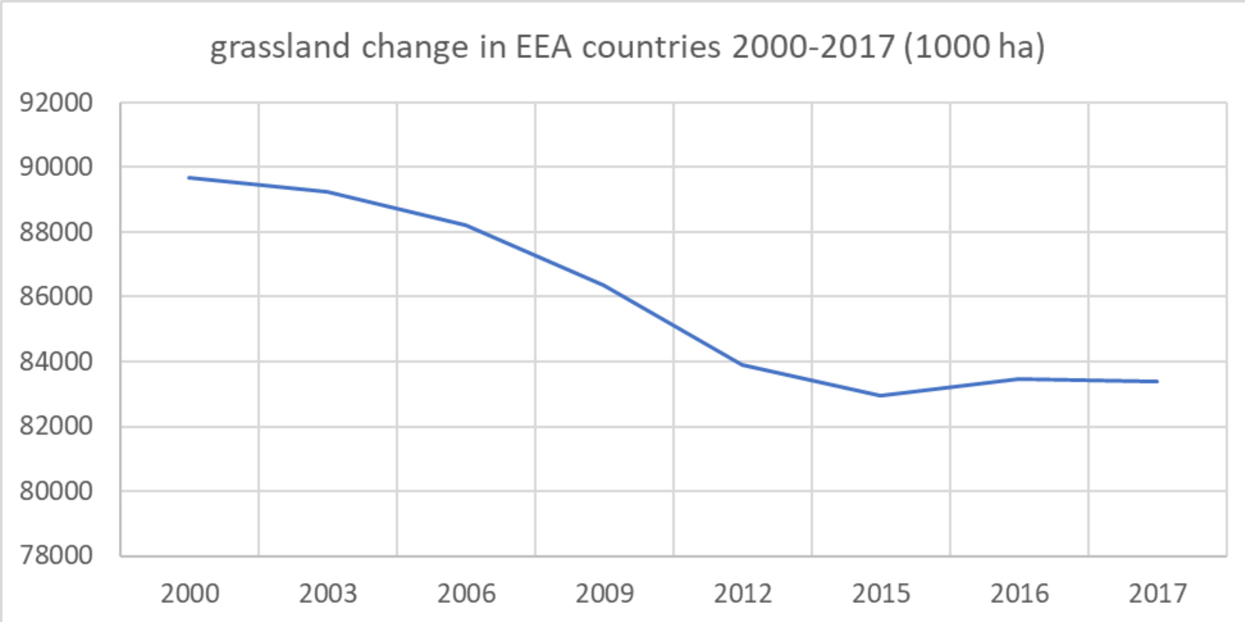


Figure 2-23 – Spatial dynamic of permanent pastures in selected EEA countries from the years 2000 - 2017 (FAOSTAT 2017).

2.3.3.2 Expected magnitude of changes based on CORINE Land Cover data

The CLC data inventory starts in 1985, with reference year of 1990 with updates in 2000, 2006, 2012 and 2018 consisting of 44 land cover classes. The CLC databases are produced by the EIONET network National Reference Land Cover (NRC/LC), coordinated by the EEA. They base on visual interpretation of HR imagery, applying semi-automated solutions and national in-situ data as well as GIS integration and generalisation. Since the 1990 database provides reliable data for only a selected number of countries, the analysis concerning grassland areas in the EEA countries focuses on the years 2000, 2006, 2012 and 2018. In this way, they are comparable to the FAOSTAT data.

2.3.3.2.1 Change Analysis

Within the CLC land cover classification, grassland is part of several subclasses and shapes various types of landscapes, such as Complex cultivation patterns (242), Beaches, dunes and plains (331), Sparsely vegetated areas (333) and salt marshes (421). The classes of Pastures (231) and Natural grassland (321) (see Table 2-8) are not exactly in accordance to the grassland definition of the HRL Grassland 2015, but provide an adequate basis for a rough analysis of the spatial and temporal dynamic of grassland.

Table 2-8 – CLC data definitions

Definition of the CLC data		
231 Pastures **Dense grass cover, of floral composition, dominated by graminacea, not under a rotation system. Mainly for grazing, but the fodder may be harvested mechanically. Includes areas with hedges (bocage).**	This heading includes: ▪ temporary and artificial pastures not under a rotation system which become permanent grasslands five years after ploughing. Significant number of natural vegetation species are present (as *Taraxacum officinale, Ranunculus* spp., *Chrisanthemum leucantemum, Knautia arvensis, Achillea millefolium, Salvia* spp., etc.), ▪ abandoned arable land not under a rotation system used as pastures (after 3 years), ▪ pastures may include patches of arable land which do not cover 25 % of the total surface, ▪ humid meadows with dominating grass cover. Sedges, rushes, thistles, nettles, cover ▪ less than 25 % of the parcel surface, ▪ scattered trees and shrubs (10–20% of surface).	This heading excludes: ▪ military exercising grass fields (without grazing) (class 321), ▪ salt meadow located in intertidal flat areas (class 423), ▪ lawns inside sport and leisure facility areas (class 142), ▪ high-productive natural alpine meadows far from houses and/or crops (class 321), ▪ fodder crops (class 211), ▪ derelict grassland where semi-ligneous/ligneous vegetation cover at least 25 % of the parcel (class 322/324), ▪ strong humid meadows where hydrophile plant species cover at least 25 % of the parcel (class 411), ▪ herbaceous grass cover composed of non-palatable and undesirable species for cattle as Molinia spp. and Brachypodium spp. (class 321).
321 Natural Grassland **Low productivity grassland. Often situated in areas of rough, uneven ground. Frequently includes rocky areas, briars and heathland.**	This heading includes: ▪ Low productivity grassland. Often situated in areas of rough, uneven ground. Frequently includes rocky areas, briars and heathland. ▪ This heading includes: ▪ saline grasslands grown on temporary wet areas of saline soils, ▪ humid meadows where sedges, rushes, thistles, nettles cover more than 25 % of the parcel, ▪ natural grasslands with trees and shrubs if they do not cover more than 25 % of the surface to be considered, ▪ high-productive Alpine grasslands far from houses, crops and farming activities, ▪ herbaceous military training areas, ▪ grasslands which can be grazed, never sown and not otherwise managed by way of ▪ application of fertilizers, pesticides, drainage or reseeding except by burning, ▪ grasslands with a yearly productivity less than 1.500 units of fodder per ha, ▪ herbaceous grass covered composed of non-palatable gramineous species such as *Molinia spp.*and *Brachypodium spp.*, ▪ derelict natural grassland where ligneous vegetation cover less than 75 % of the area, ▪ grasslands found on calcareous soils with a high proportion of calcicole species of limestone, chalk Machair or Karst, ▪ grasslands dotted with bare rock areas which represent less than 25 % of the surface.	This heading excludes: ▪ grey dunes (class 331), ▪ swampy grassland (class 411), fallow land (class 211).

2.3.3.2.2 Results

The analysis of the dynamic of the CLC data for the years 1990-2018 reveals a high diversity concerning the amount of the grassland area, the percentage of both classes as well as the amount of change within these classes as shown in Figure 2-24 and Figure 2-25. The data from the year 1990 reflect a different database and is therefore not suitable for interpretation and comparisons. After CLC the overall area of grasslands increased between 2000 and 2012 followed by a slight decrease from 2012 to 2018. The internal dynamics of the grassland classes however show a different development, i.e. the area of pastures increases continuously whereas the natural grasslands experience a decrease throughout the years (see Table 5-11in the Annex).

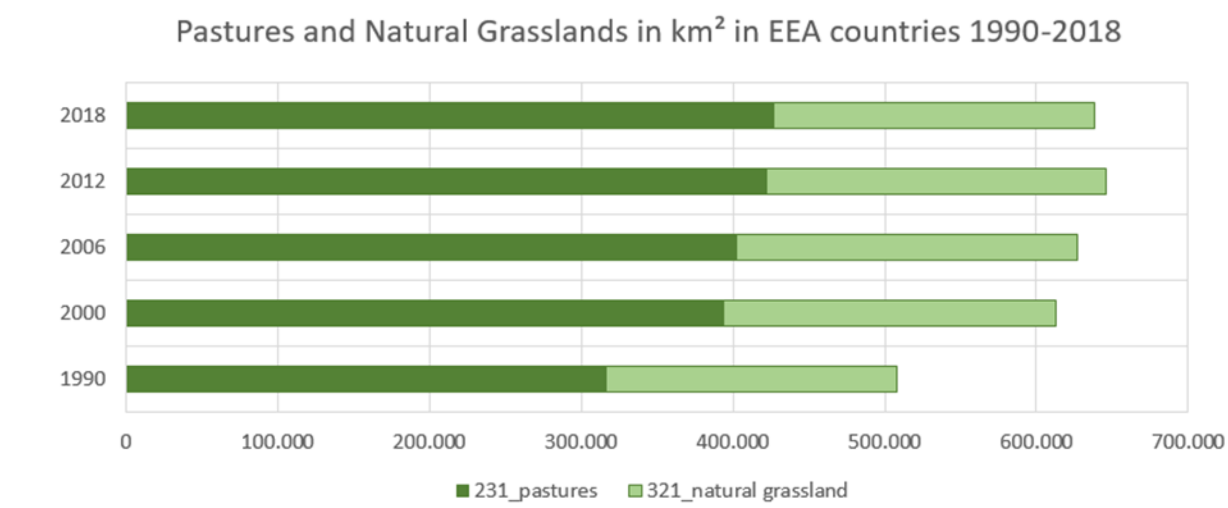


Figure 2-24 – Summarized grassland areas (Pastures and natural grasslands and their dynamic 1990-2018 (CLC 1990-2018); data from the year 1990 reflect a different database and are therefore not suitable for interpretation.

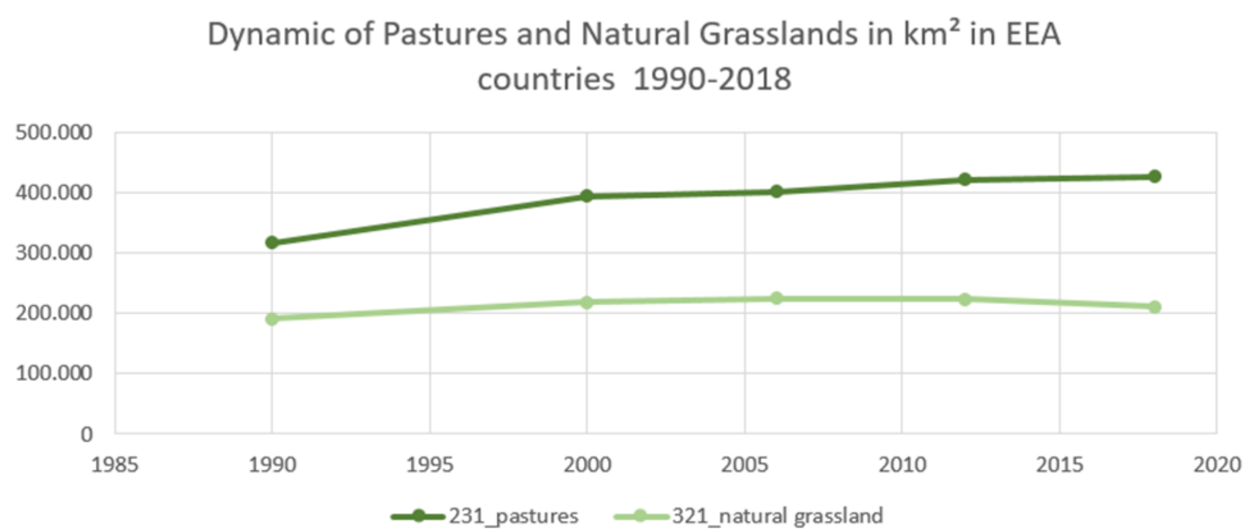


Figure 2-25 - Differing dynamic of pastures and natural grassland areas (CLC 2000-2018)

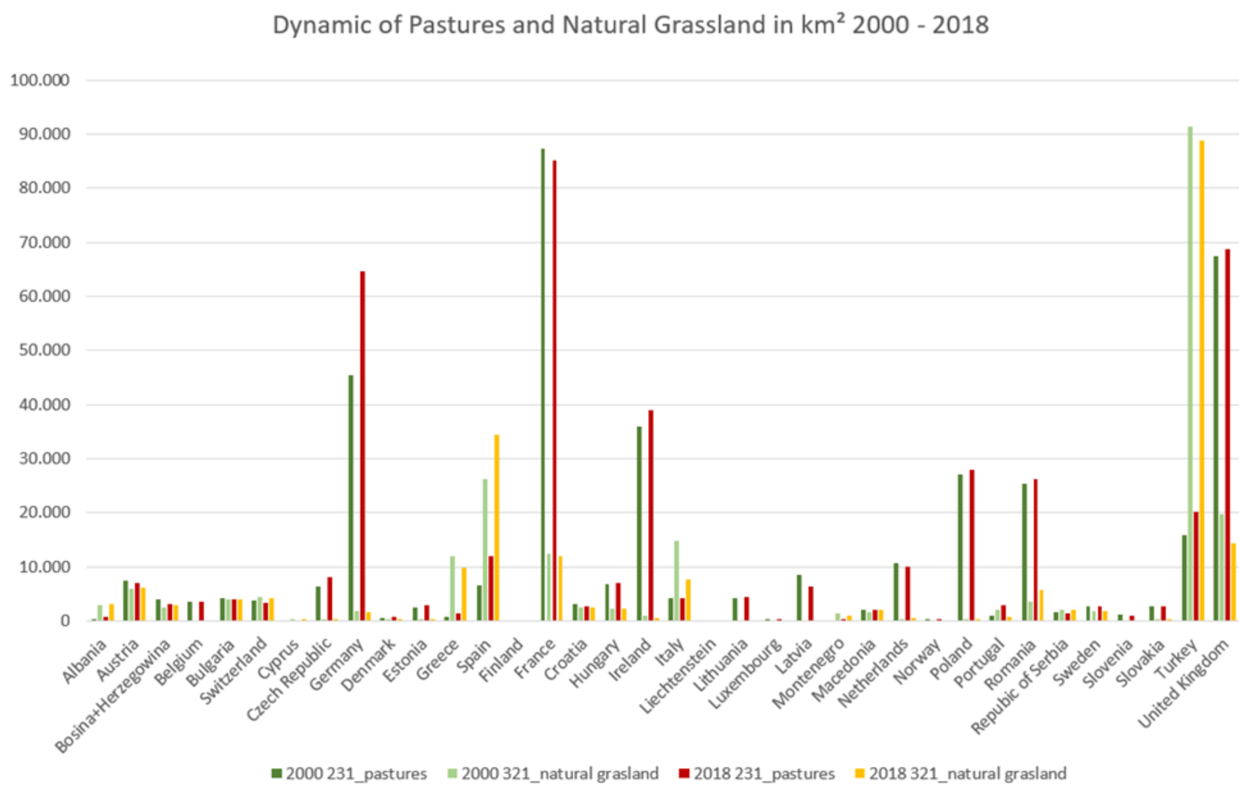


Figure 2-26 – Change of Pasture and Natural Grassland areas from the years 2000 up to 2018 (CLC 2000-2018).

Figure 2-26 shows the grassland loss/gain based on the CLC data for the years 2000-2018. Pastures show a remarkable increase from 2000 to 2018 in Germany and smaller increases in countries like Ireland, Romania, Turkey and the United Kingdom. Decreasing pasture areas can be observed for example in Austria, France, Latvia and the Netherlands. On the other hand, natural grasslands increased over the period from 2000 to 2018, e.g. in Spain and Romania. Other countries like Turkey record a decrease in natural grassland during that period.

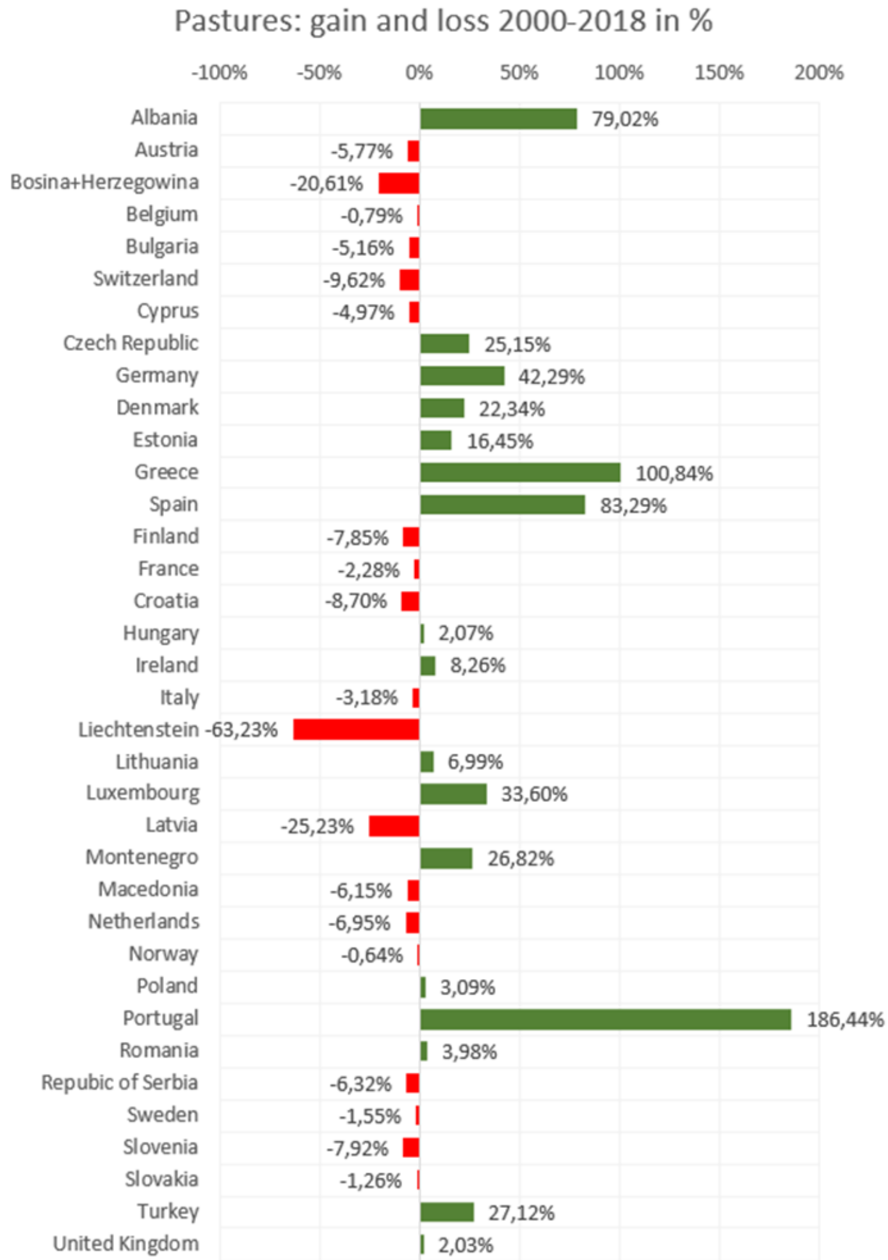


Figure 2-27 – Gain and loss within the pasture areas of the EEA countries (2000-2018) in percentages based on the status layers.

Furthermore, Figure 2-27 illustrates in detail the gain and loss for pasture areas in the EEA countries. The percentages over all countries indicate changes over 20% for pastures. Strongly increasing pasture areas with over 20% gain can be observed in Albania, Czech Republic, Germany, Denmark, Greece, Spain, Luxembourg, Montenegro, Portugal and Turkey. On the other hand, strongly decreasing pasture areas with over 20 % loss are located in Bosnia and Herzegovina and Lichtenstein. Further details on the dynamics could be gathered by analyzing the CLCC data as opposed to the status layers which exhibit a 25ha MMU compared with a 5ha MMU. Within the CLC status layer, only net changes are considered and not the combined areas which are affected by gains and losses. However, in order to show the dynamic of grasslands from the years 2000-2018 – in comparison to the FAOSTAT analysis the status layers are more suitable for an analysis.

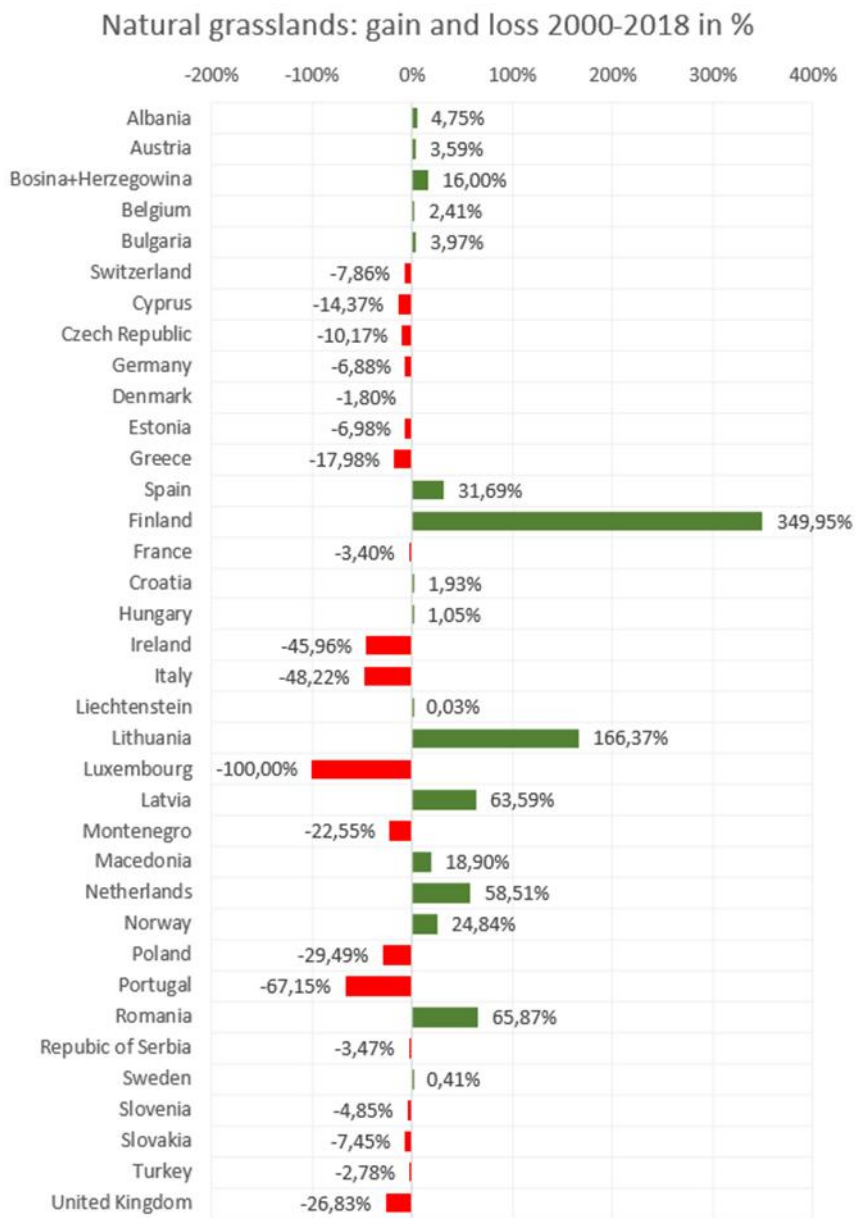


Figure 2-28 – Gain and loss within the natural grassland areas of the EEA countries (2000-2018) in percentage based on the status layers.

The analysis of the gain and loss within natural grasslands for the years 2000-2012 indicate changes over 30% for pastures. Strongly increasing natural grassland areas with over 30% gain could be observed in Finland, Netherlands, and Romania. On the other hand, strongly decreasing natural grassland areas with over 30% loss are located in Ireland, Luxemburg, Norway and Portugal. Additionally, to the gain of loss of natural grassland and pastures the changes between grassland and agricultural areas needs to be considered. When extending the analysis time frame to the years 2000-2018, as depicted in Figure 2-28, not only Finland, the Netherlands and Romania but also Spain, Lithuania and Latvia show a strong increase in percentage of natural grasslands (> 30%). Furthermore, Ireland, Italy, Luxembourg and Portugal show a strong decrease (< -30%).

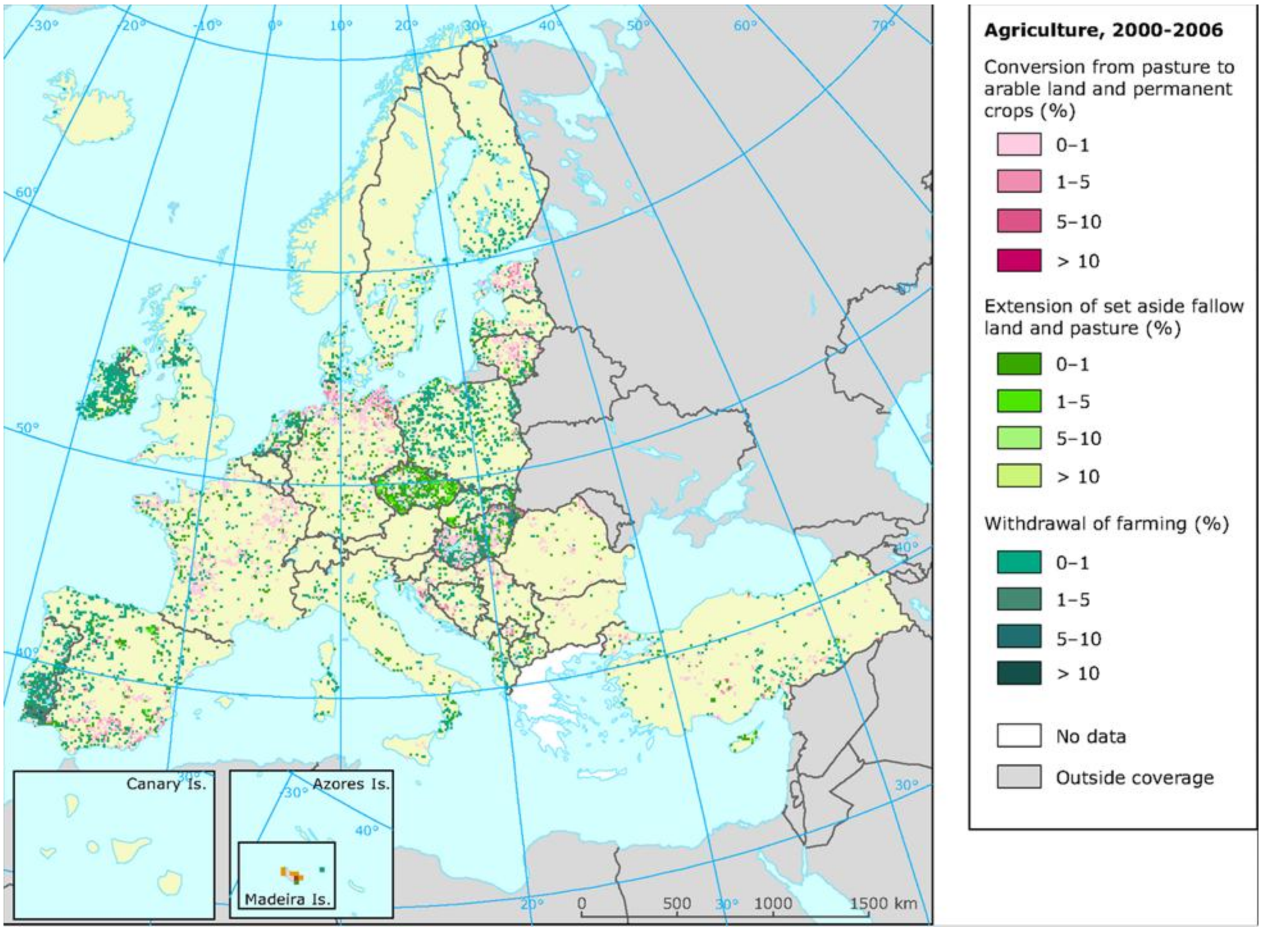


Figure 2-29 – Change in agriculture 2000-2006; Land Cover Flow (LCF) codes taken into account for the map: LCF41, LCF46, LCF6 (EEA, 2013).

Figure 2-29 shows the recorded changes in three categories of CLC from 2000-2006. Conversion from pasture to arable land and permanent crops mainly took place in the Baltics and northern Germany as well as sparsely throughout central France and southern Spain. Extension of set aside fallow land and pasture intensely took place in the Czech Republic and to a lesser degree in Scandinavia, western Spain and the Balkans. Withdrawal of farming was predominantly recorded in the Republic of Ireland, Portugal, eastern Hungary, Poland and the Netherlands.

Although the time range of the CLC data base (see Table 5-13 in the Annex) being not sufficient to draw final conclusions on the expected change of pastures and Natural grassland dynamic, some point can be stated:

There are countries where the distribution of both types of grassland is nearly balanced within the analyzed time period, such as Austria, Bulgaria, Switzerland, Croatia, Macedonia or the Republic of Serbia (see Figure 2-27). On the other hand, some countries reveal a disproportionally high percentage of natural grassland compared to pastures in both time slots, 2000 and 2012, namely Albania (433/775 km^2 pastures and 2.948/3.088 km^2 natural grassland), Greece (700/1.406 km^2 pastures and 11.935/9.789 km^2 natural grassland) or Turkey (15.803/20.088 km^2 pastures and 91.311/88.776 km^2 natural grassland). Furthermore, several countries show a significant increase in pastures and at the same time a strongly decrease in natural grassland, here to name Germany (+42% pastures, -7% natural grassland), Greece (+101% pastures, -18% natural grassland), Portugal (+186% pastures, -67% natural grassland), Ireland (+8% pastures, -46% natural grassland), Turkey (+27% pastures, -3% natural grassland) and the UK (+2% pastures, -27% natural grassland). Other countries reveal an overall increase in both areas. It may be assumed that arable land or forest areas have been converted into pastures here.

As already mentioned, the data source has to be analysed with care. Outliers like the example of Finland might not necessarily reflect real change but could also rely on changing methods of data acquisition.

2.3.3.3 Expected magnitude of changes based on LUCAS data from EUROSTAT

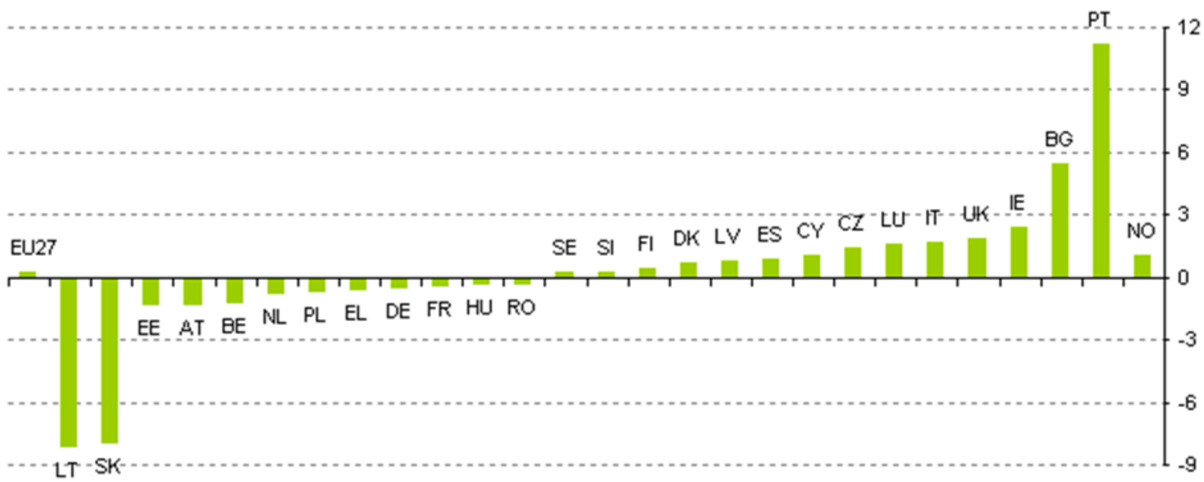


Figure 2-30 – Change in points of percentage for the share of grassland in total UAA, 2003-2007 (EU, 2013).

According to EUROSTAT, the European Union had 172 million ha of UAA in 2007. 104 million ha (60%) were arable land while 57 million ha (33%) were permanent grassland and 11 million ha (6%) were crops. Grassland plays an important role in animal fodder production as grassland and fodder drops together made up 43% of UAA in 2007.

Overall, the share of grassland throughout the European Union increased slightly from 2003 to 2007. However, as can be seen in Figure 2-30, for some countries the changes were significant. Lithuania and Slovakia both lost more than 7 percent of their grassland area during these years. On the other hand, Bulgaria experienced an increase of over five, Portugal one of over 10%.

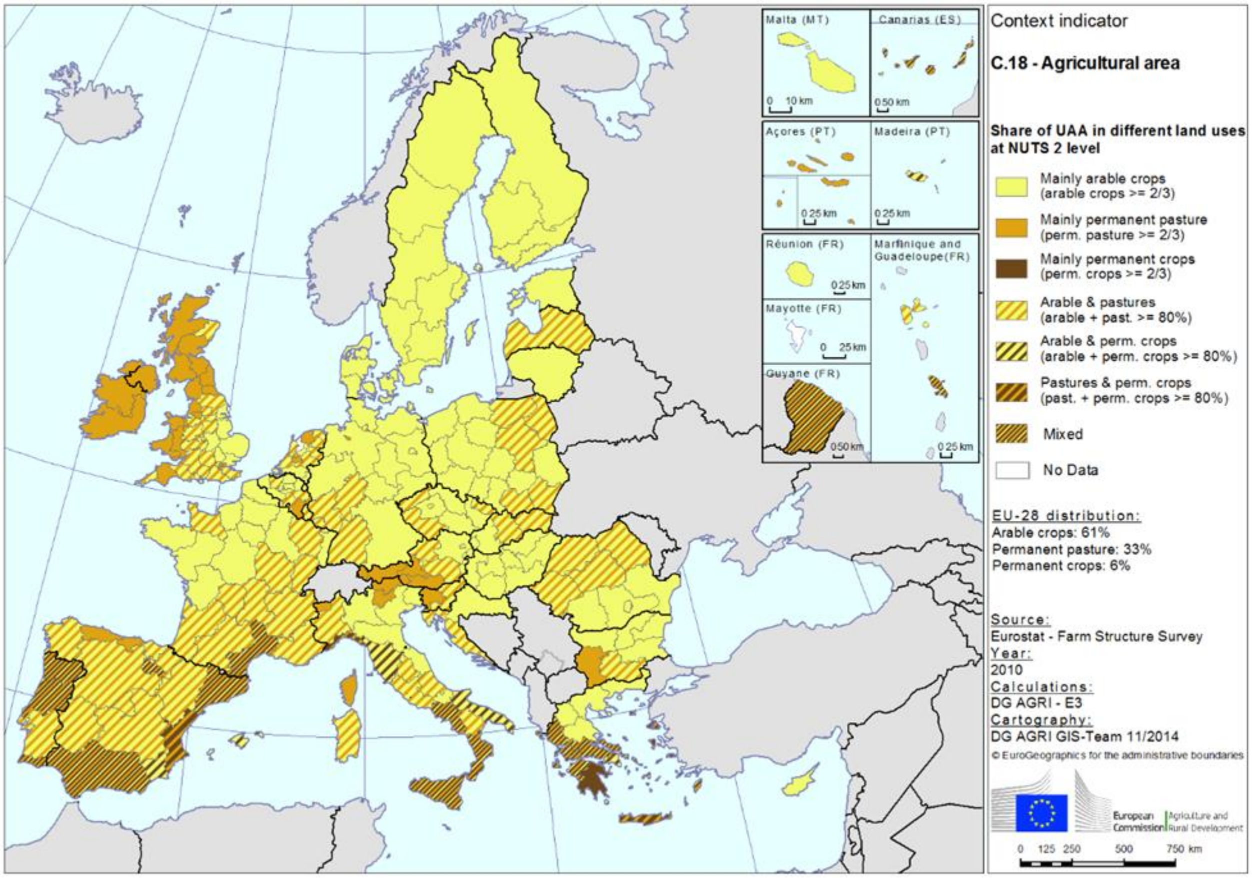


Figure 2-31 – Distribution between agricultural crops and pastures in 2010 (EU, 2013).

In 2010 the majority of UAA regions was mainly covered by arable crops (yellow in Figure 2-31) or made up of arable land and pastures (yellow and orange stripes in Figure 2-31). Exceptions are Wales, Scotland, Ireland, western Austria and western Bulgaria, all of which are covered manly by pastures (orange in Figure 2-31). In the Mediterranean many regions are mixed between all three land uses.

The changes between the share of UAA in 2010 (see Figure 2-31) and 2013 (see Figure 2-32) show that the number of regions dominated by two land use types combined significantly decreased. These regions tended to have a 67% majority of a land use class in 2013 where they were mixed in 2010. This large scale change appears in all larger countries, from Spain though southern France and western Germany to eastern Poland and northern Romania. It is also visible in England, smaller CEE countries and Latvia. Among the changing regions mountainous ones tend to a majority of permanent grassland and meadows while relatively flat areas tend to a majority of arable land. On the contrary, formerly mixed agricultural areas largely remained mixed.

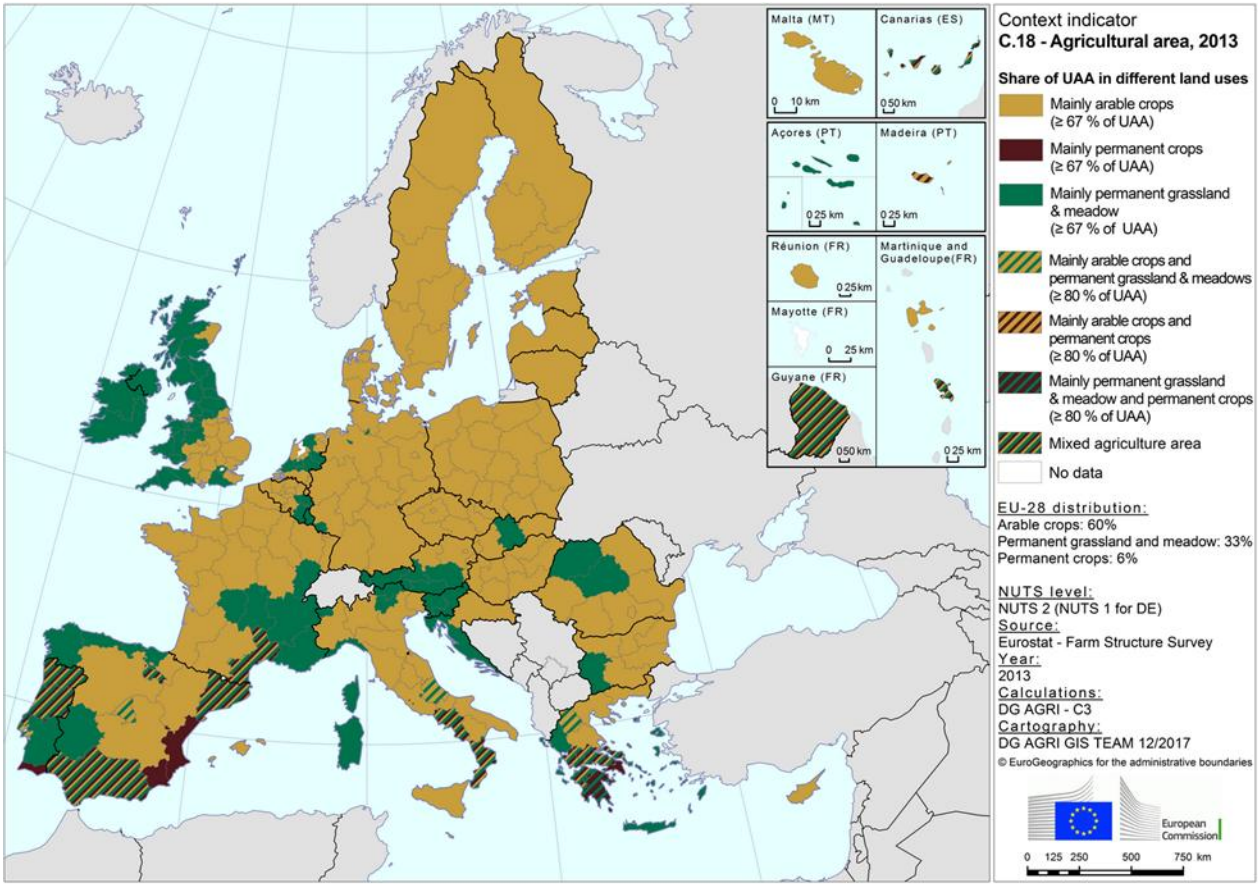


Figure 2-32 – Distribution between agricultural crops and pastures in in 2013; https://ec.europa.eu/agriculture/cap-indicators/context/2017/c18_en.jpg

In 2015 the shares of total land use in the EU-28 were 22.2% of cropland, 20.7% was grassland. Forests, artificial areas, scrublands, wetlands and water area made up the rest of the land cover. Grasslands mainly appear in regions where either crop growing is unfeasible or as overgrowth over forest clear-cuts. Areas with low shares of grassland have harsh (extremely hot or extremely cold) conditions. This is visible in the northern countries (Finland and Sweden) as well as on Mediterranean islands (Malta and Cyprus). On the contrary the temperate Republic of Ireland is the only EU member state with more than half of its area as grassland in 2015 (56.3 percent) (Eurostat, 2017).

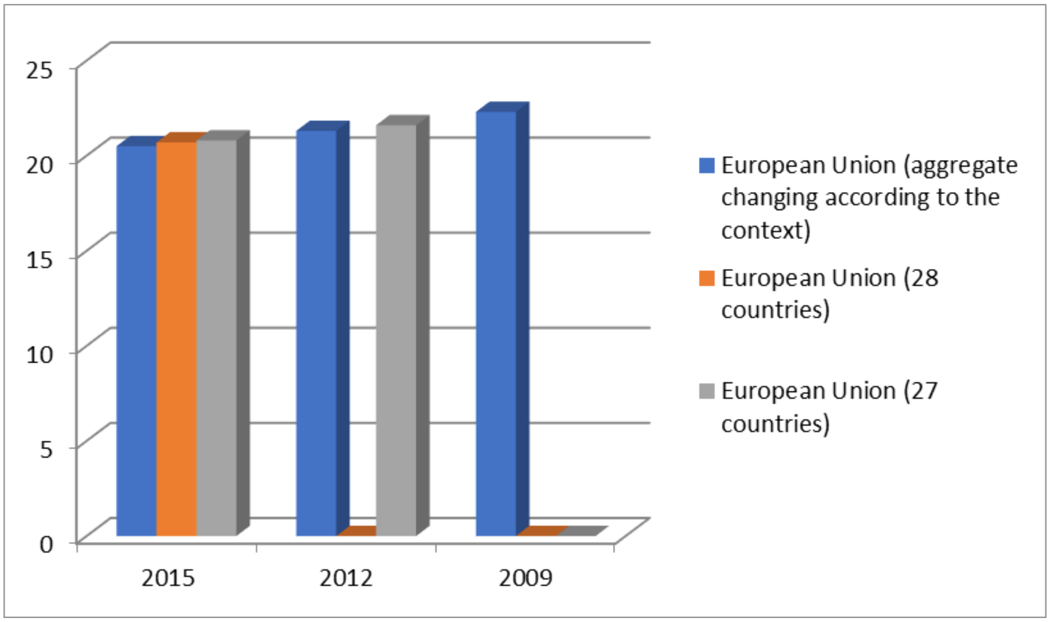


Figure 2-33 – EU land cover - grassland in percentage (Eurostat 2017).

Figure 2-33 shows the change of grassland in the entire European Union. The three-year intervals show a decrease of grassland since 2009. Since data is only available from the date of a country joining the union, data for all 28 countries is missing for 2012 and 2009 as data for 27 countries is missing for 2009. Still, a trend is visible, even when taking into account that Croatia's membership brought a country with below average grassland share into the union.

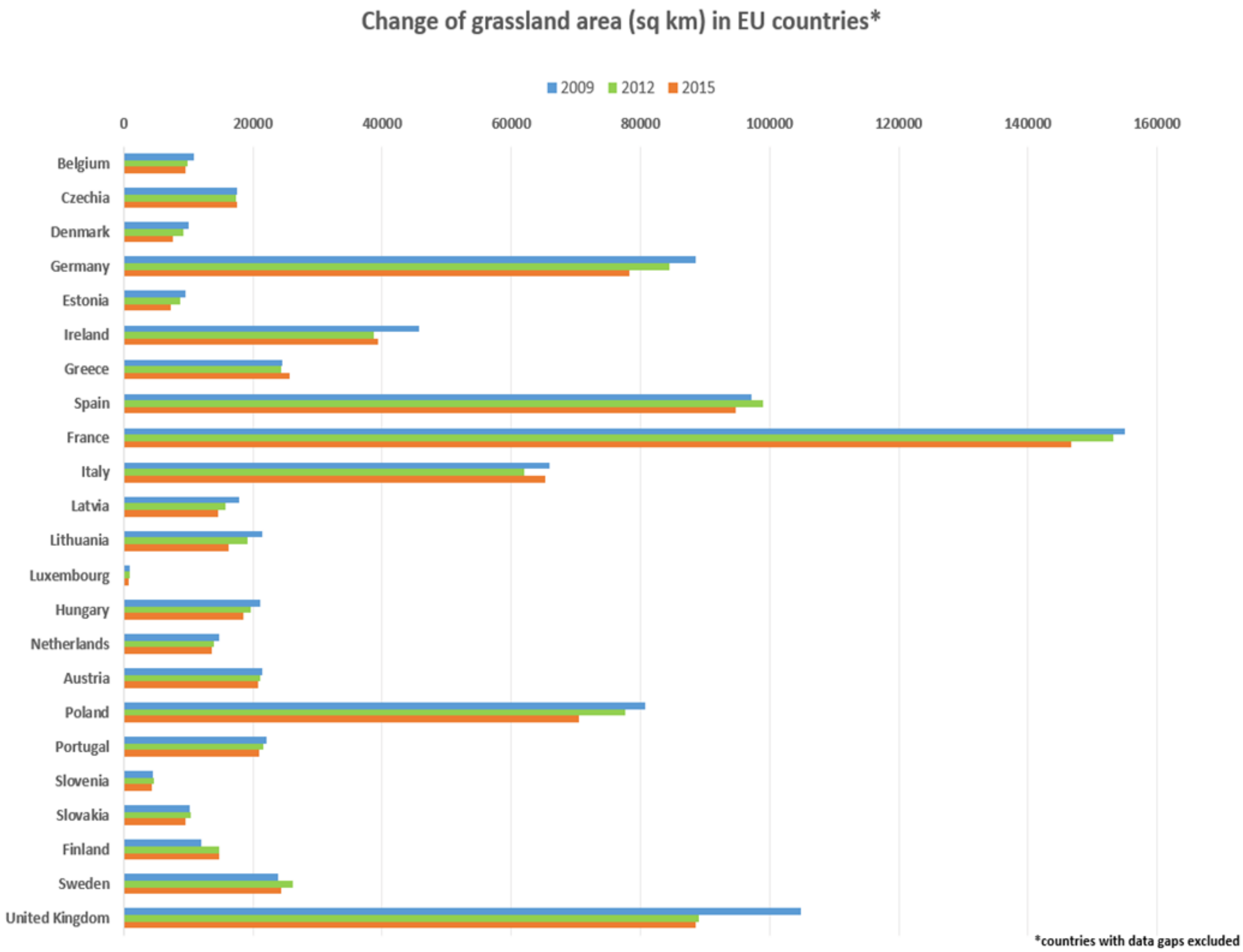


Figure 2-34 – Land cover - grassland in percentage for European member states from 2009 – 2015 (Eurostat 2017).

Looking at Figure 2-34 the strong differences between countries become visible. The lowest shares of grassland are to be found in Sweden and Finland. This was also established in the CLC data, but there Hungary was found to have a comparable share of grassland to Sweden, which in LUCAS data is not the case. Ireland and the UK have the highest percentages of grassland, followed by Belgium and The Netherlands. What these countries with high shares have in common is a reduction of their grassland since 2009. Like in the overall European statistics the lacking data from countries before their joining of the European Union makes comparisons difficult.

2.3.3.4 Conclusion

The analysis of all three data sources, FAO, Eurostat and CLC shows that there is high diversity in Europe concerning both, amount of grassland areas as well as the spatial and temporal dynamics of those land cover types. For example, grassland cover in Ireland decreased from 65% in 2009 to 56% in 2015. In Lithuania, Eurostat reports a decrease from 30% in 2012 to 25% in 2015 whereas for Malta, an increase from 17% in 2012 to 23% in 2015 can be observed. The investigated data on grassland areas in Europe all agree in showing an overall loss in grassland areas over 2000-2015, 2000-2017 and 2000-2018, respectively. However, the magnitude of this recorded loss differs between the different studies. The FAO statistics show a general trend

of grassland loss from 2000-2017 of ~-7%. The LUCAS data also show a trend for grassland loss within the EEA-39 countries of overall -8%. What should be considered is that the results from different data sources are based on different grassland definitions. The CLC data differentiates between natural grasslands and pastures showing an overall gain for pastures of ~8% from 2000 to 2018, whereas a loss for natural grasslands (~-4%) could be observed. Although the overall area of grasslands seems to slightly increase (~4%), the dynamic within the different grassland classes reveals that natural grassland is on decline whereas the area of pasture increases between 2000 and 2018.
The overall trend also seems to indicate an accelerating change rate in the recent few years. Given the knowledge that grasslands are highly valuable ecosystems that need protection, these analyses confirm the need for a dense and accurate monitoring and therefore the need for a reliable data basis. The production of such an accurate data basis by use of HR data and the combination of a highly automated classification and an elaborate approach resulting in a pan-European grassland vegetation cover may on the one hand show the effects of precedent political, economic and agricultural decisions and on the other hand provide the basis for future regulating measures.

2.4 Defining an incremental update for HRLs

Currently updates are provided every 3 years around a reference year with a +/- one-year tolerance for image acquisition. Yearly incremental update would mean that this approach would no longer be suitable. Instead, even though it may still be tricky to obtain a full pan-European coverage on a yearly basis, it may still be possible to provide yearly updates using the latest cloud free or S-1 image available for any given area. A cut-off date could be set (e.g. 31 October to coincide with the northern hemisphere vegetation cycle) to stop image acquisition for the current year and image acquisition could then start for the next yearly update. These yearly updates would be supported by a QC layer which among other things would indicate the number of valid cloud free observations available for any given pixel on a monthly basis (higher quality is expected if cloud free observations are available for every month rather than having the same number of images but over only a few months during the year.

The incremental update product would ideally contain only detected gains or losses. The yearly or more cycle could still be kept to provide status layer updates which would include corrections made possible by getting a longer observation period, especially for layers covering a limited proportion of the total area such as IMD. This status layer update would be an opportunity to integrate the incremental yearly updates and correct for omission and commission errors from previous years.

The production of yearly incremental updates would ensure that omission and commission errors are kept to a minimum. Currently the change detection approach is based on a post-classification approach by computing the difference between the previous and current status maps. Potential omission and commission errors are taken into account to provide corrective information in the update as a complement to the loss/gain information. Such errors were documented in in the revision of the IMP HRL time series and in this project, errors can come from:

- Change in sensor specifications, in particular spatial resolution;
- Regional particularity, such as the prevalence of bare soils in the South-East region, leading to more confusion with urban areas, despite a careful selection of training samples;
- The scarcity of EO information over cloudy regions.

The first issue is expected to be tackled by the use of Sentinel constellations for future HRL updates, leading to a more balanced rate of commission and omission errors and the third is expected to be improved by the introduction of SAR data from S-1 twin satellites. In addition, it may be in the future possible to move from the current post-classification approach to an image to image change detection considering that unlike in the first years of the HRL production, there will now be more consistency in terms of input data thanks to the Sentinel. However, this will require that a better and more consistent atmospheric correction is applied.

2.5 Defining the most appropriate update frequency, considering the dynamics/stability and EO data requirements

Most land cover types at a pan-European or global scale include a wide range of variation in vegetation cover, plant structure, and understory or background condition, as well as significant variability in the way the vegetation cover changes throughout the annual cycle. In such a highly variable environment, classification algorithms often need considerable tuning to optimize their accuracy (Strahler et al., 2006). For each thematic product, an analysis will be performed for defining the optimal update period related to environmental conditions (e.g., vegetation phenology, cloud coverage etc.) and the expected accuracy related to the user needs. However, this ideal time period will be mainly facing the EO data availability which is the principal limitation. The data source for the HRLs production will progressively be shifted from the European HR image coverage 2012/2015/2018 (ESA DWH) to the nominal S-1/-2 data provision. This will ensure more frequent acquisition and continuous change monitoring services. The proposed yearly update frequency combining full coverage inventories with incremental spatially partial updates will be tested with different data provisions and assessed in real monitoring conditions over some prototype sites.

2.5.1 Imperviousness Layer

As shown earlier, the current production of the HRL Imperviousness relies on data acquired over a three-year period (reference year +/- one year). Therefore, it does not currently seem possible to reduce the current 3-yearly cycle based on the experience from the HRL2015 production.
It should also be noted that the rate of change, although always steadily increasing, is still very small particularly when compared against the whole area of Europe. The average annual increase between 2006 and 2012 is just over 0.5% for a total area representing less than 5% of the total area. At European level, this represents an area of between 1-2,000 km² per annum which is extremely little especially considering that it tends to be scattered over the entire country in a large number of small patches. This makes the detection of urban expansion quite a challenging task.
Nevertheless, in the second phase of the project, the yearly prototype (2017-2018) realized over the South-West demonstration site has proven that S-1 dataset (and its temporal statistics over the year) can improve the S-2 optical classification.

It is also clear that there seems to be a geographical heterogeneity in the magnitude of changes observed. Interestingly, this pattern seems to correlate quite well with the difficulty in obtaining cloud-free EO data coverage with a lower expansion of urban areas in countries in the British Isles and northern Europe for which cloud-free EO data is problematic and a greater expansion rate in southern European countries, calling for a heavy use of S-1 datasets, which can be more time-consuming to properly fully exploit, thus lengthening the production. Therefore, the update frequency could potentially be higher in those countries with a greater urban expansion rate and better image coverage.

For imperviousness, the small area concerned with changes and image availability does not play in favour of increasing the update frequency, but this is based on the past situation in terms of image availability. The combined use of S-2 and Landsat will certainly improve the cloud-free situation and the accuracy of detecting

new built-up areas, although the availability of cloud-free optical data is still likely to remain critical in cloud prone northern Europe, but the use of S-1 has shown to also improve the situation by guaranteeing an image acquisition every 6 days. Test conducted during the second phase showed that the image availability situation has significantly improved with respect to S-2, even more in combination with S-1.
Therefore, yearly updates could be possible, but as mentioned in section 2.4, yearly updates would only depict detected changes which would then be integrated in status layer updates that would still be produced on a 3-year or perhaps longer cycle to provide spatially and temporally consistent HR IMD Layer time series.

2.5.2 Forest Layer

The choice of an appropriate incremental update frequency for the HRL Forest on a pan-European level depends on both, practical constraints (i.e. the magnitude and detectability of actual forest change rates) as well as technical constraints (i.e. associated data requirements etc.). In terms of practical constrains, section 2.3.2 showed the overall order of magnitude of possible change rates which can be expected for Europe's forests. In terms of technical constraints, section 2.3.1 introduced the data used for the HRL 2015 production as a minimum indication. Beyond that, the current Sentinel satellite constellation (primarily S-1 and S-2) does already today offer a higher frequency of relevant satellite data coverages than available for any previous CLMS products and HR Layers. This can be leveraged for future HR Layers.

To define adequate update frequencies of the forest layer product, it is also crucial to understand the dynamics of loss and regrowth in forest cover and its characteristics. Regeneration of forest cover can take up to 5–10 years in temperate climate conditions until a recovery (increase) of tree canopy cover to reach a level of 10 % in a "disturbed" forested area is observed. The loss of forest cover after natural or man-made impacts such as wind-throw or selective logging, an acute loss of tree cover (i.e. a clear-felling or deforestation) can be monitored immediately after a related event (Bartels et al., 2016). Besides that, it should be taken into consideration that in context of an increasing industrial biomass production, certain tree species (e.g. *Salix viminalis*) have a faster regrowth rate and can be harvested already 2-5 years after planting (Slepetys et al., 2012).

In the end, the crucial aspect for defining an appropriate update frequency may not be the small overall net change (i.e. currently: gain) in forest area as observed during the last years in Europe. Any future incremental HRL Forest update methodology must rather be capable of properly depicting the changes also in those regions where losses occur with a higher magnitude and/or frequency compared to other areas of Europe, and where the current HRL 3-year update cycle is particularly insufficient to allow policy-makers to understand and react to such rapid changes and/or change 'focus areas'. In that respect, especially countries, where the impact of climate change is stronger, may need more attention in terms of monitoring environmental and forest disturbances. As climate change is linked with an enlarged risk of extreme events, pests and diseases, certain impacts on forest ecosystems can already be observed today. Southern Europe for example, is confronted with such changes due to climate change, which are often linked to extreme drought and a rapid loss of green biomass due to forest fires (Lindner et al., 2014).

In terms of technical feasibility (i.e. availability of necessary EO data frequencies in combination with state-of-the-art information extraction algorithms), a yearly (or two-yearly) HR Forest Layer update cycle for the whole EEA-39 appears technically feasible, as it has been successfully demonstrated in the second project phase. Presumably a one-year cycle is more appropriate as it can be aligned with the regular 3-year update cycle of the CLMS products. Shorter frequencies (e.g. less than one year) seem to not allow ensuring a sufficient thematic quality of identified changes in a homogeneous manner across Europe, mainly due to the small overall change extents in such short time spans and the associated difficulty to discriminate 'real changes' from 'noise' (i.e. the typical and unavoidable mapping uncertainty/error) in the data linked to an insufficient information depth/length of a reduced EO data time series.

In a practical sense, rapid changes of the tree-covered area in a major extent occur very unevenly distributed over the European land surface, as described in the previous two paragraphs. Such rapid changes are always linked to a local/regional decreases of forest/tree cover and can appear due to (legal or illegal) logging, storm damage, fire, diseases or other natural disasters. In contrast, regional increases of forest/tree cover take place over longer time spans and consequently need longer monitoring cycles. The same is true for changes in forest characteristics and properties such as tree cover density or dominant leaf type.

A synoptic assessment of the above discussed technical and practical aspects of change monitoring leads to the conclusion that an incremental update scheme for the HRL Forest may have to follow a two-staged approach:

1) Changes in the extent of tree/forest cover can be monitored in an incremental update cycle of 1 year, capturing primarily rapid (negative) changes (i.e. logging, deforestation, forest damage);
2) Changes in forest characteristics/properties (such as tree cover density, dominant leaf type) as well as typically slower increases in the tree-stocked area (i.e. regrowth, reforestation) can be complemented in the established 3-year update cycle (as is currently the case).

Such incremental update concept would allow retrieving spatially explicit information on the overall most relevant variable, i.e. the tree/forest cover extent, in a three times more frequent fashion than it is currently the case, and on the full EEA-39 extent. Furthermore, this approach would ensure the fitting of the HRL Forest product into the pan-European Copernicus Land Monitoring Service concept and observation cycles. Additionally, it would allow also setting up more regional downstream services, building on the enhanced and more frequent (incremental) HRL Forest information, e.g. in combination with local/regional in-situ data such as forest inventories, management plans, etc.

2.5.3 Grassland

The analysis in chapter 2.3.2, Expected magnitude of changes, comprises the different data sources of FAOSTAT, EUROSTAT and CLC which have some limitation concerning differing definitions of grassland, different spatial and temporal ranges and acquisition methods (i.e., varying availability of data). Nevertheless these data can be well used as proxy for tendencies on grassland development. The analysis indicates the high spatial diversity of grassland areas and their spatial and temporal dynamics within the EEA-39 countries. In terms of change detection, that raises the question of update frequencies relating to a full coverage product versus partial incremental updates. Several aspects contribute to the assessment of how closely grassland vegetation should be monitored:

- the natural variability and growing dynamic
- the role of human intervention
- the availability of EO data
- differentiation between real changes and technical changes

<u>NATURAL VARIABILITY AND GROWING DYNAMIC</u>

Grassland vegetation is first and foremost determined by the local and seasonal climatic conditions. It is well adapted to regional variations of biogeographic conditions. Annual as well as perennial grasslands turn out to be reliably growing every year in the same areas (Cosentino et al. 2014). In case of human impact like mowing, intensive grazing or even tilling, photosynthetic activity declines rapidly and spectral characteristics change. The increase and decrease of photosynthetic activity, as well as the diversity of different grassy plants, is reflected in a highly variable spectral range for grasslands. Additionally, grasslands are part of manifold different landscapes and environments, mixing up with trees, shrubs, humid and swampy areas or dry and rocky landscapes, surrounding water bodies, or are influenced by growing on different soil types. All these land cover features influence the spectral response of grassland, ending up in a highly diverse range of "typical" grassland spectra.

For mapping grassland, it is required to consider the whole growing cycle which is slightly shifted from Northern to Southern Europe, due to varying climatic conditions (see AD07, chapter 2.3.3.3: *Mapping Mediterranean Grassland with Multi-temporal Earth Observation Data*). In order to consider the most adequate time slots of the growing season for *all* European countries, in some climate zones even winter months of the previous calendar year (October – February) have to be taken into account for grassland detection. In order to accurately detect grassland vegetation cover and its life cycle changes, it is recommendable to use time series that comprise imagery covering at least one full growing season per climate zone. Relating to a pan-European approach this means data acquisition for two years in order to provide imagery for ideal time slots for all growing seasons.

<u>ROLE OF HUMAN INTERVENTION</u>

Grassland change appears in both directions (loss and gain) within a short time period, caused by natural phenomena like permanent droughts or flooding, but in most cases related to human interventions. Grassland *loss* may occur through conversion to agricultural fields, for example, or through conversion to urban areas or due to the abandonment of pastures which leads to the development of shrubby vegetation within a short time period and in medium term even to regrowth of trees. Grassland *gain* may happen when arable land has not been tilled for a certain amount of time and regrowth of grassy vegetation takes place. It should be noted that what is visible on the ground (i.e. the actual 'land cover') may differ from what is regarded a grassland from a legal-administrative point of view – which typically resembles more 'land use' aspects. For example, in Germany, cropland that has not been tilled for a 5-years period will be legally regarded as grassland. These regulations differ between the European countries.

Grassland, like other land cover types with (at least partially) semi-natural vegetation, are under pressure due to conflictive land use demands, competing with economic activity, increased mobility, urbanization and pollution to name some. The analysis of national statistics reveals a decline of (semi-)"natural grasslands" (corresponding to the CLC-land cover nomenclature), whereas the area of permanent pastures seems to slightly increase. In order to protect (semi-) natural grassland areas and to manage grasslands in a sustainable way, the EU and national entities have made efforts to establish common rules and regulations for grassland protection and management within the Common Agricultural Policy of the European Union CAP (EC about CAP 2017). The *Greening* requirements, for example, linked with the direct payments of the EU to farmers, the necessity of an approval obligation for the tilling of grassland and the complete prohibition of the conversion of Ecologically High Sensitive Grassland areas (protected by Natura 2000 regulations in areas of the Flora-Fauna-Habitat FFH Directive) are exemplary parts within the CAP guidelines and decisions. Farmers, as well as states who aim at benefitting from EU payments, have to be compliant with EU regulations (BfN: Agrarreport 2017; BfN: Grünlandreport 2014; CAP 2015). Temporal and spatial implementation of these regulations strongly differs within the EU member countries.

Availability of EO data In theory, the availability of EO data is not anymore a limiting factor for detecting grassland with a pan-European coverage. Optical S-2 A and B data are available about every 5 days. SAR data of S-1 A and B provide data every 6 days. However, depending on the geographical location and climate conditions in Europe, clouds, haze and shadow effects due to low solar zenith angles in late autumn and winter months, can significantly reduce the number and quality of suitable optical satellite data for certain regions. SAR imagery similarly suffer from radar shadowing effects in mountainous areas or from data gaps caused by snow. Thus, despite additional use of Landsat data and the integration of S-1 SAR data (see AD07, chapter 2.3.3.1 *HRL Grassland production*), there still might be an insufficient coverage of EO data per growing season for certain regions. The research on this topic is still ongoing and the potential of using SAR data for bridging the information gap in optical data is still an issue to be worked on.

DIFFERENTIATION BETWEEN REAL CHANGES AND TECHNICAL CHANGES

As a consequence of management schemes like mowing or intense grazing, or caused by weather effects like drought, large areas of grassland might appear as non-grassland in satellite imagery, but this is only a temporary effect and therefore no real change. In order to largely avoid being misled by such effects, a careful selection of adequate image acquisition time slots for the reliable detection of grassland is essential. Nevertheless such effects might be unavoidable in some small areas, where it is extraordinarily dry over a longer period within a reference year, as shown in Figure 2-35.

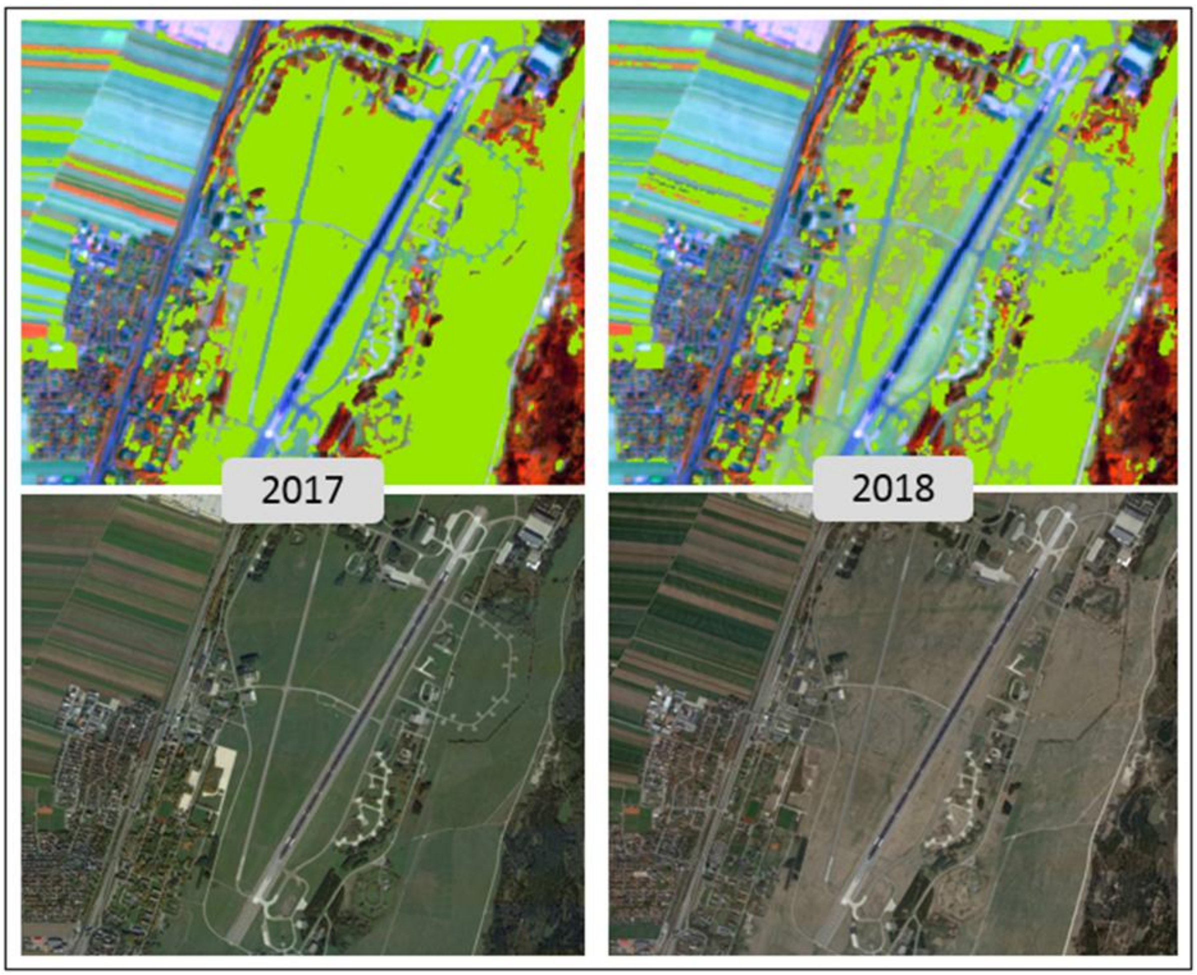


Figure 2-35 – Effects of drought on the classification result

(Top images: Classification results with underlying S2 imagery (RGB: NIR, SWIR, Red); bottom images: © Google Earth)

Another challenge is the differentiation of real land cover/use changes and "technical changes", i.e. differences in two consecutive classification time steps caused by e.g. increases in the spatial resolution of the used EO imagery, advancements in the detection technology, etc., resulting in a thematic and/or spatial accuracy enhancement of a more recent compared to a former grassland classification. The reliable discrimination of real vs. temporary or technical changes within any regular update frame is still an issue, specifically if the time intervals between the inventories are shortened, e.g. towards annual schemes.

CONCLUSION

The EU aims at the protection of important ecosystems such as grasslands and needs basic information for this purpose. Detected first signs of changes often indicate general tendencies of transformation and potential threats. In that sense, the detection of (negative) change (i.e. grassland loss) can indicate the need for implementing regulatory counter-measures, whereas a positive change (i.e. a grassland increase) can be an indicator for the effectiveness of already established measures. Therefore, EO based change detection can be an important monitoring tool for agro-political and environmental issues as well as e.g. for urban planning. Defining an adequate update frequency strongly depends on the definition of *change* itself, e.g. on which scale (variations caused by macro conditions like climate change or such caused by potentially smaller scale human impact), for which magnitude and for which purpose a change is regarded significant.

Changes in grassland are highly dynamic by nature within one growing season – and loss and gain can happen within a short time period induced by extreme weather conditions or by human intervention. These considerations speak in favor of an annual incremental update. Notwithstanding, the verification of changes require considering real/technical changes, as the example of the drought in 2018 in the Central region shows. In this regard, the change products accuracy assessment and the relevance of the probability layers is paramount, as it is explained in the change detection proposal and validation approaches in WP34 [AD 07], and implemented in the demonstration sites in WP43 [AD 09].

Concerning the implementation of a higher (e.g. annual) update frequency, several factors are still challenging:

- Identification of adequate optical EO data acquisition time slots for the accurate detection of grassland: within a pan-European approach, these time slots have to cover varying growing seasons (e.g. also over winter time in Mediterranean areas) and therefore may have to span more than one calendar year. This calls for regionally adjusted, different time slots.
- Differentiation of real changes versus temporary or technical changes
- Mitigation of certain information gaps (i.e. less dense time series) due to cloud cover, haze or low sun angles in certain geographical regions.

3 Testing of methods for incremental updates

The previous chapter has shown that despite the experience accumulated during the HRL 2015 production, the main limiting factor to increase the update frequency of HRLs still remain in the availability of cloud-free EO data. This is mainly because the S-2 constellation has yet to be fully deployed and the use of S-1 data was so far only introduced for the production of the grassland layer, but has yet to be implemented for the imperviousness and forest layer. Another factor that would contribute to increase the update frequency is to improve the accuracy of the change detection. However, even though the focus of the HRLs is on change detection, there are no detailed specifications on determining the accuracy of changes. Specifications only focus on the accuracy of status layers for which the target is set at 90% for both producer and user accuracy, but the results from the previous chapter show that in all three cases (imperviousness, forest and grassland), this level of accuracy is still above the expected level of change over the current 3-year period. Therefore, the specifications should now shift to focus more on change detection and set targets in terms of change area estimate uncertainty, but this means that the focus should not only be on the HRL itself, but also on the sampling design and intensity (i.e. number of sample per unit area) of the reference data used to assess the uncertainty.

3.1 Testing of incremental updates for IMP layers

Currently, the only experience available is that of HRL Imperviousness for which 4 dates are now available, but little analysis was performed in relation to uncertainty analysis. There was just recognition that the previous implementation of the HRL production led to inconsistent results temporally and spatially and as a result, a re-analysis of the previous status and change layers was performed during the 2015 production. However, there was still not target set in terms of level of uncertainty to be reached.

Therefore, the objective of the phase 1 (sections 3.1.1 and 3.1.2) was to assess the level of improvement achieved by the re-analysis of the historical layer during the HRL2015 production and develop suitable methods for ensuring spatially and temporally consistent incremental updates of HRL products at an appropriate time frequency based on the combination between time series-derived classification and change detection algorithm for the HRL Imperviousness. The production of the HRL imperviousness (as well and other HRLs) focuses on the creation of a reliable built-up mask, which is then combined with NDVI data to derive the imperviousness degree, since most of the sources of errors are attributable to the correctness of the input built-up mask, all the effort is dedicated to improving the accuracy of the detection of new built-up areas.

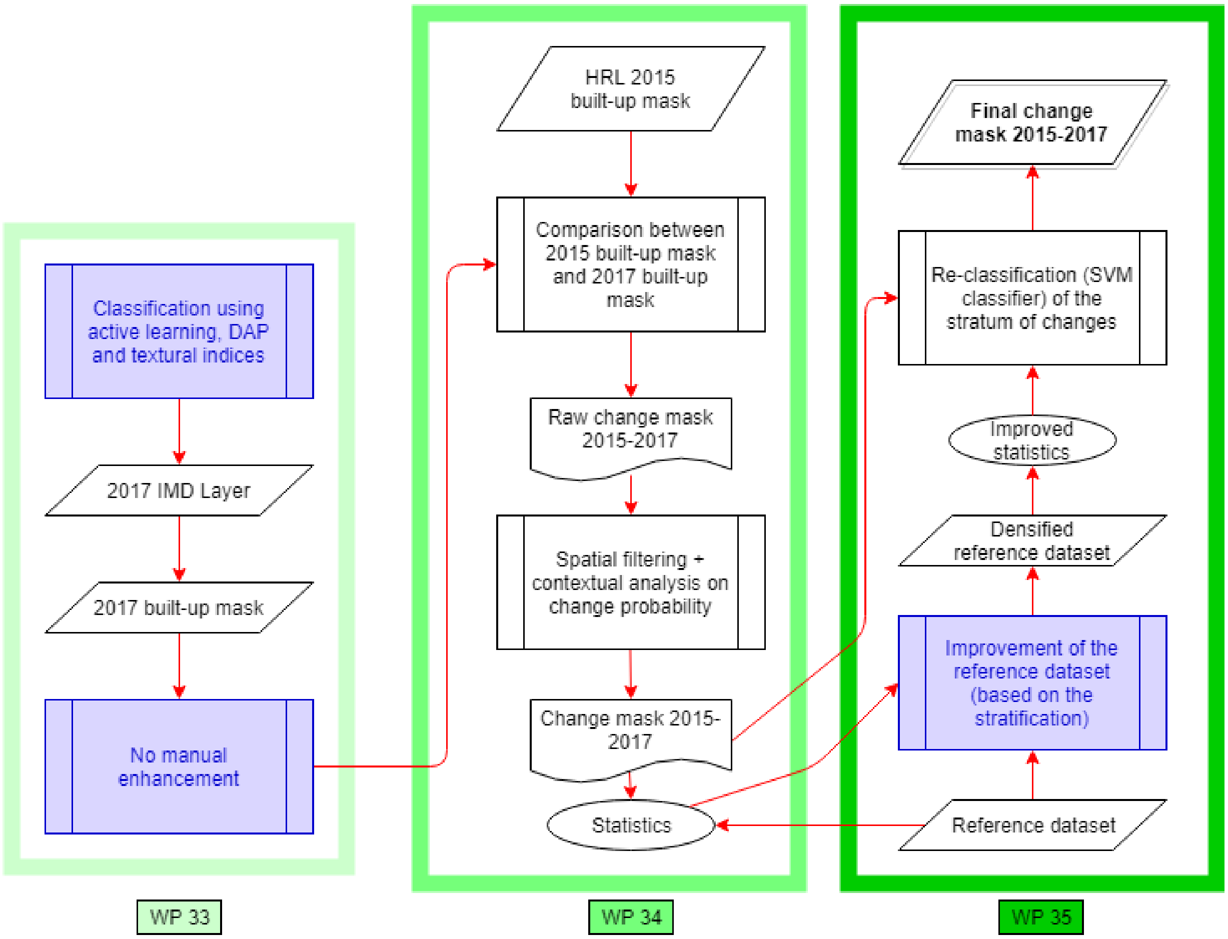


Figure 3-1 – Proposed workflow

Changes within the existing built-up mask (i.e. increase or decrease of imperviousness degree) are dealt with the phase 2 of the implementation of this WP (section 3.1.3). A general overview of the workflow applied over the selected test sites is illustrated in the Figure 3-1 above. During the phase 2, the main focus was done on the characterization of the imperviousness degree changes within the IMC layer. For this purpose, a second specific reference dataset for the statistical calibration of the imperviousness degree changes was implemented; aiming to derive a reliable sealing changes and limit noise due to the calibration and ensuring spatially and temporally consistent incremental updates of HRL change products.

3.1.1 Characterization of outputs from automated change detection

During the phase 1, a specific Reference sample dataset for the statistical calibration of changes was created as part of this WP35 in order to characterize the changes detected by comparing the original HRL2015 built-up mask with the new built-up mask layer for the 2017 and then 2018 reference years to ensure that there are no spatial inconsistencies between the layers of the different epochs.

3.1.1.1 Detection of new built-up areas

Following the outcomes of the WP 33 and 34, two products were generated, a new built-up status mask for 2017/2018 and a 2015-17/18 or 2017-2018 change built-up masks.

The Imperviousness built-up mask layer for 2017 or 2018 (depending the test site) was created as part of WP33 (see Figure 3-2 and Figure 3-3) and the classification was performed using supervised machine learning methods to create the updated built-up mask for 2017 and 2018. The production of the built-up mask is achieved with selection of reference (or training) data. It works in both interactive and batch mode. In the former case, the user is given some specific pixels to label (e.g. by photo-interpretation), while in the latter case only relevant samples from the training sets will be used (leading to a better modelling of land cover classes as well as a more efficient classification process). Following the results of the WP31 (separability of the information for thematic classifications) and WP33 (Time Series Analysis for Thematic Classification), the input data selected rely on multispectral information and granulometry by mathematical morphology (Differential Attribute Profiles (DAP)).

The results of the validation exercise performed in the frame of the WP33 for the HRL IMD 2017/2018 input layer are quantified in Table 3-1.

Table 3-1 – New HRL 2017 and 2018 - accuracy.

	Producer accuracy	User accuracy
HRL IMD 2017 South-West	85.19%	85.19%
HRL IMD 2018 South-West	91.90%	88.32%
HRL IMD 2018 Central	94.12%	88.89%
HRL IMD 2018 South-East	83.33%	83.33%

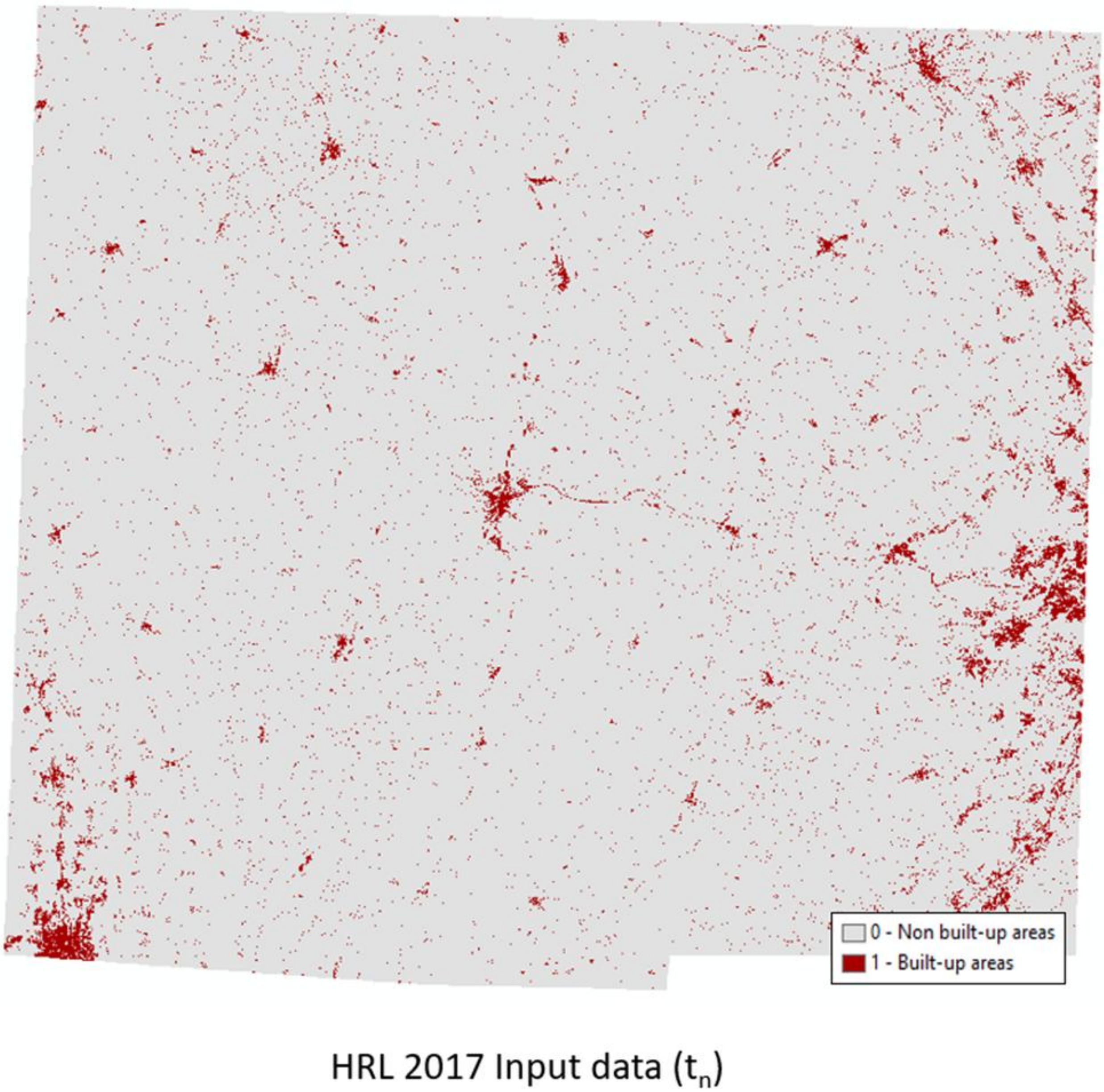
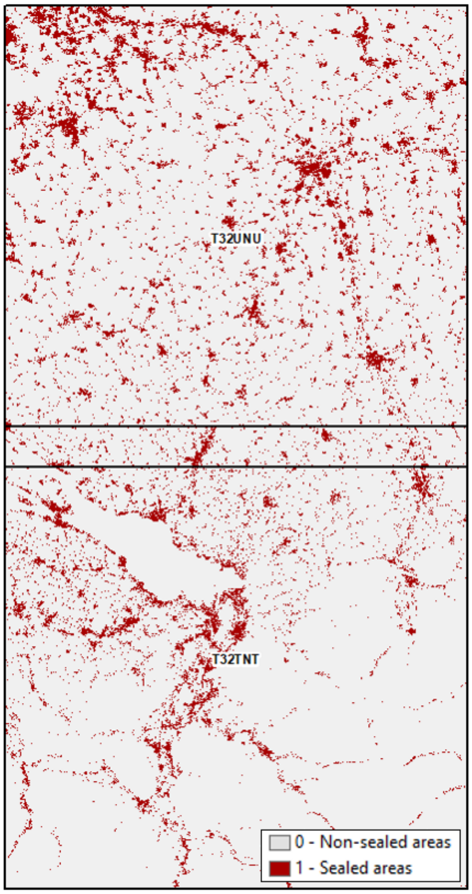
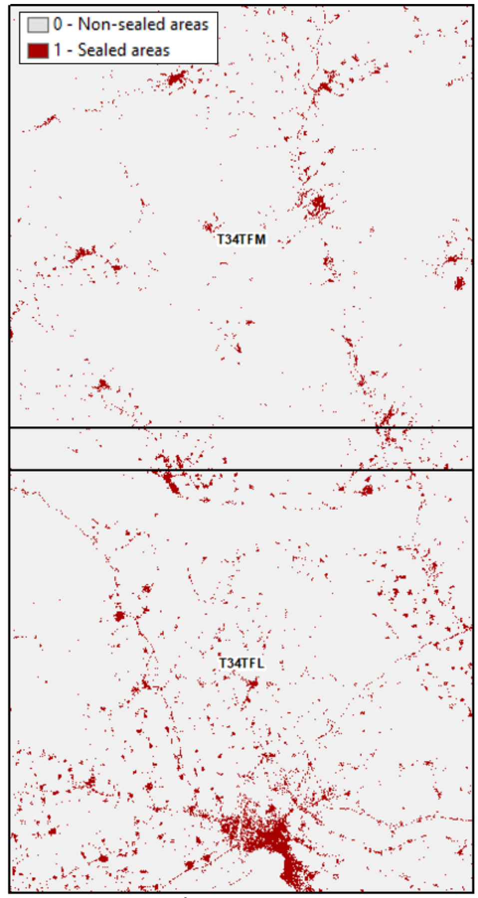


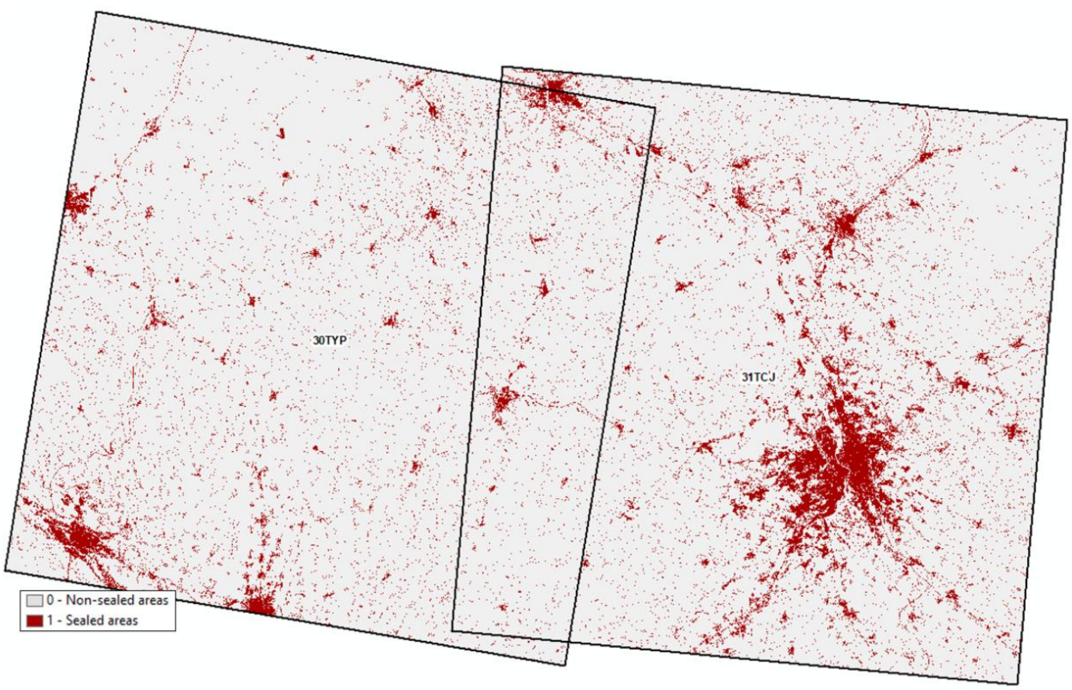
Figure 3-2 – The Imperviousness built-up mask layer 2017.



Central test site



South-East test site



South-West test site

Figure 3-3 – The Imperviousness built-up mask layer 2018 for the phase 2 test site

The Change 2015-2017/18 and 2017-2018 layers were then produced as shown in Figure 3-5 and Figure 3-6. To determine the built-up changes 2015-2017/18 and 2017-2018, the supervised classification result for 2017/2018 (machine learning algorithm using DAP profiles) is combined with the built-up mask from the HRL Imperviousness 2015 produced during the operational HRL production outside this project (see Figure 3-4). This step not only reveals 2015-2017/18 built-up changes, but, as said before, it also detects potential omission errors in the built-up mask 2015 as well as potential commission errors of the 2017/2018 built-up area.

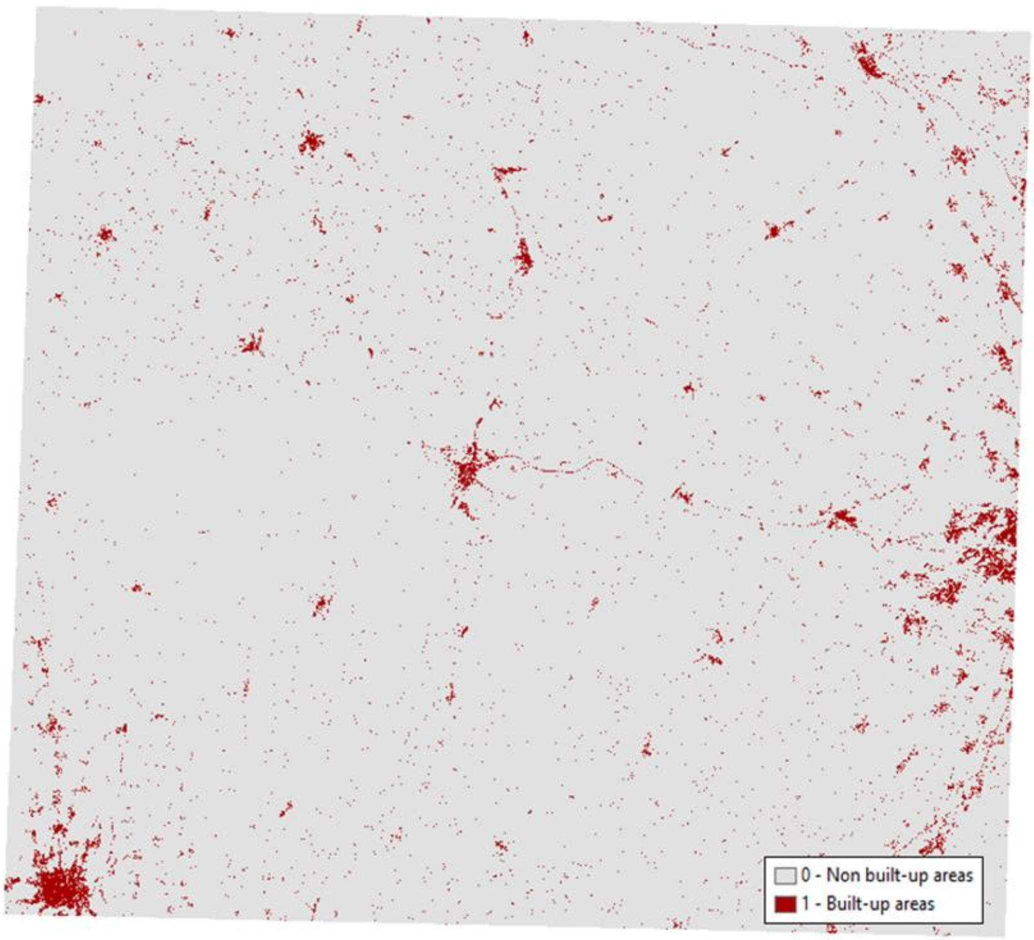


Figure 3-4 – HRL IMD 2015 built-up mask layer for the SW phase 1 test site

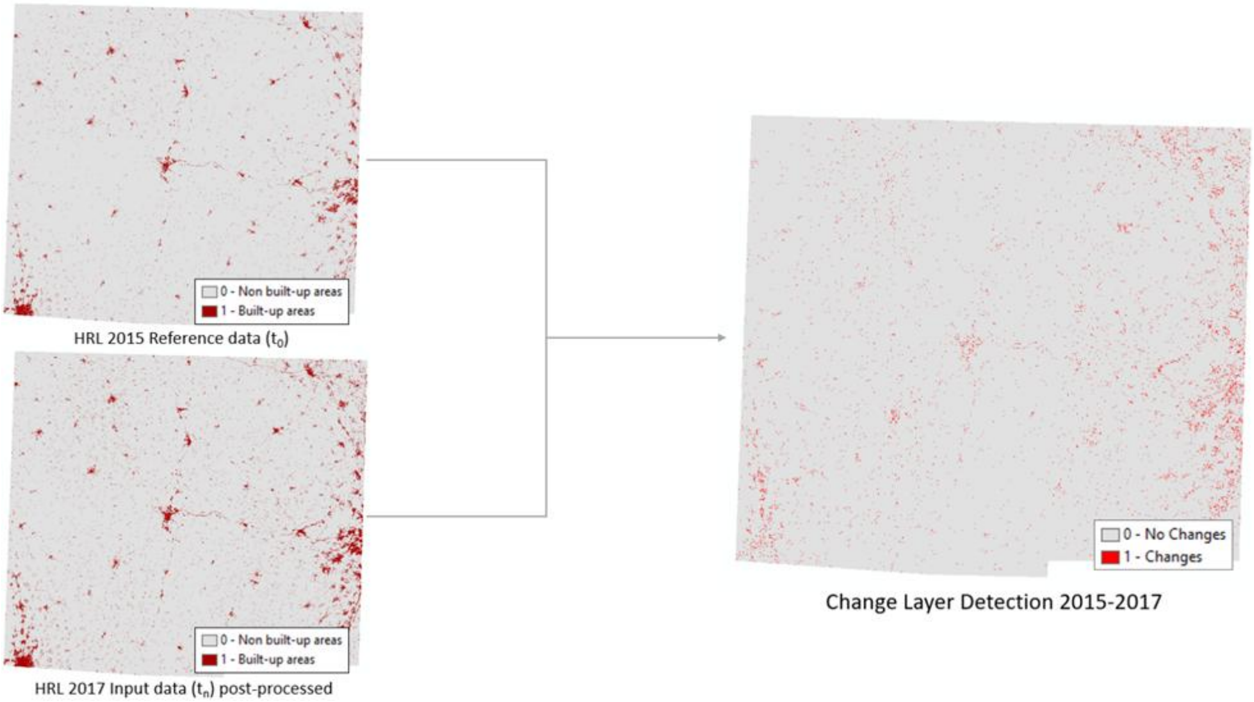
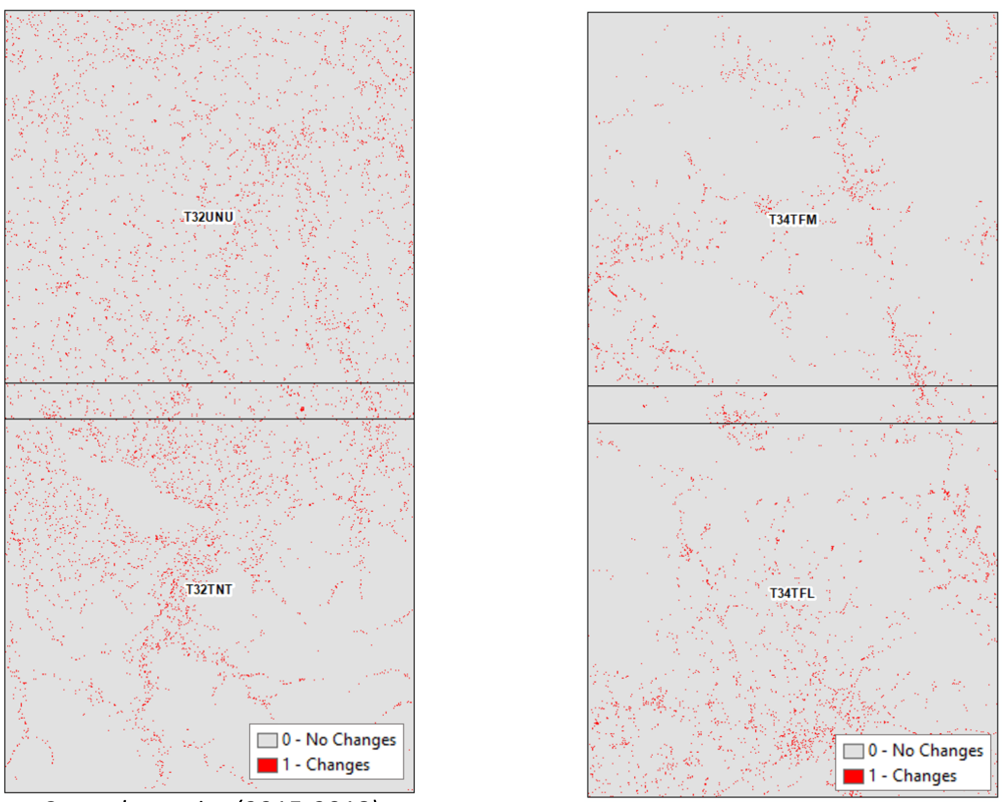
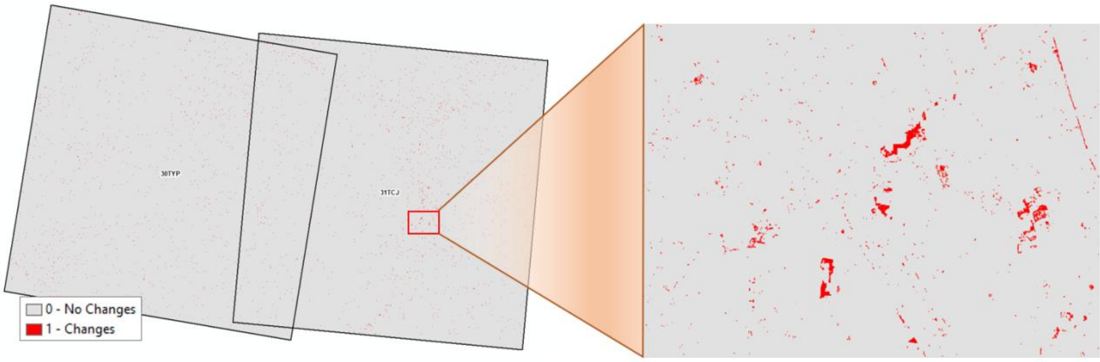


Figure 3-5 – Change layer detection for the SW phase 1 test site.



Central test site (2015-2018) *South-East test site (2015-2018)*



South-East test site (2017-2018)

Figure 3-6 – 2015/17-2018 change layers detection for the phase 2 test sites

3.1.1.2 Characterization of areas of change

One of the key requirements is to ensure the temporal consistency and comparability between the different time intervals and that there should be no spatial inconsistencies between the layers of the different epochs. The main reasons for the presence of temporal and spatial inconsistencies are as follows:

- Impervious areas typically represent less than 5% of the total EEA-39 even though the level of omission and commission are still below the set threshold of 10% the area represented by a 10% error in the delineation of the built-up mask can still be greater than the actual area of change between the two periods.
- Although some errors are included in the reference layer, new errors can be included in the detection of change between two periods. The change layers' errors can be due to the following factors:
    - Omission of change;
    - Technical change (i.e. commission errors) due to:
        - Geometric and phenological differences between the two periods leading to false increase or decrease of Imperviousness degree (these can be filtered out to some extent by applying a suitable threshold adapted to local circumstances);
        - Commission errors added for the new period;
        - Omission errors detected for the previous period;

Due to the semi-automated nature of the HRL production workflow, it is not possible to guarantee that all errors can be removed from the change layer. However, the relative magnitude of actual change versus the errors contained in the change layer for each time interval should be known in order to provide a basis for improving the temporal consistency between each layer. Therefore, there is a need to develop a reference dataset that will be used to determine the relative proportion of actual change versus all the error components described above, as shown in Figure 3-5 and in Figure 3-17. To be valid, this calibration dataset should be selected based on a probability sampling approach. Since the focus is on change, the approach will help assess:

- The new built-up for the year 2017/2018;
- The omission errors from 2015 – the undetected built-up pixels of 2015;
- And the commission errors from 2017/2018 – the pixels falsely flagged as built-up in 2017/2018.

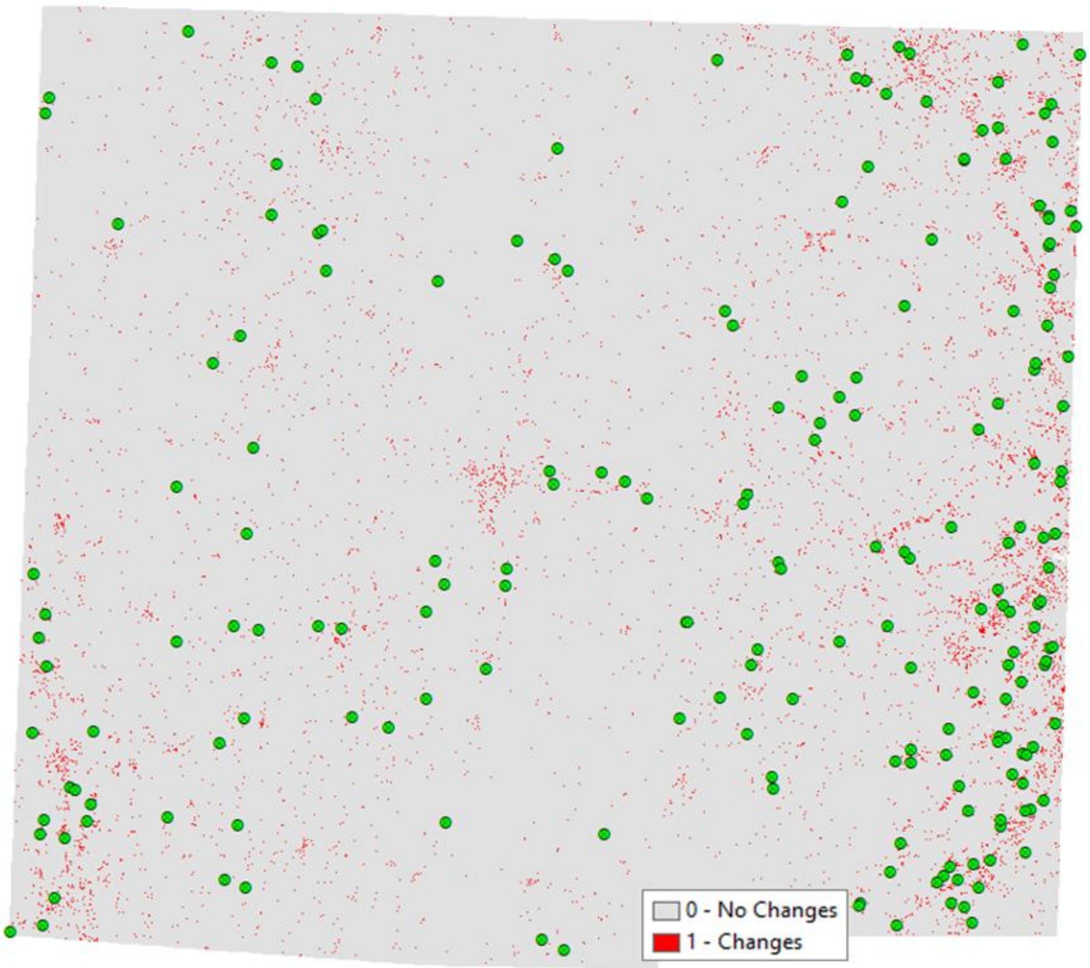


Figure 3-7 – Reference calibration samples overlaid on the 2015-2017 change mask for the SW phase 1 test site

For the test site of the phase 1, 197 sample point/pixel units were randomly selected based on the change stratum defined as the output from WP34 [AD07] by comparing the HRL2015 built-up mask with the newly created 2017 layer as illustrated in the figure above. The results obtained from the reference calibration dataset confirmed the outcome of the WP34 [AD07] and are as follows:

Table 3-2 – Characterisation of 2015-2017 change stratum for the SW site

	% of total change areas
New built-up 2017	9,64%
Omission errors 2015 (undetected built-up 2015):	76,65%
Commission errors 2017 (false built-up 2017)	13,71%

Based on the calibration dataset, the relative magnitude of actual change is estimated to only represent 9.64% of the total area detected as changed from the automated change detection procedure. Thus, the errors concern the remaining 90% of the change areas detected. Most of these, almost 77%, represent omission errors from 2015 and just less than 14% represent new commission errors from 2017.

As explained in WP34 [AD07] and regarding the omission errors from the previous period, it should notice that the specifications of the reference image data for 2015 is different to that of the 2017 input data. For 2015, the production was mostly based on Landsat data whereas the 2017 built-up was produced from S-2 resulting in a 9-fold improvement in spatial resolution (i.e. a Landsat pixel is characterized by 9 S-2 pixels); explaining that most of the omission errors concern small and isolated built-up features as illustrated in the figures below.

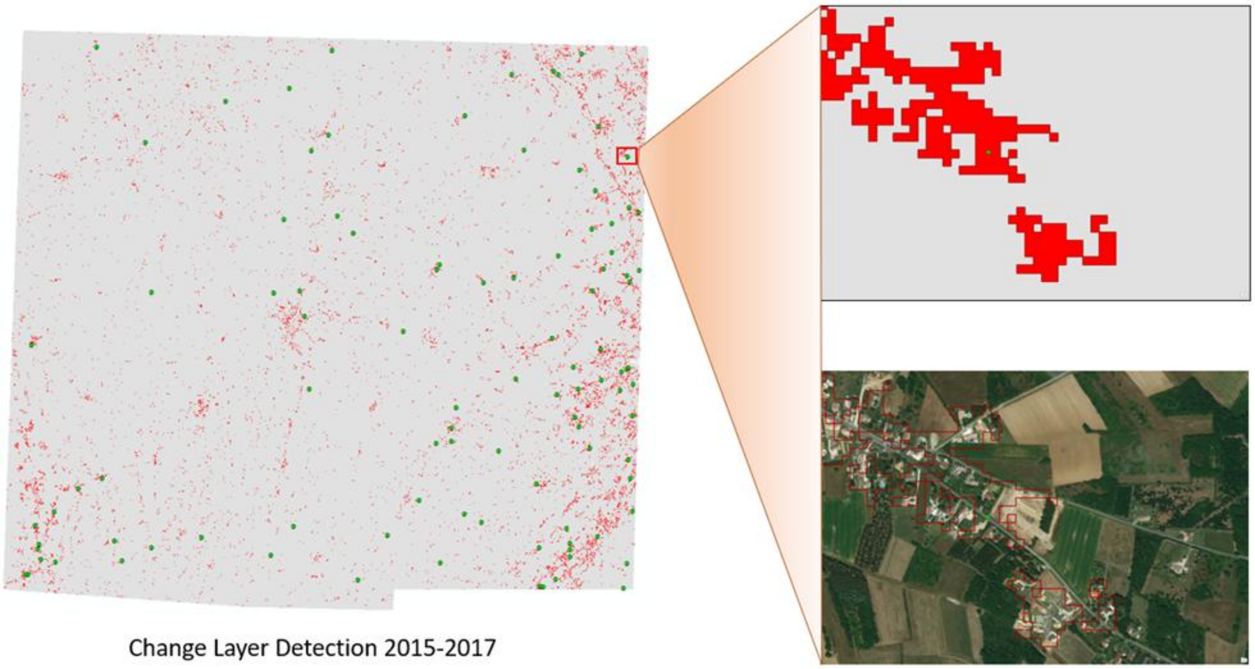


Figure 3-8 – Example of calibration point for the newly detected built-up in 2017

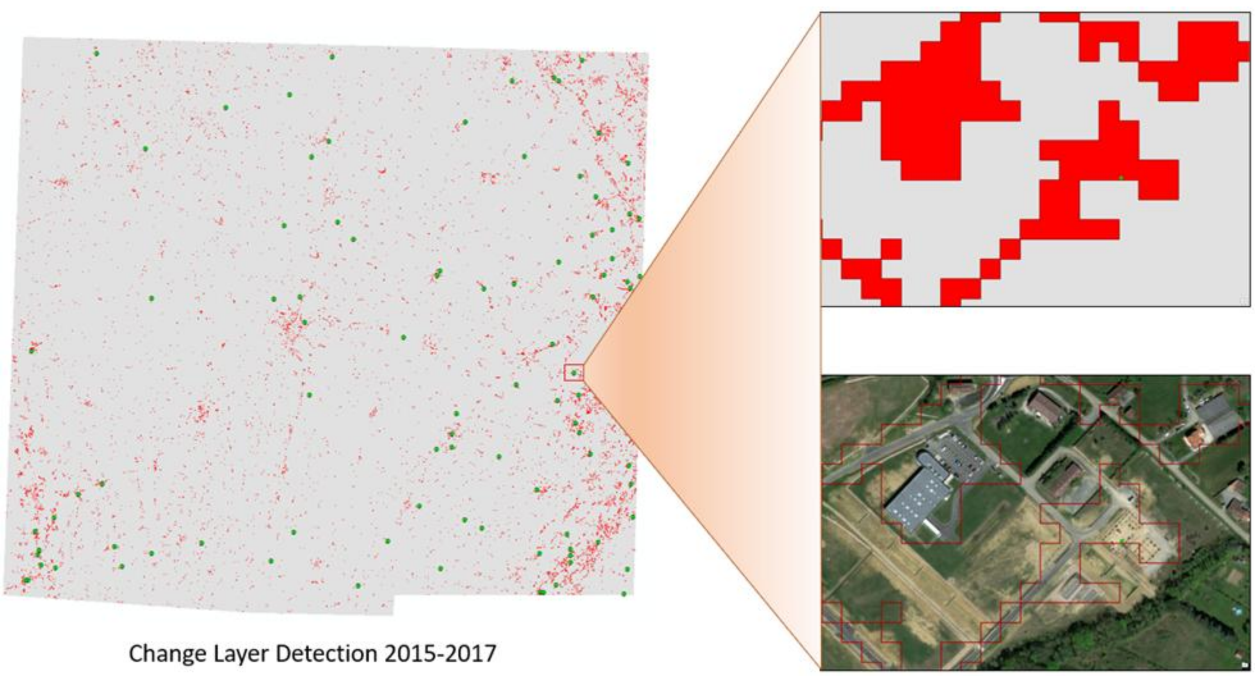


Figure 3-9 – Example of omission errors 2015 (undetected built-up in 2015)

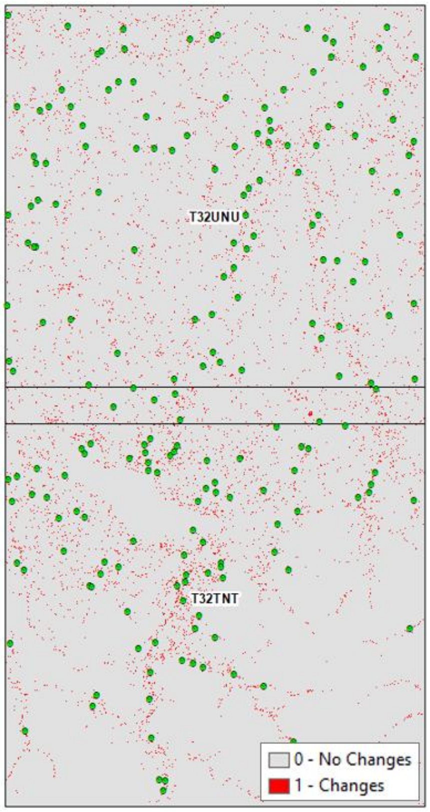
Figure 3-10 – Example of commission errors for 2017, false built-up in 2017

For the test sites of the phase 2, 200 sample point/pixel units were randomly selected based on the change stratum defined as the output from WP34 by comparing the HRL2015/17 built-up mask with the newly created 2018 layer. The results obtained from the reference calibration dataset confirmed the outcome of the WP34 and are as follows:

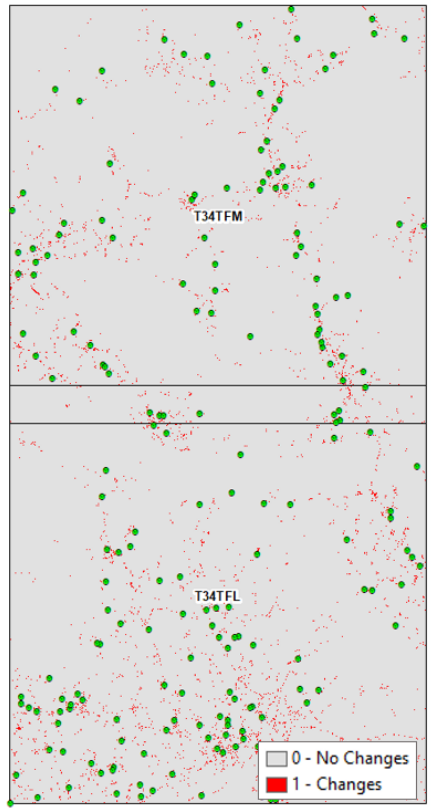
Table 3-3 – Characterisation of 2015/17-2018 change stratum for the phase 2 test sites

% of total change areas				
	South-West		Central	South-East
New built-up 2018	19.00%	**New built-up 2018**	14.00%	7.00%
Omission errors 2017* (undetected built-up 2017):	48.00%	**Omission errors 2015* (undetected built-up 2015):**	68.50%	69.50%
Commission errors 2018* (false built-up 2018)	33.00%	**Commission errors 2018* (false built-up 2015)**	17.50%	23.50%
Total Change Area (km²)	75.70	**Total Change Area (km²)**	410.25	280.85

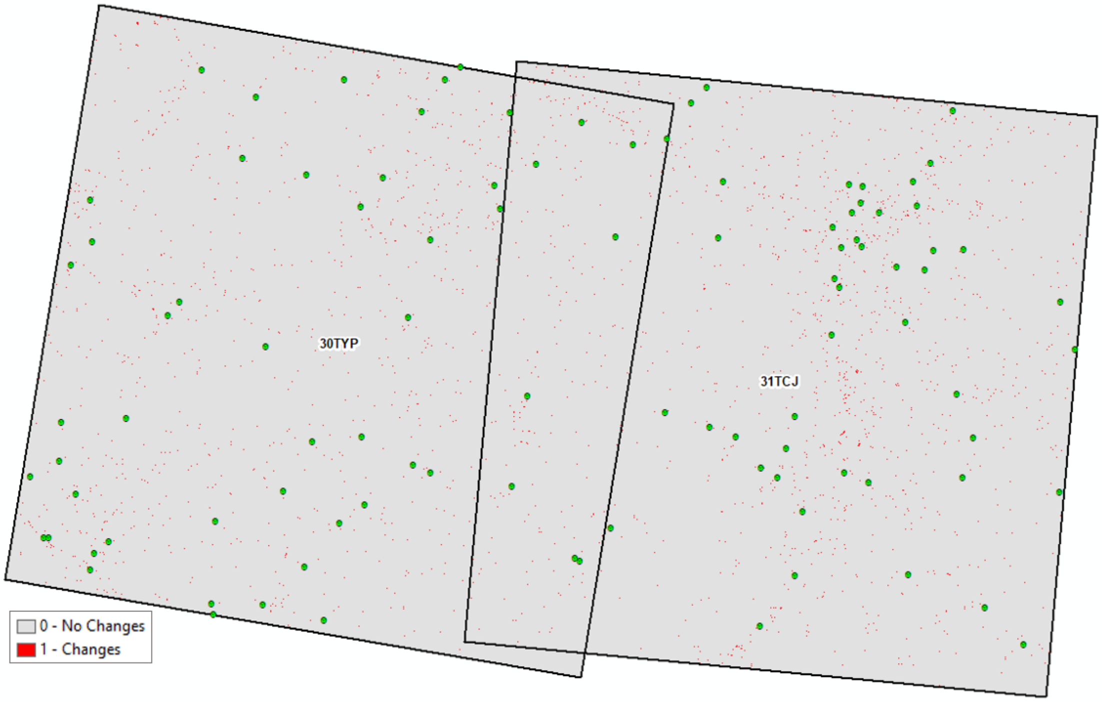
Regarding the South-West site and based on the calibration dataset, the relative magnitude of actual change is estimated to only represent less than 20% of the total area detected as changed from the automated change detection procedure. Thus, the errors concern the remaining 80% of the change areas detected. It must be notice that the change detection for the South-West site is done on the 2017-2018 time period since the HRL IMD 2017 has been created as part of the phase 1; explaining the relative proportionality between the omission and commission errors (48% vs 33%) and the greater new built-up statistic (19%). The low total of change area (75.70 km²) in comparison with the 2015-2017 change layer also shows the relevance of the change detection approach. Concerning the Central and South-East sites, the relative magnitude of actual change is estimated to only represent respectively 14% and 7% of the total area detected as changed (see Figure 3-12). Regarding the source of errors, almost 70%, represent omission errors (see Figure 3-13) from 2015 and just less than 24% represent new commission errors (see Figure 3-14) from 2018. So, the statistics obtained from the calibration dataset confirm the outcomes of the phase 1.



Central test site (2015-2018)

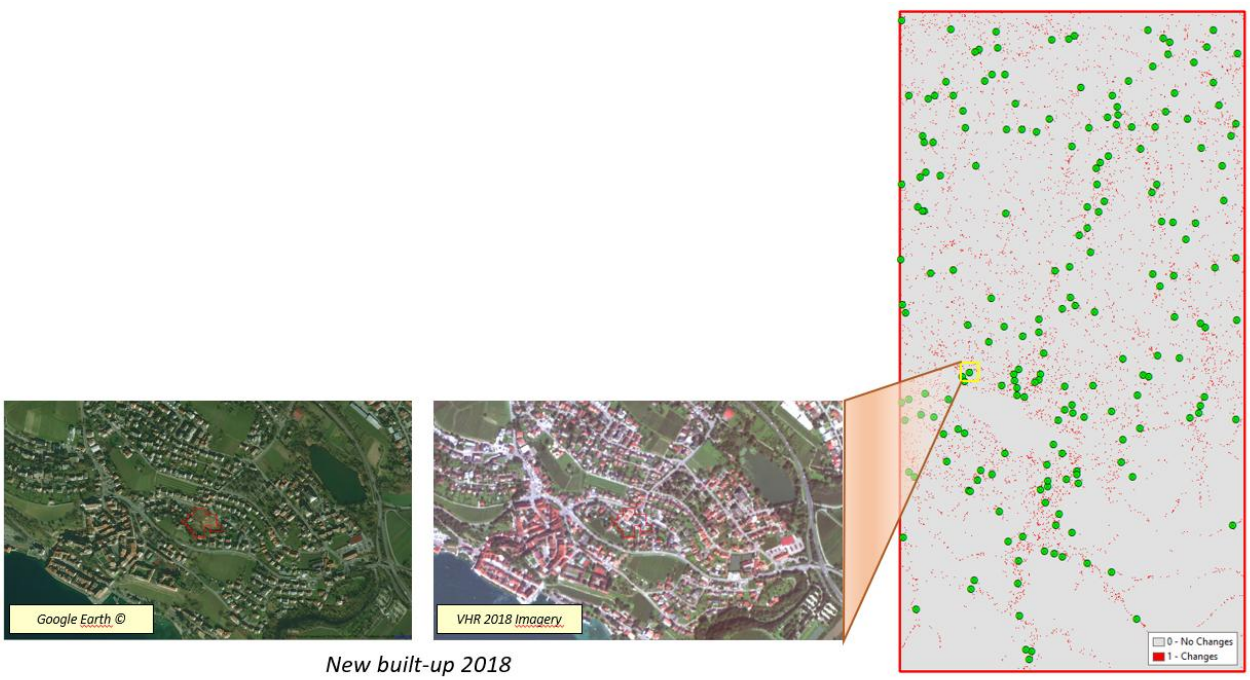


South-East test site (2015-2018)



South-West test site (2017-2018)

Figure 3-11 – Reference calibration samples overlaid on the change masks for phase 2 test sites



New built-up 2018

Figure 3-12 – Example of calibration point for the newly detected built-up in 2018

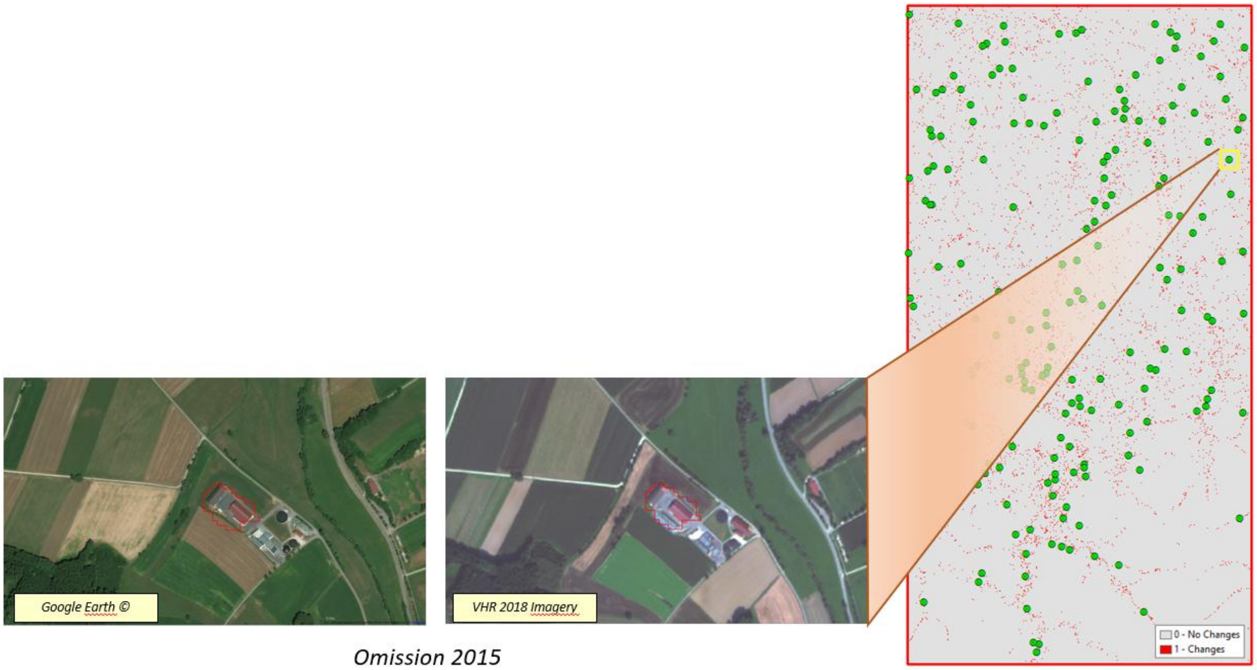


Figure 3-13 – Example of omission errors 2015 (undetected built-up in 2015)

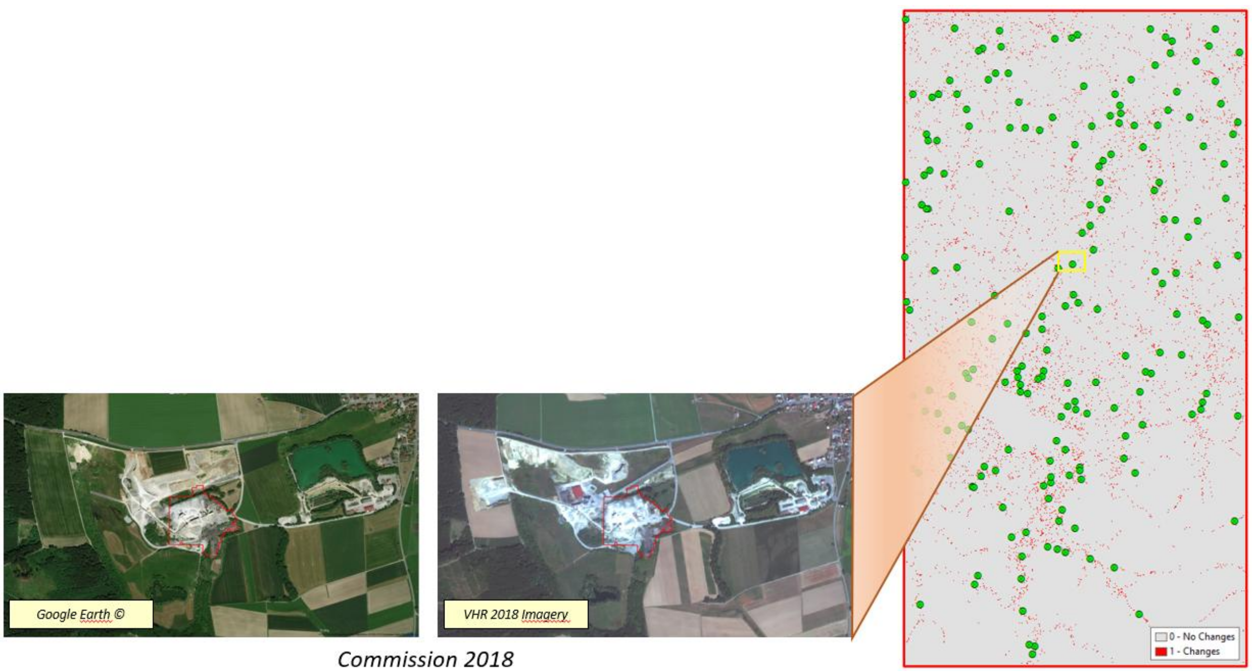


Figure 3-14 – Example of commission errors for 2018, false built-up in 2018

The level of omission detected in the 2015 built-up mask means that it will need to be re-processed in order to provide spatially and temporally consistent changes. This is not a reflection of the lower quality of the 2015 data but is linked to the change in input EO data now based on S-2. At the very least, omission errors should be flagged in the built-up change mask layer.

3.1.2 Assessment of spatial and temporal consistency: Ensuring continuous traceability of changes

For the re-processing of the 2015 and 2017 built-up masks the existing Imperviousness layer 2015 and 2017 are utilized, together with the re-processed HR IMAGE2015 and 2017 (Landsat and S-1/-2) datasets and, where appropriate, additional information from Google Earth/Bing Maps. The main target is to fine-tune the classification outputs to ensure better consistency over time.

3.1.2.1 Reduction of bias algorithm

In an initial step, the new 2017 built-up mask is overlaid to the existing 2015 mask, and an initial change 2015-2017 is created and thematically classified (stable areas, built-up changes 2015-2017 and potential omission from 2015 and commission errors from 2017

The procedures described above resolve potential geometry issues between the layers at different reference year, but there could be substantial differences in the relative amount of changes detected which needs to be corrected to ensure consistency over time.

That is why a Post-Classification Comparison (PCC) is implemented (see Figure 3-15).

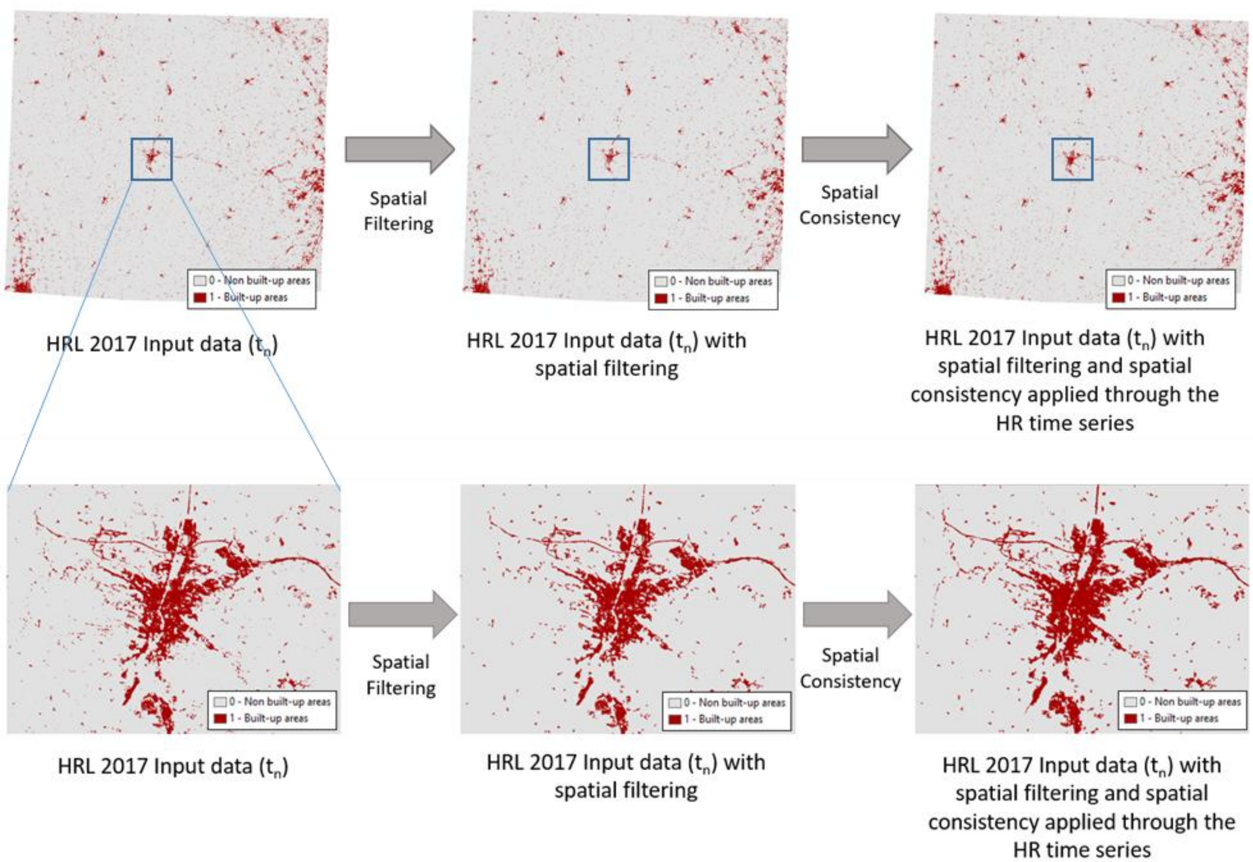


Figure 3-15 – Post-classification processing.

This method involves the following steps:

- A post-processing filtering procedure was applied (see WP34 [AD07]). Indeed, there is a significant portion of noise due to single pixels or isolated pixels (small aggregated group of pixels), which are most likely misclassifications. Such noises should be reduced/removed with post-classification filtering approaches.
- A spatial and temporal consistency procedure relying on the reference calibration data– the purpose is to ensure the consistency and comparability between the different dates, so as to prevent problems linked to an "image-to-image approach", related to the possible divergences in terms of acquisition, and/or of geometry between the two periods.

This procedure relies heavily on the use of the reference dataset for the statistical calibration of changes described above.

This dataset is used to produce statistics representing the expected area of change for each of the target categories and strata following the structure presented in the table below. As illustrated and because sample units were selected as a probability sample, an area estimate accompanied by its uncertainty expressed as a confidence interval can be produced for each listed category and time interval based on the following formulas (Taylor et al. 1997). The estimate of the proportion of land area covered by category c is given by:

$$\overline{y_c} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

With the variance:

$$var(\overline{y_c}) = \left(1 - \frac{n}{N}\right)\frac{1}{n(n-1)}\sum_{i=1}^{n}(y_i - \overline{y_c})^2$$

Where y_i is the proportion of segment i covered by class c, N is total number of segments in the region, n is number of segments in the sample. The estimate of the class area is:

$$\hat{Z}_c = D\,\overline{y_c}$$

With the variance:

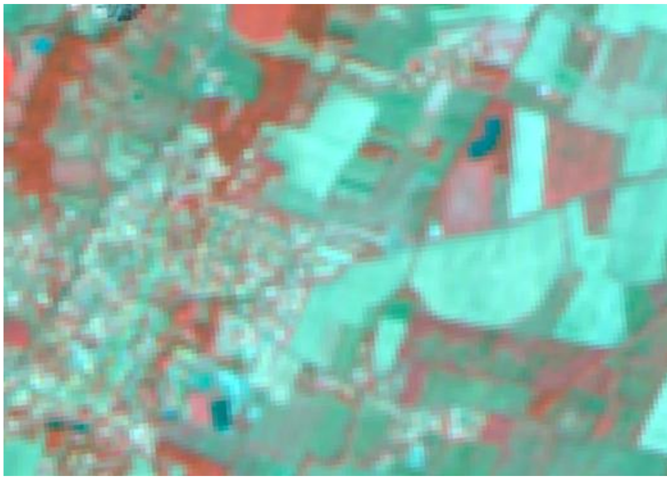
$$var(\hat{Z}_c) = D^2\, var(\overline{y_c})$$

Where D is the production unit area.

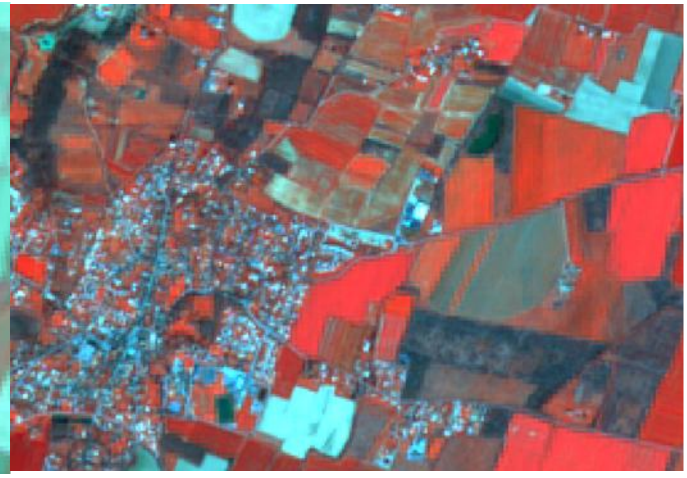
Table 3-4 – Example of area statistics generated from the reference dataset for the statistical calibration of changes for a given time interval and production unit Z Time interval: 2006-12

	Actual change	Commission from new reference year	Omission from previous reference year
Change 2015-2017 stratum	A ± 95% CI	B ± 95% CI	C ± 95% CI

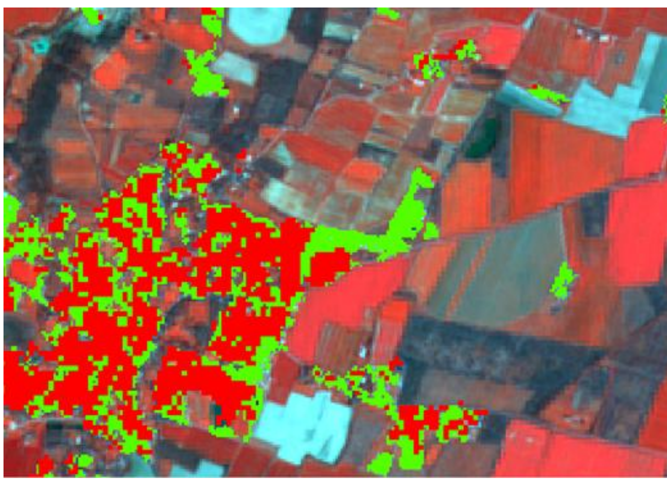
The estimates obtained for the 2015-2017 change layer provide a basis to target the re-processing that needs to be applied for each layer. In the change stratum, the objective is to separate the three categories listed above. This is achieved by adopting a re-classification approach linking the three categories with suitable training data between 2015 and 2017 imagery.



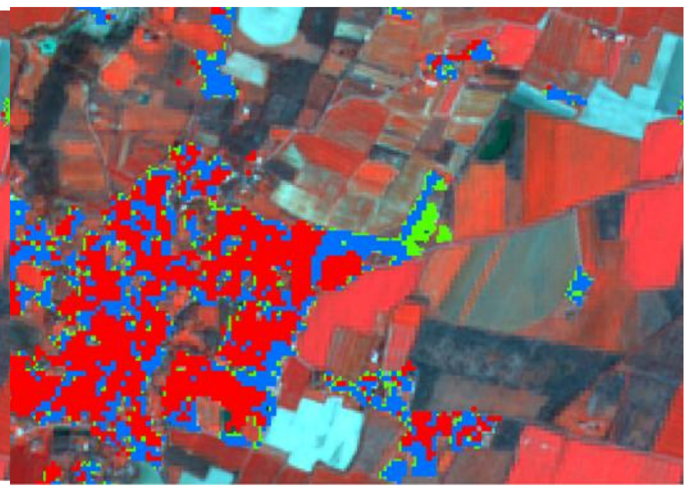
Ressoursat-02 (2015)



S-2 (2017)



S-2 (2017) and change mask (WP34)
Red: Stable built-up
Green: Change built-up



S-2 (2017) and Reclassified change mask (WP35)
Red: Stable built-up
Blue: omissions from 2015
Green: New built-up 2017

Figure 3-16 – Extract of the reclassified 2015_17 HRL Imperviousness built-up masks

Based on the reprocessing process (confirmed by the calibration dataset), the relative magnitude of actual change is estimated to just under 10% of the total change areas. In other words, of the total area initially detected as changed from the output of WP34 [AD07], only about 10% effectively represent new built-up areas and the remaining 90% are mostly omissions undetected in 2015 (76.7%) and new commission errors introduced by the 2017 new built-up mask (13.7%) as indicated in Table 3-2.

Most of the omission errors (as shown in the Figures above) concern small and isolated built-up features and roads. As explained in the WP34 [AD07], this is mostly attributable to the change of resolution between Landsat and S-2.

Regarding the commissions from 2017, we find mostly usual errors like small gardens, bare soils in the neighborhood of impervious scattered areas, as seen in Table 3-5. It should be noted that the original change layer represented a nearly 50% increase of the artificial area in the test area which is huge and unrealistic considering that in fact over 75% of the detected changes were omission from 2015. In the re-classified layer, new built-up areas represent a 4% increase which appear more realistic and already represent a substantial increase over a 2-year period.

Table 3-5 – Results of the reclassification for 2015-2017.

	2015	2017	2015-2017
Original built-up mask (km²)	212,00	350,90	138,90
Reclassified built-up areas (omission - km²)	104,96	-	-
Reclassified non built-up areas (commission - km²)	-	20,26	-
Final reclassified built-up mask (km²)	316,96	330,64	13,68

Figure 3-17 below shows the results of the re-classification procedure performed on the original built-up change masks for 2015 and 2017. Results are now much closer than the values as based on the calibration data.

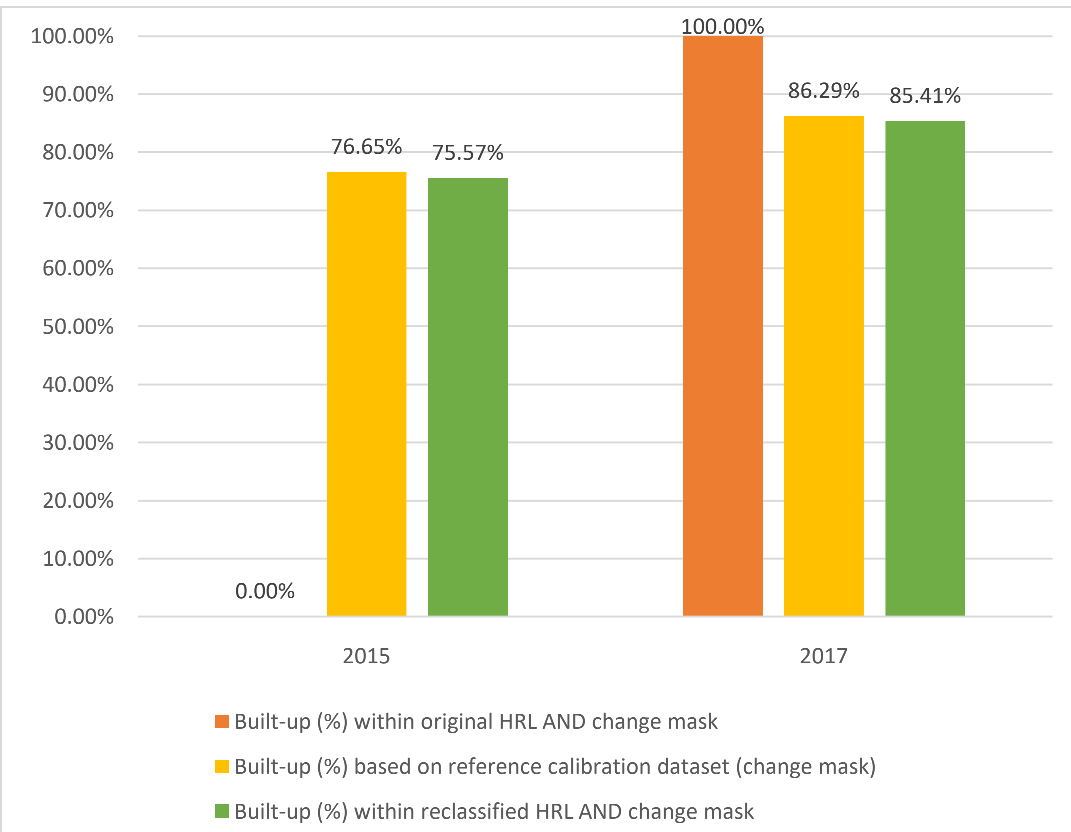


Figure 3-17 – Comparison of the original built-up change layer, calibration data and the reclassification results for the 2015-2017 period.

The improvement is even more visible when focusing on change statistics as illustrated in Figure 3-18.The re-classified change layer is well within the confidence interval of the calibration data thus providing spatially and temporally consistent change detection.

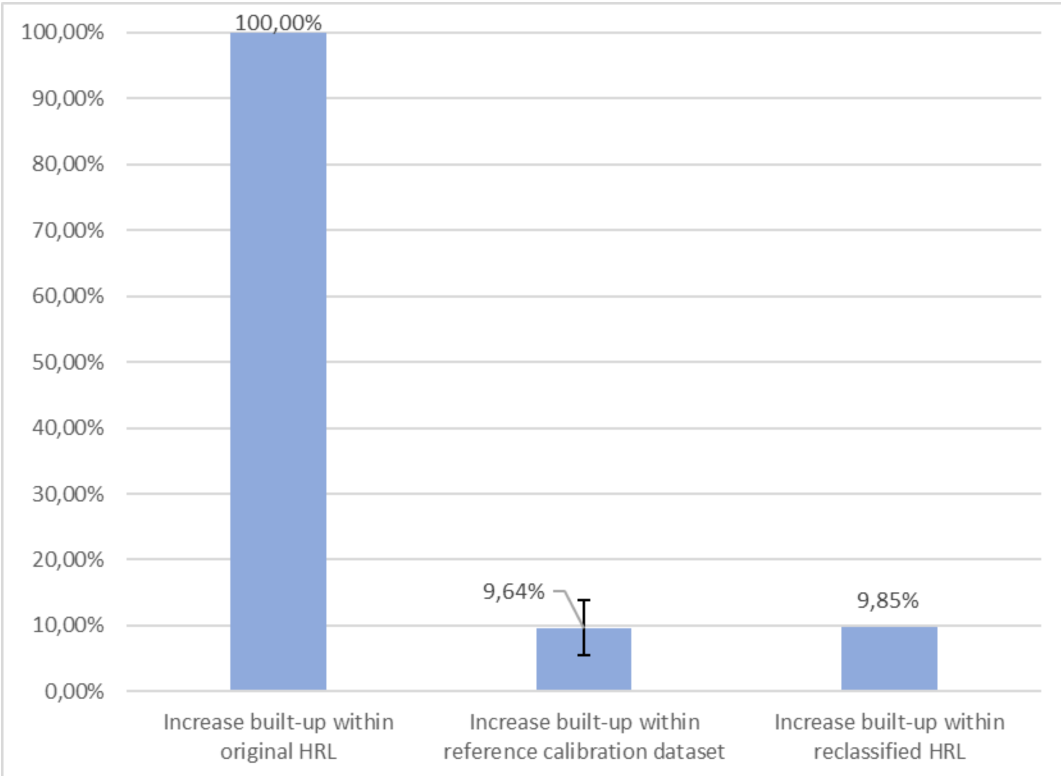


Figure 3-18 – Comparison of the detected change areas from the original new built-up mask stratum.

3.1.2.2 Added value of methodologies in comparison to the ones used in other (CLMS) contracts

It is worth comparing the performance of the new procedure developed as part of the project with the one which was implemented as part of the "HRL 2015 – Lot 1: Imperviousness products" project. The main differences between the two approaches is that a more sophisticated reclassification procedure (involving the combination of Differential Attribute profiles with SVM) was applied here taking full advantage of the increased spatial and temporal resolution of S-2. The method has been further developed within an active learning framework for producing the layer 2018 and the revised change layer focusing on 2018. Regarding the CLMS HRL re-analysis of the historical HRLs, a simpler re-classification procedure was applied based on was limited to the EO data available then (mostly Landsat, IRS and SPOT) for phase 1. In addition, the calibration data used for ECoLaSS was densified and optimised to better focus on initially detected changed areas compared with the HRL2015 production. This also shows in the results obtained by exhibiting a wider confidence interval. Further work is required to determine the optimal level of sampling intensity needed to apply the method operationally at a pan-European level. Nevertheless, there was still a substantial improvement in the re-processing of the 2006, 2009 and 2012 layer as part of the CLMS HRL2015 production, even though the improvement is more substantial in the procedure developed as part of this work (as shown in the previous section).

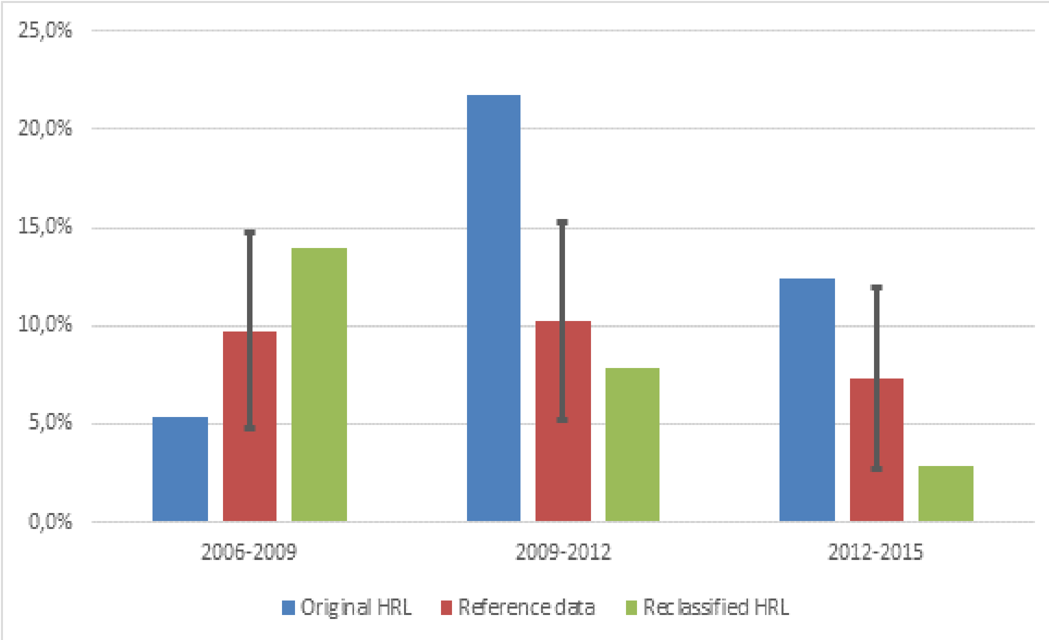


Figure 3-19 – Comparison of the detected change areas expressed as a percentage of the total area for the HRL2015 production within the selected test area for the original historical layers, the calibration reference data and the re-analysed reclassified HRL.

3.1.2.3 Accuracy assessment of changes

Finally, even though the main objective of the HRL production is to obtain reliable change area statistics by reducing the bias, as demonstrated above, improving the accuracy of change detection will result in a reduction of the uncertainty (i.e. confidence intervals of change area statistics). An accuracy assessment procedure was carried out based on selecting 200 sample units randomly selected within the change stratum and compared with the original and re-classified layer. Results are shown in the tables below.

Table 3-6 - Error matrix for the original 2015-17 change layer

Original 2015-17 change layer for South-West site		**REFERENCE**					
		New Built-up	**Omi. 2015**	**Comi. 2017**	**Total**	**User**	**Comi.**
PRODUCT	**New Built-up**	14	157	29	**200**	**7,00%**	**93,00%**
	Omi. 2015	0	0	0	**155**	**0,00%**	**100,00%**
	Comi. 2017	0	0	0	**26**	**0,00%**	**100,00%**
	Total	**14**	**157**	**29**	750		
	Prod.	**100,00%**	**0,00%**	**0,00%**			
	Omi.	**0,00%**	**100,00%**	**100,00%**			

Table 3-7 - Error matrix for the reclassified 2015-17 change layer

Reclassified 2015-17 change layer for South-West site		REFERENCE					
		New Built-up	Omi. 2015	Comi. 2017	Total	User	Comi.
PRODUCT	New Built-up	12	7	0	19	63,16%	36,84%
	Omi. 2015	0	149	6	155	96,13%	3,87%
	Comi. 2017	2	1	23	26	88,46%	11,54%
	Total	14	157	29	200		
	Prod.	85,71%	94,90%	79,31%			
	Omi.	14,29%	5,10%	20,69%			

It should be noted that the reclassification procedure is most effective in re-assigning omission errors to the 2015 layer with accuracies above or close to 95% for both producer and user accuracies. The classification of commission errors is less effective, but still with high accuracies approaching respectively 90% for user and 80% for producer accuracies. The identification of actual changes is above 85% for producer accuracy which is satisfactory, but just above 60% for user accuracy. This is still much improved from the initial value and most of the remaining commission actually relate to omission from the 2015 layer. This may be due to the lower quality of the imagery from 2015 and the fact that the 2015 omission covers an area nearly 8 times larger than the new built-up area. This may mean that an additional iteration is required to remove the outstanding omission from 2015 from the new built-up area. This could be achieved through the following procedure:

- Apply an additional reclassification procedure on the revised new built-up area perhaps based on active learning methods;
- Perform a manual enhancement procedure, as currently done for the HRL 2018 production, considering that this should take minimal effort since the entire exercise would only focus on a very small portion (4%) of the study area.

The phase 1 of the project demonstrated the feasibility and the relevance of the reclassification procedure (including both production years 2015 and 2017). As part of the phase 2, only the reclassification of the new reference year 2018 was done for the 3 test sites. Results of the reclassification are shown in the tables below.

Table 3-8 - Error matrix for the original 2015-18 SW change layer

Original 2015-18 change layer for South-West site		REFERENCE					
		New Built-up	Omi. 2015	Comi. 2017	Total	User	Comi.
PRODUCT	New Built-up	12	95	201	308	3,90%	96,10%
	Omi. 2015	0	0	0	0	0,00%	100,00%
	Comi. 2017	0	0	0	0	0,00%	100,00%
	Total	12	95	201	308		
	Prod.	100,00%	0,00%	0,00%			
	Omi.	0,00%	100,00%	100,00%			

Table 3-9 - Error matrix for the reclassified 2015-18 SW change layer

Reclassified 2015-18 change layer for South-West site		REFERENCE					
		New Built-up	Omi. 2015	Comi. 2017	Total	User	Comi.
PRODUCT	New Built-up	12	94	6	112	10,71%	89,29%
	Omi. 2015	0	0	0	0	0,00%	100,00%
	Comi. 2017	0	1	195	196	99,49%	0,51%
	Total	12	95	201	308		
	Prod.	100,00%	0,00%	97,01%			
	Omi.	0,00%	100,00%	2,99%			

Table 3-10 - Error matrix for the original 2015-18 Central change layer

Original 2015-18 change layer for Central site		REFERENCE					
		New Built-up	Omi. 2015	Comi. 2017	Total	User	Comi.
PRODUCT	New Built-up	56	259	40	355	15,77%	84,23%
	Omi. 2015	0	0	0	0	0,00%	100,00%
	Comi. 2017	0	0	0	0	0,00%	100,00%
	Total	56	259	40	355		
	Prod.	100,00%	0,00%	0,00%			
	Omi.	0,00%	100,00%	100,00%			

Table 3-11 - Error matrix for the reclassified 2015-18 Central change layer

Reclassified 2015-18 change layer for Central site		REFERENCE					
		New Built-up	Omi. 2015	Comi. 2017	Total	User	Comi.
PRODUCT	New Built-up	56	259	8	323	17,34%	82,66%
	Omi. 2015	0	0	0	0	0,00%	100,00%
	Comi. 2017	0	0	32	32	100,00%	0,00%
	Total	56	259	40	355		
	Prod.	100,00%	0,00%	80,00%			
	Omi.	0,00%	100,00%	20,00%			

Table 3-12 - Error matrix for the original 2015-18 SE change layer

Original 2015-18 change layer for South-East site		REFERENCE					
		New Built-up	Omi. 2015	Comi. 2017	Total	User	Comi.
PRODUCT	New Built-up	15	177	81	273	**5,49%**	**94,51%**
	Omi. 2015	0	0	0	0	**0,00%**	**100,00%**
	Comi. 2017	0	0	0	0	**0,00%**	**100,00%**
	Total	**15**	**177**	**81**	273		
	Prod.	**100,00%**	**0,00%**	**0,00%**			
	Omi.	**0,00%**	**100,00%**	**100,00%**			

Table 3-13 - Error matrix for the reclassified 2015-18 SE change layer

Reclassified 2015-18 change layer for South-East site		REFERENCE					
		New Built-up	Omi. 2015	Comi. 2017	Total	User	Comi.
PRODUCT	New Built-up	15	176	1	**192**	**7,81%**	**92,19%**
	Omi. 2015	0	0	0	**0**	**0,00%**	**100,00%**
	Comi. 2017		1	80	**81**	**98,77%**	**1,23%**
	Total	**15**	**177**	**81**	**273**		
	Prod.	**100,00%**	**0,00%**	**98,77%**			
	Omi.	**0,00%**	**100,00%**	**1,23%**			

The results show the improvement of the change layer regarding the commission errors 2018 due to the reclassification procedure applied for 2018. As mentioned above, no reclassification was undertaken for 2015 which explains the level of 2015 omission errors after the reclassified procedure. It is interesting to notify that the correction of the 2018 commission errors are greater with the Active Learning algorithms (used for the generation of the 2018 IMD status layer) in comparison with the 2017 status layer obtained with SVM classifiers.

3.1.3 Sensibility characterization of the change calibration

Following the outcomes of the WP35, once the re-classification procedure is finalized, actual change products can be generated:

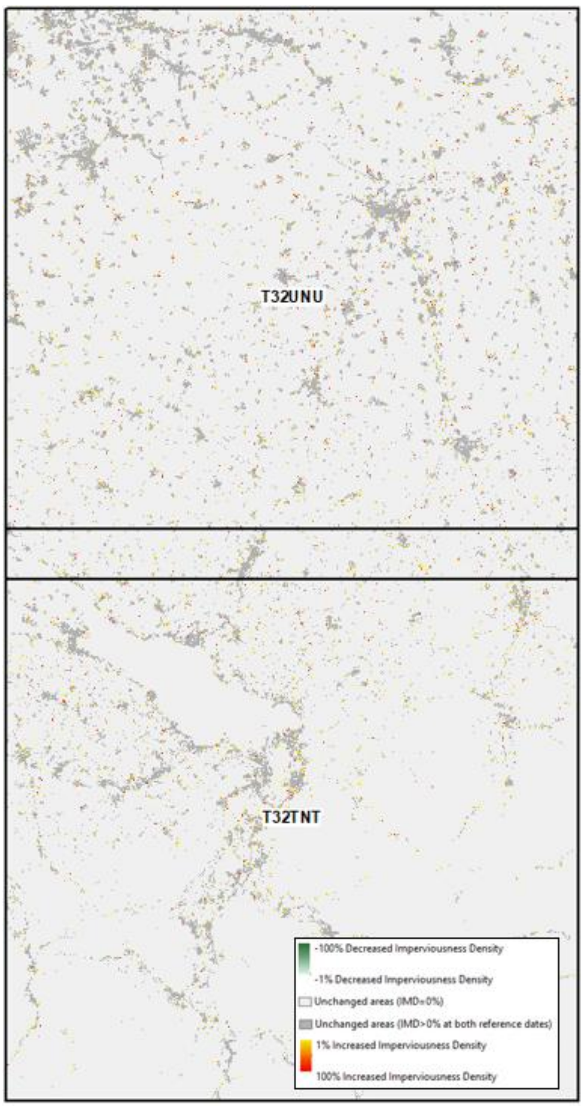
- Degree of Imperviousness change 2015/17-2018 Layer (IMC 2015/17-2018)
- Degree of Imperviousness change classified 2015/17-2018 Layer (IMCC 2015/17-2018)

At first, at 20m, the change degree layer is calculated by direct subtraction of the 20m improved imperviousness values but without any further filtering, thereby guaranteeing full consistency of all products. The result displays the total imperviousness degree change values from -100% to +100%, according to the thresholds set at the relative calibration and without any thematic classification applied. In other words, the first-step change layer only consists of a continuous layer with change values from -100% decrease to +100% increase and not a categorisation of changes.

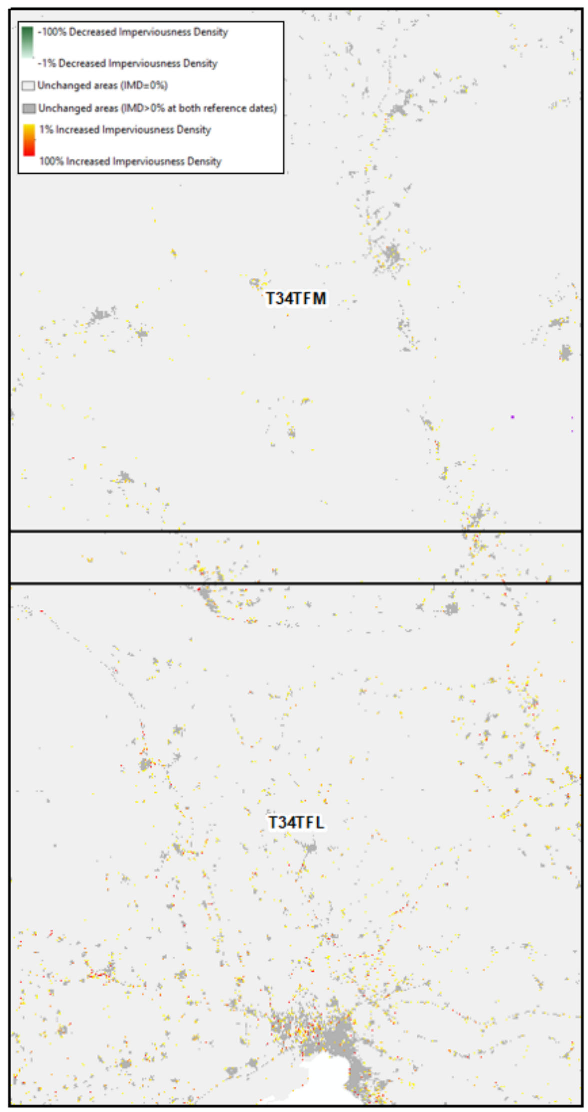
Then, a rule-based derivation of the IMC values based on a spatial filtering is applied in order to take into account the different specifications:

1. Minimum increase/decrease of the imperviousness degree between 2015 and 2018 to be considered as actual changes; otherwise differences are considered as noise from the calibration and so stable sealed surfaces.
2. Minimum contiguous area of pixels following the rule 1) to be considered as actual changes (increase/decrease); otherwise differences are also considered as noise from the calibration and so stable sealed surfaces.

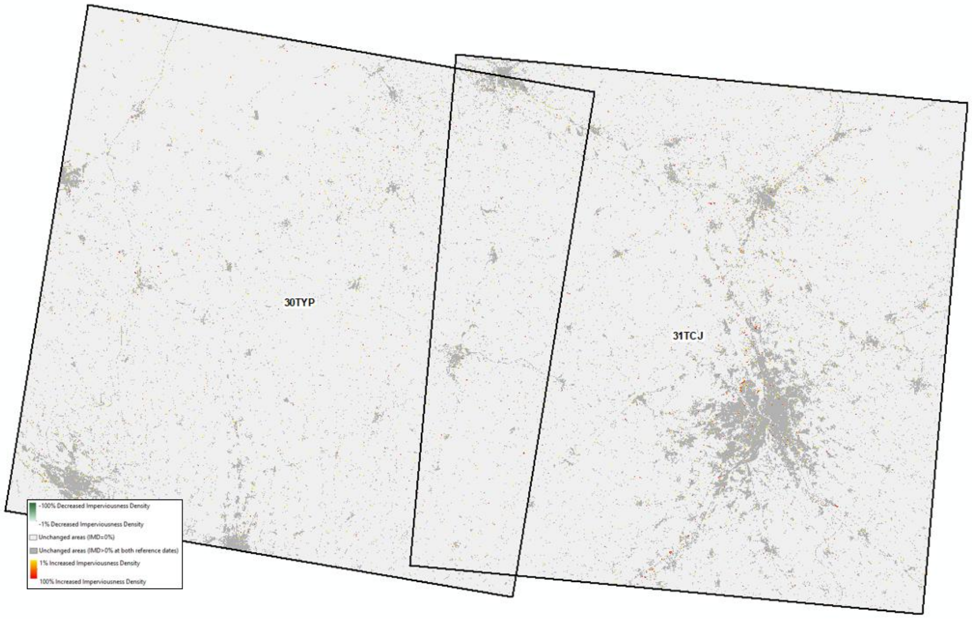
The rule-based derivation aims to derive a reliable sealing changes and limit noise due to the calibration and the 20-meters spatial resolution of the HRL 2015 layer (in comparison with HRL 2017 Prototype, based on Sentinel-2 at 10-meters resolution). The results of the HRL Imperviousness change prototypes are shown in Figure 3-20.



Central test site (2015-2018)



South-East test site (2015-2018)



South-West test site (2017-2018)

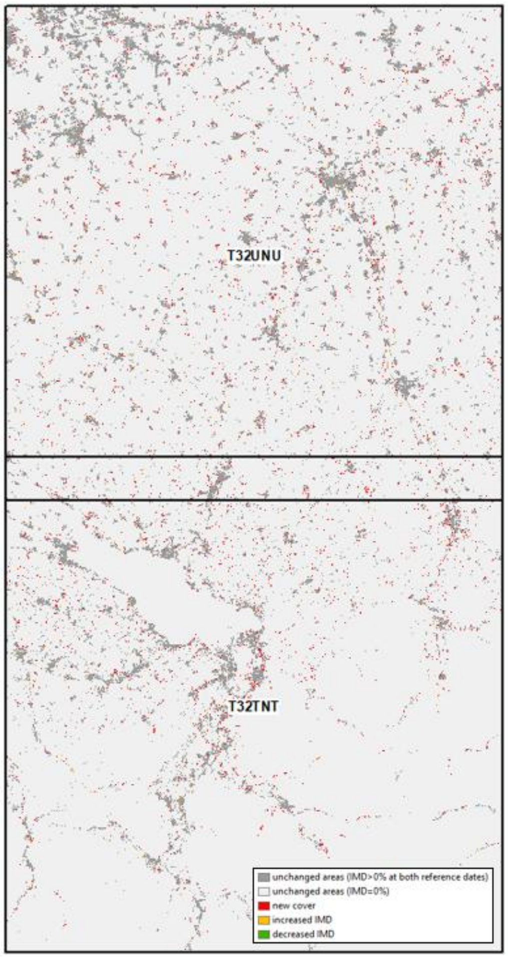
Figure 3-20: Final HRL Imperviousness Change prototypes for the phase 2 test sites

To be fully compliant with the actual specification of the products, the derived change layer is then converted into a ‘classified change’ layer. For this purpose, the continuous change values will be thematically aggregated into the following categorical classes according to the rule base defined in Table 3-14 below.

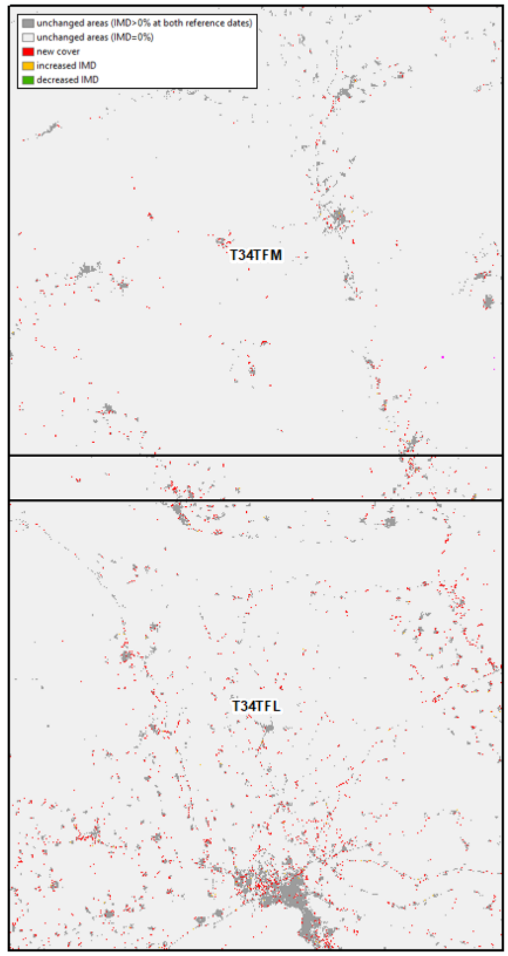
Table 3-14: Specifications of the ‘classified change’ layer

Class Code	Classified change. Class name	IMD t1	IMD t2
0	unchanged areas with IMD=0%	0%	0%
1	new cover (increased imperviousness density, 0% IMD at first reference date)	0%	>0%
2	loss of cover (decreasing imperviousness density, 0% IMD at second reference date)	>0%	0
10	unchanged areas (IMD>0% at both reference dates)	>0%	>0%
11	increased IMD (IMD>0% at both reference dates) subject to a 20% threshold for 4px contiguous areas	>0%	>>0%
12	decreased IMD (IMD>0 at both reference dates) subject to a 80% threshold for 4px contiguous areas	>>0%	>0
254	unclassifiable in any of parent status layers	254	254
255	outside area	255	255

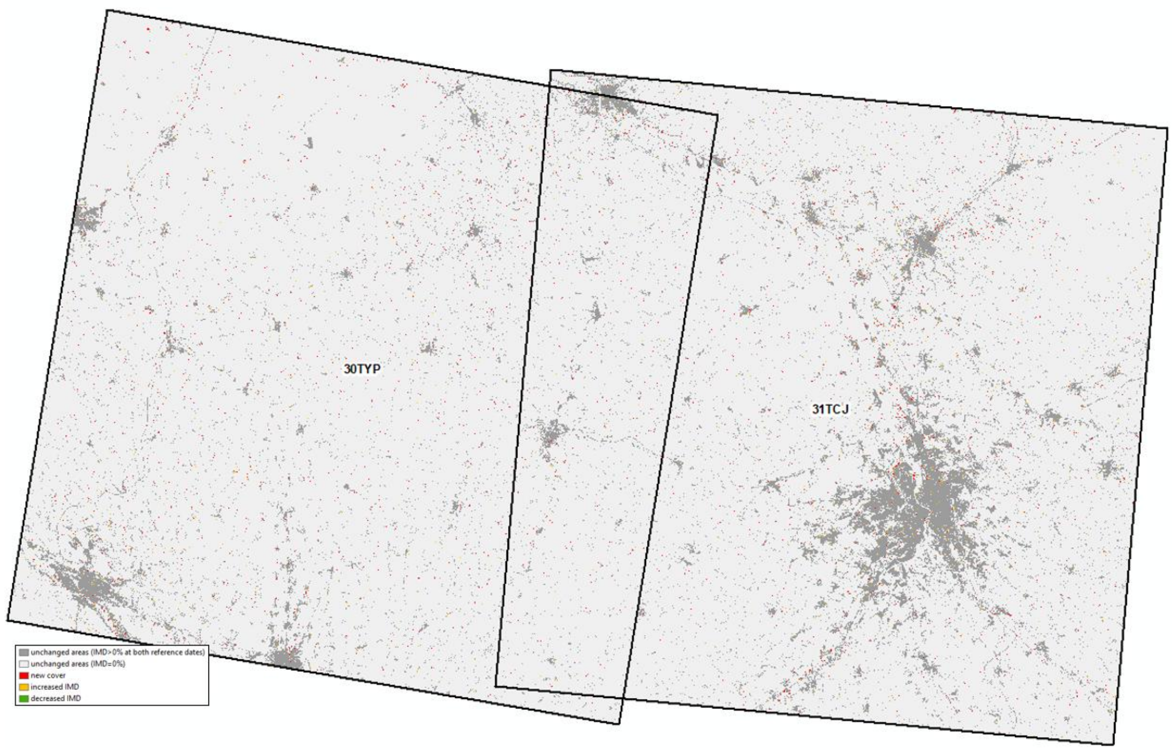
The final results of the implementation of the production of the Imperviousness Change Prototype 2015/17-2018 (as part of the phase 2) are presented in the Figure 3-21:



Central test site (2015-2018)



South-East test site (2015-2018)



South-West test site (2017-2018)

Figure 3-21: Final HRL Imperviousness Classified Change prototypes for the test sites

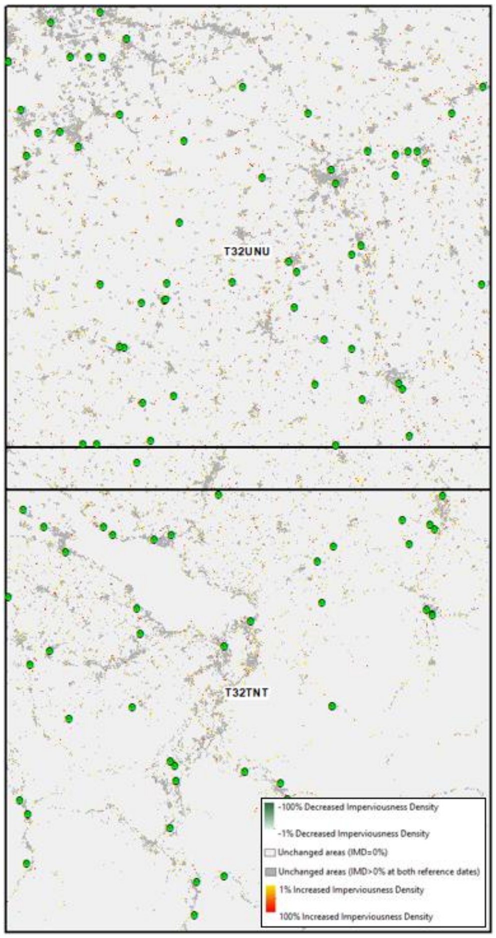
From an imperviousness degree perspective, the resulting layer IMC 2015/17-2018 change layer obtained from the 2015/2017 and 2018 improved status layers does not only reveal 2015/17-2018 changes (increase/decrease of imperviousness degree) but it also detects potential omission errors in the imperviousness degree layer 2015 (under-estimation of sealed surfaces) as well as potential commission errors of the 2018 sealed area (over-estimation of sealed surfaces).

In phase 2, a sensibility test for the change detection was conducted; aiming to differentiate between “actual increase” and “technical changes”. Indeed, the relative magnitude of actual change versus the errors contained in the change layer for each time interval should be known in order to provide a basis for improving the temporal consistency between each layer.

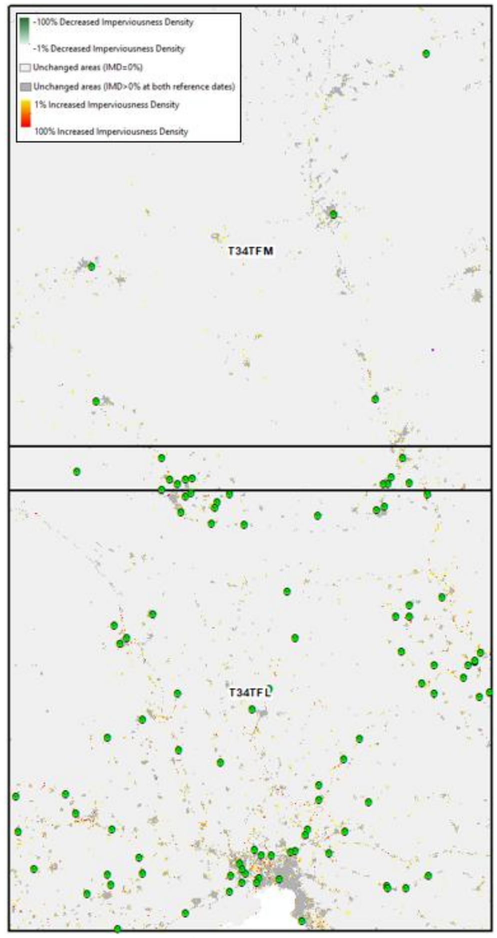
Therefore, as it’s done for the assessment of the actual new built-up in comparison with the technical issues (section 3.1.1.2), there is a need to develop a reference dataset that will be used to determine the relative proportion of actual increase degree versus all the error components described hereafter:

- The imperviousness increase degree between 2015 and the year 2017/2018;
- The omission errors from 2015 – the under-estimation of imperviousness degree 2015.
- the commission errors from 2017/2018 – the under-estimation of imperviousness degree in 2017/2018.
- And the commission errors from both years 2015 and 2017/2018 – the under-estimation of imperviousness degree in 2015 and 2017/2018.

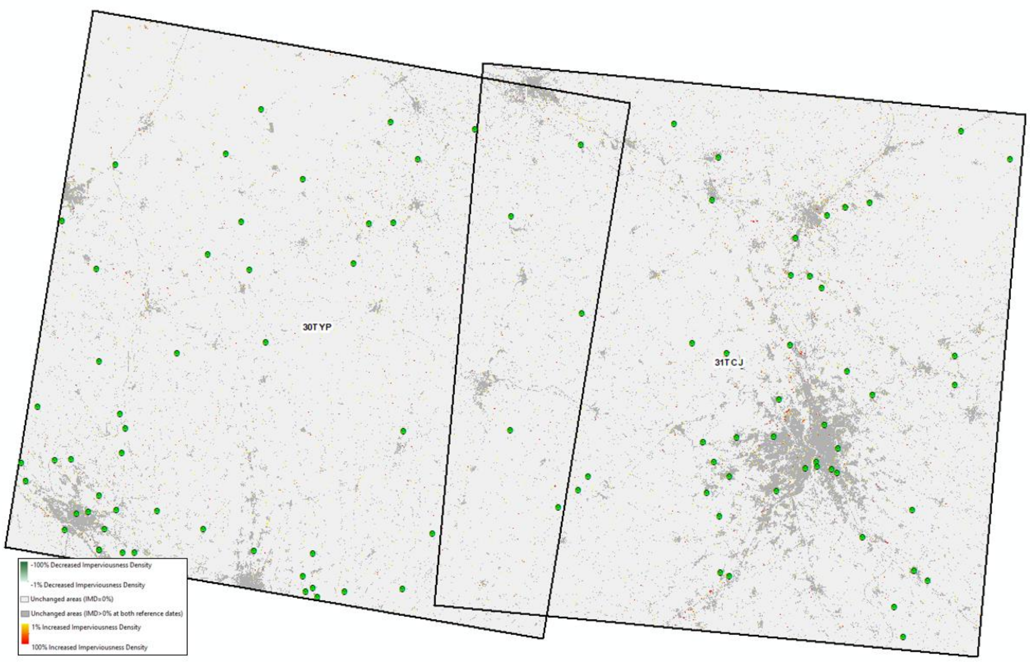
To be valid, this calibration dataset should be selected based on a probability sampling approach.



Central test site



South-East test site



South-West test site

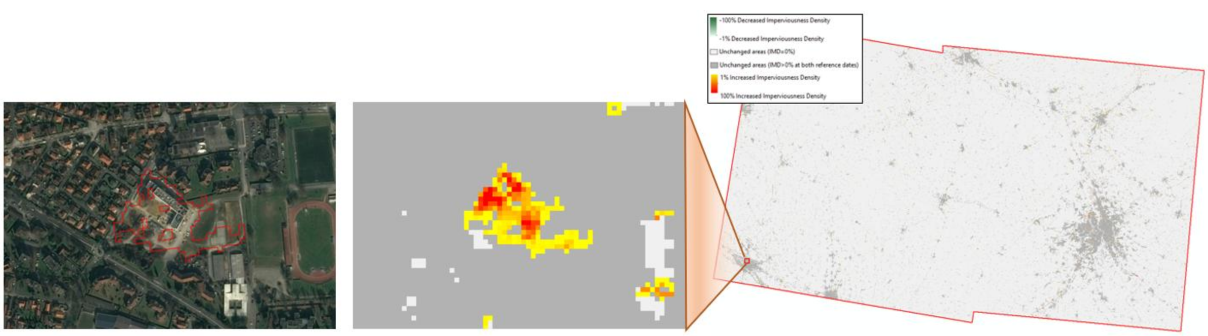
Figure 3-22 – Reference calibration samples overlaid on the 2015-2018 IMC layer for test sites

For the test site of the phase 2, 300 sample point/pixel units were randomly selected based on the increase stratum as shown in Figure 3-22. The results obtained from the reference calibration dataset are as follows:

Table 3-15 – Characterisation of 2015/17-2018 change degree stratum for the phase 2 test sites

% of total increase areas				
	South-West		Central	South-East
Increase IMP 2015-2018	29.00%	**Increase IMP 2015-2018**	45.00%	38.00%
Omission errors 2015 (under-estimation IMP 2015)	39.00%	**Omission errors 2015 (under-estimation IMP 2015)**	40.00%	43.00%
Commission errors 2018 (over-estimation IMP 2018)	16.00%	**Commission errors 2018 (over-estimation IMP 2018)**	9.00%	12.00%
Commission errors 2015 and 2017/2018	16.00%	**Commission errors 2015 and 2018**	6.00%	7.00%
Total Increase Area (km²)	27.81	**Total Increase Area (km²)**	27.81	5.83

Based on the calibration dataset, the relative magnitude of actual increase is estimated to represent 29%, 45% and 38% (respectively for the South-West, Central and South-East test site) of the total area detected as increased from the automated change detection procedure as shown in Figure 3-23. Thus, the errors concern the remaining 55 to 70% of the change areas detected. Most of these represent omission errors from 2015 (around 40% for each test site) and just less than 16% represent new commission errors from 2018.



Increase imperviousness degree 2015-2018

South-West site

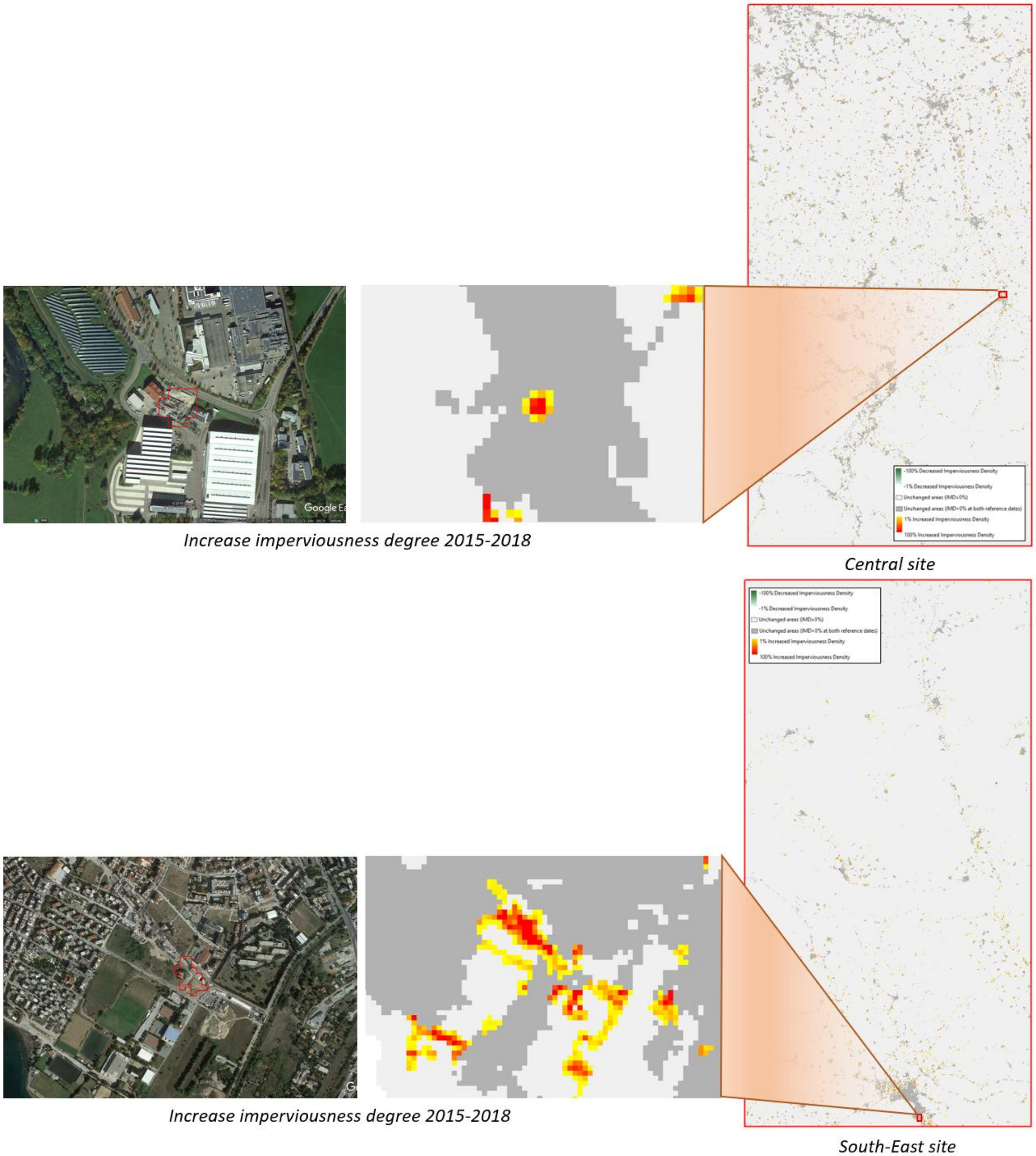


Figure 3-23 – Example of increase imperviousness degree

As explained in WP34 [AD07] and regarding the omission errors from the previous period, it should be noticed that the specifications of the reference image data for 2015 is different to that of the 2017 input data. For 2015, the production was mostly based on Landsat data whereas the 2017 built-up was produced from S-2 resulting in a 9-fold improvement in spatial resolution (i.e. a Landsat pixel is characterized by 9 S-2 pixels).

3.2 Testing of incremental updates for FOR layers

In the first project phase an image-to-image change detection approach has been tested in the test site North (two S-2 tiles; ca. 20,000 km²) in Sweden using different combinations of Sensors (S-2 and/or S-1) and observation periods (spring, spring/summer, full year) [see AD06]. Results were very promising and in accordance with the best performance-cost ratio, it was recommended to use optical Sentinel-2 data from the spring period (15.03.-15.06.) only in order to simulate an incremental update at 20 m resolution, focussing on forest loss in the period 2015 to 2017.

At the end of the first project phase, the developed approach has been applied on the whole demonstration site North (six S-2 tiles, ca. 60,000 km²), but frequent cloud cover in the northern S-2 tiles hampered the tree cover detection and leaf type discrimination, which was fully based on optical data at this point in time. The selected map-to-map approach (see Figure 3-24) worked well, but results were below expectations as the input masks from 2015 and 2017 differs significantly in terms of spatial resolution and accuracy (omission and commission errors in 2015/2017). For this reason and due to the error propagation over time, the Minimum Mapping Unit has been set to 3 ha in order to capture reliable areas of forest loss. As such a MMU is not satisfying from a user perspective, several measures have been identified to improve the results:

- Including of Sentinel-1 SAR time series data (timely consistent with S-2 features)
- Integration of additional Sentinel-2 time features, based on spectral bands
- Improved sampling based on a HRL2015 Sampling Layer
- Application of a feature selection method
- NDVI-based plausibility analysis of detected changes

The above mentioned measures have been successfully tested in the second project phase. Based on the experiences and lessons learned from project phase 1, the workflow for the incremental update has been significantly improved by using a combined optical and SAR approach [see AD06] with a subsequently applied NDVI plausibility analysis for detected changes (see Figure 3-25). By using consistently produced and improved Tree Cover Masks at 10m resolution for the years 2017 and 2018, both omission and commission errors could be significantly reduced. The achieved overall accuracy figures exceed the 90 % in each test site and the MMU for forest loss could be finally set to 1 ha, which is a considerable improvement compared to the 3 ha MMU of project phase 1. This MMU is also in line with the change products of the ongoing HRL2018 production.

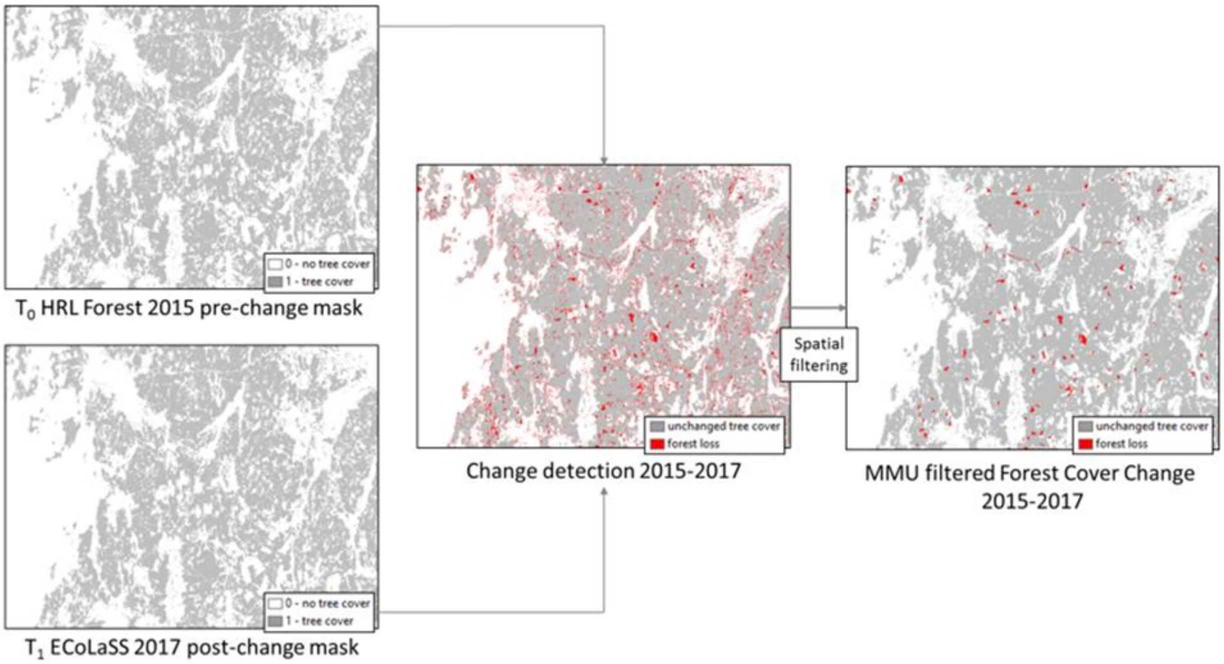


Figure 3-24 – Map-to-map approach for generation of the Forest Incremental Update Layer 2015/2017 at 20m spatial resolution

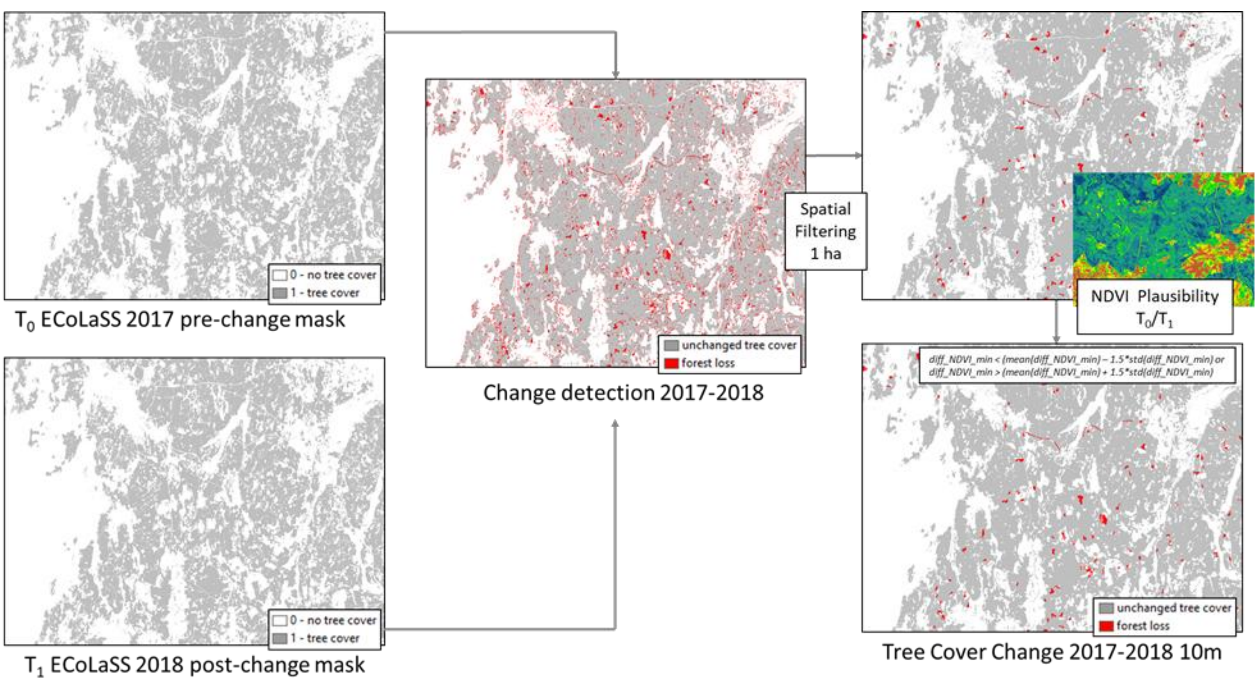


Figure 3-25 – Map-to-map approach for generation of the Forest Incremental Update Layer 2017/2018 at 10m spatial resolution

A detailed description of the workflow to generate the Forest incremental updates is given in [AD06]. Final results of the incremental update layer called Tree Cover Change (TCC) 2017-2018 are presented in the report "D42.1b - Prototype Report: Consistent HR Layer Time Series/Incremental Updates".

4 Conclusions and outlook

4.1 Availability of input EO data

Based on the outcome of the HRL 2015 production, the availability of EO data remained a major limiting factor with data acquired +/- one-year of the reference year, thus requiring nearly three years of data in total to achieve complete coverage and as a result limiting the update to the current 3-year period. However, this was the first implementation of the HRL production based on dense time series as opposed to a two coverages per year approach in the past. The number of cloud-free observations still remains limited in some areas (e.g. Northern Ireland, Norway & Iceland), but are substantially improved through integration of Landsat data and ESA third party missions.

However, the production of the HRLs 2015 could only begin to take advantage of the availability of Sentinel-2 (S-2A) as the constellation of S-2 A/B was only available from mid-2017 onwards. Tests conducted in the first project phase (2017) of ECoLaSS have shown that the current 3-years updated cycle can be technically shortened to 1-2 years, if sufficient cloud-free observations are available within the selected observation period, which might differ between the various HRL products. In this context, the quality and extent of provided cloud masks is a key factor in order to derive preferably cloud-free products.

However, even with the full availability of the S-2 constellation from mid-2017 onwards, cloud cover is likely to remain a problem, particularly over northern latitudes. Therefore, the synergy between S-1 and S-2 has been further explored in the second project phase. The combination of optical S-2 data and S-1 SAR data turned out to be useful over cloud prone regions or regions with an exceptionally high and frequent cloud cover in certain years as it could be observed in the demonstration site South-East in 2018. Nevertheless, the combination does not necessarily have an added value for all prototypes and there are even some products (e.g. Tree Cover Density), which fully rely on optical satellite data.

Finally, the combined optical and SAR approach entered in the current HRL2018 production, at least for some products and in specific areas.

4.2 Expected magnitude of Change

The analysis of available statistics at pan-European level show contrasting change patterns. With respect to imperviousness, the trend is overwhelmingly in the steady increase of artificial areas to the point that the conversion of artificial areas back to agriculture or other land use is negligible. However, artificial areas still represent of very small proportion of the overall area and even though the trend is steadily increasing it seems to have stabilised in the last decade, but it is difficult to see whether this is as a result of new policies or just due to the economic activity. Nevertheless, the increase of artificial areas typically represents about 6,000 km² over EEA-39, which is still very small and challenging to characterise, but there is considerable variability across Europe with steadier growth in Southern Europe compared with Northern Europe. This could justify more frequent incremental update in areas where the growth is more substantial. Interestingly, this also coincides with areas less prone to cloud cover.

Forest dynamics are more complex with both areas where forest is increasing and decreasing even though the net change is toward increasing forested areas. Forest also cover a much greater area than urban areas by a factor of 6 to 8 and the net change represent about 30,000 km² at the European scale, but this represent net change and the area affected by forest dynamics can theoretically be larger when considering the areas affected by loss and gain of forest cover.

Grassland is much more challenging to apprehend as grassland cover is a much more dynamic vegetation type to characterise for which it is often difficult to decouple between phenological and long-term trend. The magnitude of change appears less than that of forest making more challenging to characterise. In addition, grassland can also expand or decrease depending on the area event though the overall trend is probably towards a reduction.

4.3 Improvement of the accuracy and reduction of bias of change detection

Based on the previous parameters, EO data availability and magnitude of change, it appears feasible to increase the frequency of update. The real question is more on the ability to improve the accuracy, i.e. provide an estimate with a greater degree of confidence and reduce the bias, i.e. ensure that the level of omission and commission errors are equivalent.

A post-classification procedure was developed for the Imperviousness layer, and has been improved in the phase 2, based on a dedicated calibration sample dataset and a reclassification procedure. It will also be applied to the FOR HRL 2018 production. The West demonstration site also underwent such post-classification procedure, improving the accuracy of the change layer between 2017 and 2018.

It should also be noted that the change of resolution between the previous 20+m data and now with S-2 data (and S-1 data or some products) will yield to substantial so-called technical changes that cannot be ignored due to their magnitude rendering such a bias reduction and accuracy improvement of change detection procedure essential. In fact, although it is not desirable to reprocess the whole time series every time a new update is produced, it would seem good practice to at least re-process the previous status layer to ensure spatial and temporal consistency between subsequent reference year considering the small magnitude of changes, e.g. when HRL2018 is produced, HRL2015 should be re-processed to be consistent with the re-classified 2015-18 change layer based on the procedure described in Chapter 3. This means that two versions of a status layer should be kept: one that is consistent with the previous change period, e.g. 2012-15 and one that is consistent with the new period, e.g. 2015-18. Further details in change detection methods specific for the thematic topics addressed in ECoLaSS are described in WP34 [AD07].

Finally, even though, there are still likely to be issues in cloud prone areas, yearly updates should be possible notably thanks to the complementarity of S-1 data. It should be noted that cloud detection errors tend to tarnish the quality of the S-2 classification when the whole time series is used without filtering, and the best results for yearly incremental updates have been obtained for the IMP layers by combining best optical scene selection and temporal statistics for SAR data if necessary.

Yearly updates would only depict detected changes which would then be integrated in status layer updates that would still be produced on a 3-year or perhaps longer cycle, especially for HRLs covering a small proportion of the total area, to provide spatially and temporally consistent HR IMD Layer time series.

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EEA:
https://www.eea.europa.eu/ Last updated 04 April 2018

CAP at a glance:
https://ec.europa.eu/agriculture/cap-overview_en

Annex

Imperviousness

Table 5-1 - CLC 1990 to 2018 analysis of urban area change, part I

count artificial surfaces (Level 1)										
PAYS	clc_1990	clc_1990 km²	clc_2000	clc_2000 km²	change in urban surface	% of increase between 1990 and 2000	clc_2006	clc_2006 km²	change	% of increase between 2000 and 2006
ALBANIA			48943	489.43	489.43		73900	739	249.57	50.99%
AUSTRIA	340282	3402.82	401465	4014.65	611.83	17.98%	462189	4621.89	607.24	15.13%
BELGIUM	606577	6065.77	627147	6271.47	205.7	3.39%	631512	6315.12	43.65	0.70%
BOSNIA			70014	700.14	700.14		79870	798.7	98.56	14.08%
BULGARIA	544409	5444.09	547497	5474.97	30.88	0.57%	528900	5289	-185.97	-3.40%
CHYPRUS			66861	668.61	668.61		77360	773.6	104.99	15.70%
CROATIA	147547	1475.47	153438	1534.38	58.91	3.99%	172631	1726.31	191.93	12.51%
CZECHIA	472781	4727.81	489271	4892.71	164.9	3.49%	499627	4996.27	103.56	2.12%
DANEMA RK	275072	2750.72	290755	2907.55	156.83	5.70%	310513	3105.13	197.58	6.80%
ESTONIA	86018	860.18	87014	870.14	9.96	1.16%	91040	910.4	40.26	4.63%
FINLAND			447462	4474.62	4474.62		461412	4614.12	139.5	3.12%
France	2483938	24839.38	2679970	26799.7	1960.32	7.89%	2898322	28983.22	2183.52	8.15%
GERMANY	2728972	27289.72	2888632	28886.32	1596.6	5.85%	2998903	29989.03	1102.71	3.82%
GREECE	235881	2358.81	273264	2732.64	373.83	15.85%	355504	3555.04	822.4	30.10%
HUNGARY	522005	5220.05	545303	5453.03	232.98	4.46%	566609	5666.09	213.06	3.91%
ICELAND			30048	300.48	300.48		35562	355.62	55.14	18.35%

IRELAND	97174	971.74	133396	1333.96	362.22	37.28%	163266	1632.66	298.7	22.39%
ITALY	1316967	13169.67	1412262	14122.62	952.95	7.24%	1528637	15286.37	1163.75	8.24%
KOSOVO			24800	248	248		32732	327.32	79.32	31.98%
LATVIA	84807	848.07	84917	849.17	1.1	0.13%	125493	1254.93	405.76	47.78%
LITHUANIA	212139	2121.39	211252	2112.52	-8.87	-0.42%	208068	2080.68	-31.84	-1.51%
LUX	21226	212.26	22935	229.35	17.09	8.05%	25564	255.64	26.29	11.46%
MACEDOINE			37825	378.25	378.25		42289	422.89	44.64	11.80%
MONTENEGRO	13037	130.37	13764	137.64	7.27	5.58%	22760	227.6	89.96	65.36%
NETHERLAND	364704	3647.04	447574	4475.74	828.7	22.72%	505169	5051.69	575.95	12.87%
NORWAY			217263	2172.63	2172.63		225099	2250.99	78.36	3.61%
POLAND	1029279	10292.79	1243174	12431.74	2138.95	20.78%	1713807	17138.07	4706.33	37.86%
Portugal	176800	1768	292496	2924.96	1156.96	65.44%	339627	3396.27	471.31	16.11%
ROMANIA	1482261	14822.61	1488680	14886.8	64.19	0.43%	1252661	12526.61	-2360.19	-15.85%
SERBIA	246676	2466.76	256914	2569.14	102.38	4.15%	282177	2821.77	252.63	9.83%
SLOVAKIA	273804	2738.04	263910	2639.1	-98.94	-3.61%	280334	2803.34	164.24	6.22%
SLOVENIA	54629	546.29	55249	552.49	6.2	1.13%	56623	566.23	13.74	2.49%
SPAIN	646818	6468.18	814230	8142.3	1674.12	25.88%	1141936	11419.36	3277.06	40.25%
SUISSE			269640	2696.4	2696.4		274473	2744.73	48.33	1.79%
SWEDEN			580379	5803.79	5803.79		602487	6024.87	221.08	3.81%
TURKEY	941084	9410.84	1192470	11924.7	2513.86	26.71%	1269721	12697.21	772.51	6.48%
UK			1784527	17845.27	17845.27		1999709	19997.09	2151.82	12.06%

Table 5-2 - CLC 1990 to 2018 analysis of urban area change, part II

count artificial surfaces (Level 1)									
PAYS	clc_2012	clc_2012 km²	change	% of increase between 2006 and 2012	clc_2018	clc_2018 km²	change	% of increase between 2012 and 2018	% of increase between oldest CLC data and 2018
ALBANIA	76206	762.06	23.06	3.12%	76869	768.69	6.63	0.87%	36%
AUSTRIA	467325	4673.25	51.36	1.11%	497204	4972.04	298.79	6.39%	27%
BELGIUM	635376	6353.76	38.64	0.61%	640747	6407.47	53.71	0.85%	5%
BOSNIA	81722	817.22	18.52	2.32%	88522	885.22	68	8.32%	14%
BULGARIA	532860	5328.6	39.6	0.75%	533899	5338.99	10.39	0.19%	-2%
CHYPRUS	79768	797.68	24.08	3.11%	84037	840.37	42.69	5.35%	16%
CROATIA	176580	1765.8	39.49	2.29%	196764	1967.64	201.84	11.43%	16%
CZECHIA	507018	5070.18	73.91	1.48%	523326	5233.26	163.08	3.22%	7%
DANEMARK	307814	3078.14	-26.99	-0.87%	335852	3358.52	280.38	9.11%	11%
ESTONIA	94857	948.57	38.17	4.19%	96834	968.34	19.77	2.08%	9%
FINLAND	438805	4388.05	-226.07	-4.90%	451507	4515.07	127.02	2.89%	-2%
France	2985478	29854.78	871.56	3.01%	3231166	32311.66	2456.88	8.23%	17%
GERMANY	3374324	33743.24	3754.21	12.52%	3358428	33584.28	-158.96	-0.47%	19%
GREECE	368005	3680.05	125.01	3.52%	407636	4076.36	396.31	10.77%	36%
HUNGARY	574218	5742.18	76.09	1.34%	598778	5987.78	245.6	4.28%	9%
ICELAND	35573	355.73	0.11	0.03%	36067	360.67	4.94	1.39%	16%
IRELAND	165721	1657.21	24.55	1.50%	161719	1617.19	-40.02	-2.41%	41%
ITALY	1557760	15577.6	291.23	1.91%	1623285	16232.85	655.25	4.21%	15%
KOSOVO	35101	351.01	23.69	7.24%	50779	507.79	156.78	44.67%	29%
LATVIA	127708	1277.08	22.15	1.77%	131977	1319.77	42.69	3.34%	34%

LITHUANIA	210010	2100.1	19.42	0.93%	219763	2197.63	97.53	4.64%	-1%
LUX	26201	262.01	6.37	2.49%	27633	276.33	14.32	5.47%	19%
MACEDOINE	42856	428.56	5.67	1.34%	46098	460.98	32.42	7.56%	12%
MONTENEGRO	23384	233.84	6.24	2.74%	25338	253.38	19.54	8.36%	44%
NETHERLAND	525276	5252.76	201.07	3.98%	535363	5353.63	100.87	1.92%	31%
NORWAY	233806	2338.06	87.07	3.87%	244464	2444.64	106.58	4.56%	7%
POLAND	1763092	17630.92	492.85	2.88%	1932501	19325.01	1694.09	9.61%	42%
Portugal	349080	3490.8	94.53	2.78%	356227	3562.27	71.47	2.05%	49%
ROMANIA	1262421	12624.21	97.6	0.78%	1315529	13155.29	531.08	4.21%	-17%
SERBIA	284689	2846.89	25.12	0.89%	292771	2927.71	80.82	2.84%	13%
SLOVAKIA	287467	2874.67	71.33	2.54%	295881	2958.81	84.14	2.93%	5%
SLOVENIA	60566	605.66	39.43	6.96%	71369	713.69	108.03	17.84%	10%
SPAIN	1229137	12291.37	872.01	7.64%	1270495	12704.95	413.58	3.36%	47%
SUISSE	275304	2753.04	8.31	0.30%	284616	2846.16	93.12	3.38%	2%
SWEDEN	613214	6132.14	107.27	1.78%	640300	6403	270.86	4.42%	5%
TURKEY	1356260	13562.6	865.39	6.82%	1535966	15359.66	1797.06	13.25%	31%
UK	2017731	20177.31	180.22	0.90%	2120350	21203.5	1026.19	5.09%	12%

Table 5-3 – Observations per countries related to urban areas in LUCAS database for 2006, 2009, 2012 and 2015

Countries	LUCAS Database A11 and A12 points for 2006	LUCAS Database A11 and A12 points for 2009	% of increase between 2006 and 2009	LUCAS Database A11 and A12 points for 2012	% of increase between 2009 and 2012	LUCAS Database A11 and A12 points for 2015	% of increase between 2012 and 2015
Austria (AT)	-	110	-	159	44.55%	132	-16.98%
Belgium (BE)	41	91	121.95%	144	58.24%	142	-1.39%
Bosnia and Herzegovina (BG)	-	-	-	49	-	50	2.04%
Cyprus (CY)	-	-	-	28	-	23	-17.86%
Czech Republic (CZ)	30	52	73.33%	73	40.38%	89	21.92%
Germany (DE)	341	486	42.52%	601	23.66%	619	3.00%
Denmark (DK)	-	60	-	85	41.67%	n/a	-
Estonia (EE)	-	10	-	13	30.00%	11	-15.38%
Greece (EL)	-	79	--	82	3.80%	90	9.76%
Spain (ES)	138	291	110.87%	392	34.71%	369	-5.87%
Finland (FI)	-	89	-	60	-32.58%	58	-3.33%
France (FR)	243	460	89.30%	604	31.30%	647	7.12%
Hungary (HU)	61	71	16.39%	63	-11.27%	36	-42.86%
Ireland (IE)	-	46	-	42	-8.70%	33	-21.43%
Italy (IT)	257	413	60.70%	534	29.30%	534	0.00%
Lithuania (LT)	-	36	-	37	2.78%	37	0.00%
Luxembourg (LU)	3	3	0.00%	5	66.67%	7	40.00%
Latvia (LV)	-	21	-	20	-4.76%	20	0.00%
Malta (MT)	-	-	-	15	-	15	0.00%
Netherlands (NL)	37	86	132.43%	84	-2.33%	78	-7.14%
Poland (PL)	216	188	-12.96%	253	34.57%	275	8.70%
Portugal (PT)	-	85	-	143	68.24%	126	-11.89%
Romania (RO)	-	-	-	143	-	148	3.50%
Sweden (SE)	-	78	-	75	-3.85%	103	37.33%
Slovenia (SI)	-	10	-	14	40.00%	13	-7.14%
Slovakia (SK)	20	25	25.00%	27	8.00%	26	-3.70%
United Kingdom (UK)	-	329	-	259	-21.28%	320	23.55%

Forest

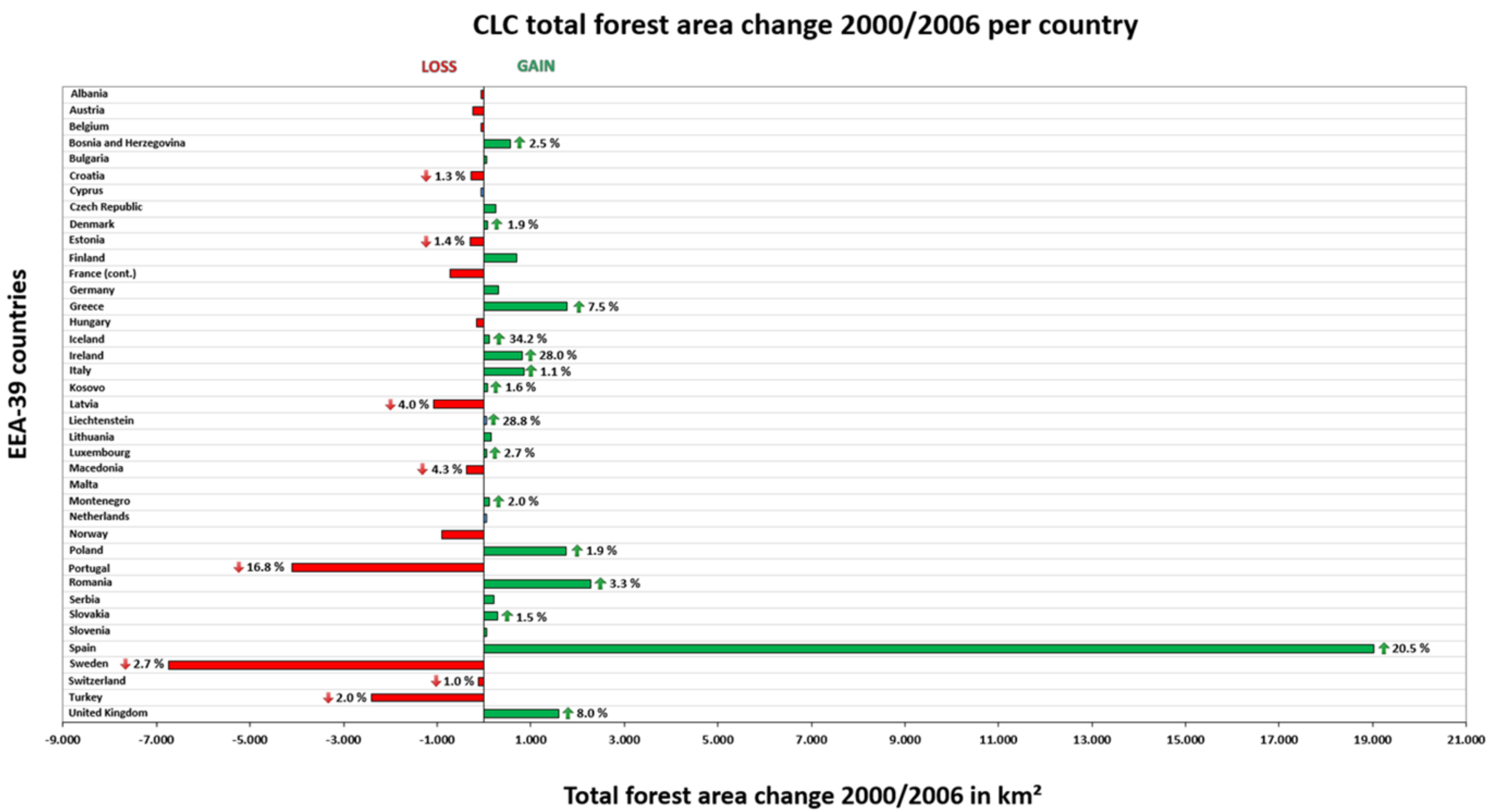

Figure 5-1 – CLC total forest area change 2000/2006 per country in km². Changes, greater or equal 1 % are given in percent (EEA, 2018c).

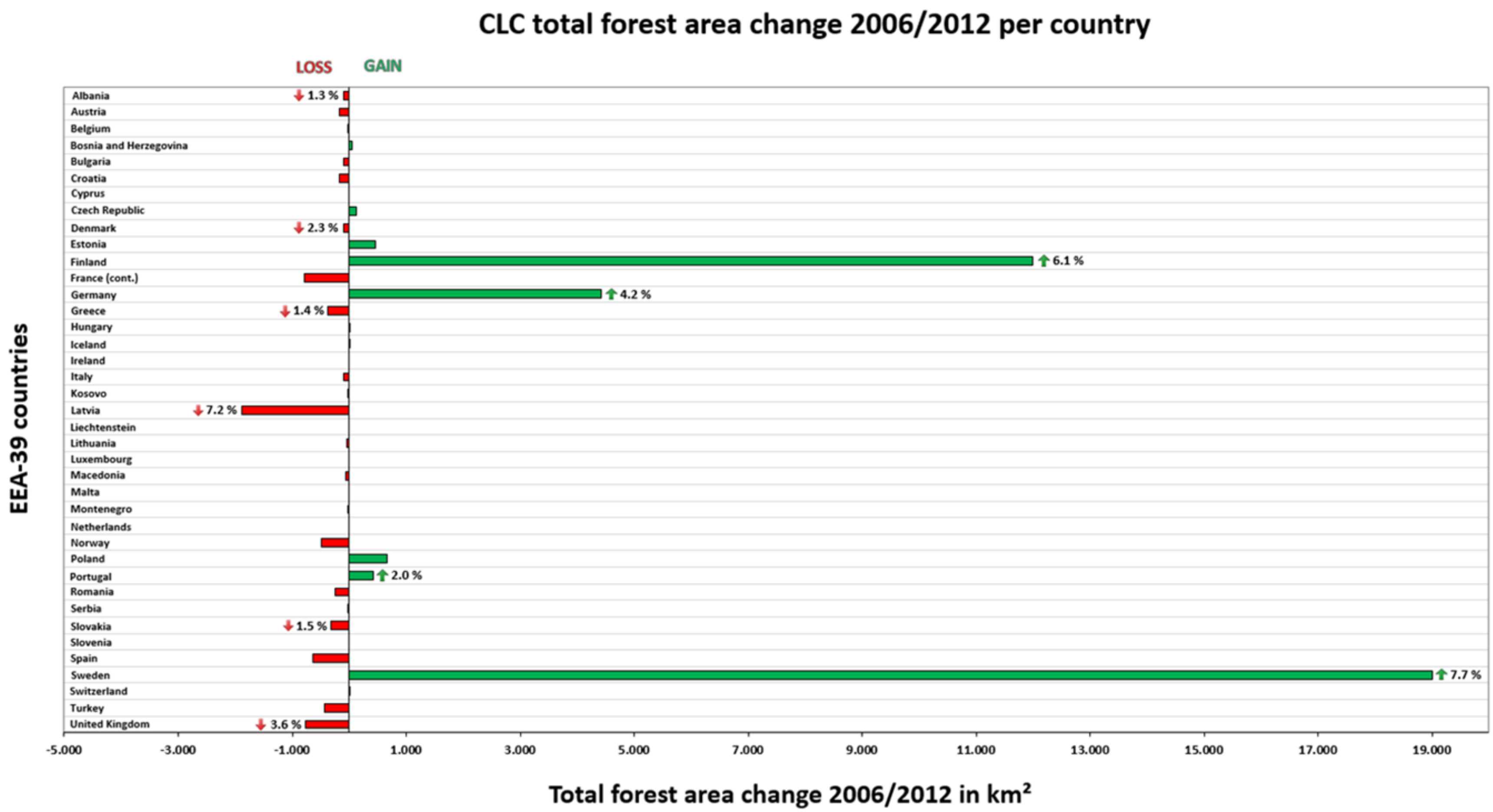

Figure 5-2 – CLC total forest area change 2006/2012 per country in km². Changes, greater or equal 1 % are given in percent (EEA, 2018c).

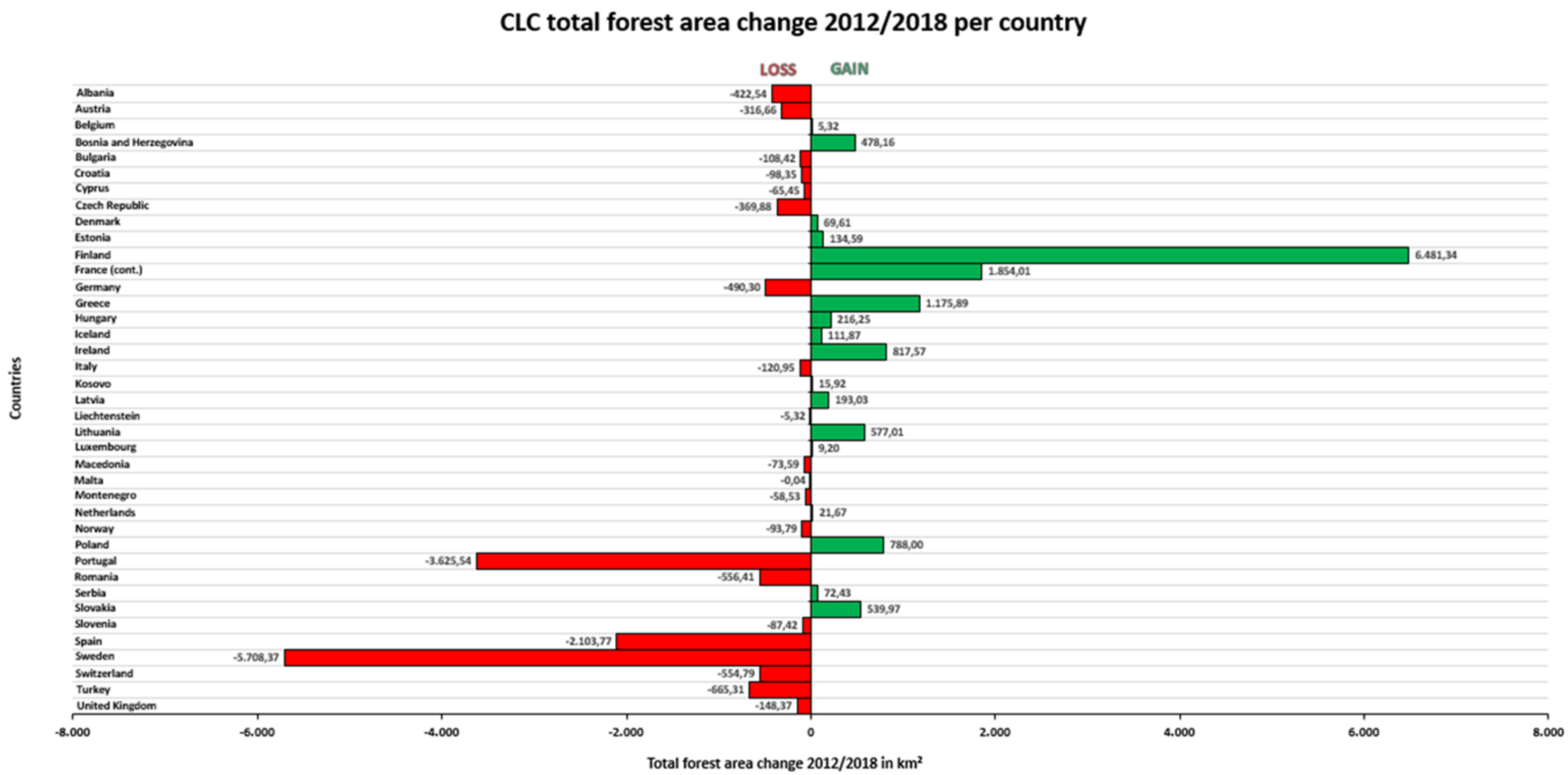

Figure 5-3 – CLC total forest area change 2012/2018 per country in km². Changes, greater or equal 1 % are given in percent (EEA, 2018c).

Table 5-4 – CLC total forest area change 2000/2006 per country and year (interpolated).

Change per year CLC 2000/2006																		
Country	CLC 2000		CLC 2001		CLC 2002		CLC 2003		CLC 2004		CLC 2005		CLC 2006	2000/2006		per year	
	Forest [km^2]	%	Forest [km^2]	%	Forest [km^2]	%	Forest [km^2]	%	Forest [km^2]	%	Forest [km^2]	%	Forest [km^2]	Change	%	Change	Mean %
Albania	7.669,96	-0,08753	7.663,25	-0,08760	7.656,53	-0,08768	7.649,82	-0,08776	7.643,11	-0,08784	7.636,39	-0,08791	7629,68	-40,28	-0,5	-6,71	-0,088
Austria	37.351,51	-0,10782	37.311,24	-0,10794	37.270,96	-0,10806	37.230,69	-0,10817	37.190,42	-0,10829	37.150,14	-0,10841	37109,87	-241,64	-0,6	-40,27	-0,108
Belgium	6.114,12	-0,00954	6.113,54	-0,00954	6.112,95	-0,00954	6.112,37	-0,00954	6.111,79	-0,00954	6.111,20	-0,00955	6110,62	-3,50	-0,1	-0,58	-0,010
Bosnia and Herzegovina	22.645,31	0,41449	22.739,17	0,41278	22.833,04	0,41109	22.926,90	0,40940	23.020,76	0,40773	23.114,63	0,40608	23208,49	563,18	2,5	93,86	0,410
Bulgaria	34.923,58	0,01801	34.929,87	0,01800	34.936,16	0,01800	34.942,45	0,01800	34.948,73	0,01799	34.955,02	0,01799	34961,31	37,73	0,1	6,29	0,018
Croatia	20.706,44	-0,21812	20.661,28	-0,21860	20.616,11	-0,21908	20.570,95	-0,21956	20.525,78	-0,22004	20.480,62	-0,22053	20435,45	-270,99	-1,3	-45,16	-0,219
Cyprus	1.546,76	-0,09385	1.545,31	-0,09394	1.543,86	-0,09403	1.542,41	-0,09412	1.540,95	-0,09421	1.539,50	-0,09429	1538,05	-8,71	-0,6	-1,45	-0,094
Czech Republic	25.925,49	0,16489	25.968,24	0,16462	26.010,99	0,16435	26.053,74	0,16408	26.096,48	0,16381	26.139,23	0,16354	26181,98	256,49	1,0	42,75	0,164
Denmark	3.851,50	0,31572	3.863,66	0,31473	3.875,82	0,31374	3.887,98	0,31276	3.900,14	0,31178	3.912,30	0,31081	3924,46	72,96	1,9	12,16	0,313
Estonia	20.957,18	-0,23189	20.908,58	-0,23242	20.859,99	-0,23297	20.811,39	-0,23351	20.762,79	-0,23406	20.714,20	-0,23461	20665,6	-291,58	-1,4	-48,60	-0,233
Finland	196.126,75	0,05905	196.242,57	0,05902	196.358,39	0,05898	196.474,21	0,05895	196.590,02	0,05891	196.705,84	0,05888	196821,66	694,91	0,4	115,82	0,059
France (cont.)	143.231,09	-0,08429	143.110,36	-0,08436	142.989,63	-0,08443	142.868,90	-0,08450	142.748,17	-0,08458	142.627,44	-0,08465	142506,71	-724,38	-0,5	-120,73	-0,084
Germany	103.920,44	0,04996	103.972,36	0,04994	104.024,28	0,04991	104.076,20	0,04989	104.128,12	0,04986	104.180,04	0,04984	104231,96	311,52	0,3	51,92	0,050
Greece	23.759,55	1,25071	24.056,71	1,23526	24.353,88	1,22019	24.651,04	1,20548	24.948,20	1,19112	25.245,37	1,17710	25542,53	1.782,98	7,5	297,16	1,213
Hungary	17.382,11	-0,15164	17.355,75	-0,15187	17.329,39	-0,15210	17.303,04	-0,15233	17.276,68	-0,15257	17.250,32	-0,15280	17223,96	-158,15	-0,9	-26,36	-0,152
Iceland	314,73	5,70542	332,69	5,39747	350,64	5,12106	368,60	4,87159	386,56	4,64529	404,51	4,43908	422,47	107,74	34,2	17,96	5,030
Ireland	2.921,26	4,67247	3.057,76	4,46390	3.194,25	4,27315	3.330,75	4,09803	3.467,24	3,93670	3.603,74	3,78760	3740,23	818,97	28,0	136,50	4,205
Italy	78.609,03	0,18319	78.753,03	0,18285	78.897,03	0,18252	79.041,04	0,18219	79.185,04	0,18185	79.329,04	0,18152	79473,04	864,01	1,1	144,00	0,182
Kosovo	4.275,56	0,26234	4.286,78	0,26166	4.297,99	0,26097	4.309,21	0,26030	4.320,43	0,25962	4.331,64	0,25895	4342,86	67,30	1,6	11,22	0,261
Latvia	27.061,46	-0,66695	26.880,97	-0,67143	26.700,49	-0,67597	26.520,00	-0,68057	26.339,51	-0,68523	26.159,03	-0,68996	25978,54	-1.082,92	-4,0	-180,49	-0,678
Liechtenstein	57,40	4,79675	60,15	4,57719	62,91	4,37685	65,66	4,19332	68,41	4,02456	71,17	3,86885	73,92	16,52	28,8	2,75	4,306
Lithuania	18.762,17	0,14201	18.788,81	0,14180	18.815,46	0,14160	18.842,10	0,14140	18.868,74	0,14120	18.895,39	0,14100	18922,03	159,86	0,9	26,64	0,142
Luxembourg	908,88	0,44249	912,90	0,44054	916,92	0,43860	920,95	0,43669	924,97	0,43479	928,99	0,43291	933,01	24,13	2,7	4,02	0,438
Macedonia	8.673,09	-0,71718	8.610,89	-0,72236	8.548,69	-0,72762	8.486,49	-0,73295	8.424,28	-0,73836	8.362,08	-0,74385	8299,88	-373,21	-4,3	-62,20	-0,730
Malta	2,10	0,00000	2,10	0,00000	2,10	0,00000	2,10	0,00000	2,10	0,00000	2,10	0,00000	2,1	0,00	0,0	0,00	0,000
Montenegro	5.685,24	0,32907	5.703,95	0,32799	5.722,66	0,32692	5.741,37	0,32585	5.760,07	0,32479	5.778,78	0,32374	5797,49	112,25	2,0	18,71	0,326
Netherlands	3.142,65	0,06465	3.144,68	0,06461	3.146,71	0,06456	3.148,75	0,06452	3.150,78	0,06448	3.152,81	0,06444	3154,84	12,19	0,4	2,03	0,065
Norway	109.345,02	-0,13729	109.194,91	-0,13747	109.044,79	-0,13766	108.894,68	-0,13785	108.744,56	-0,13804	108.594,45	-0,13823	108444,33	-900,69	-0,8	-150,12	-0,138
Poland	93.837,40	0,31273	94.130,86	0,31176	94.424,32	0,31079	94.717,79	0,30983	95.011,25	0,30887	95.304,71	0,30792	95598,17	1.760,77	1,9	293,46	0,310
Portugal	24.444,23	-2,79867	23.760,12	-2,87925	23.076,00	-2,96461	22.391,89	-3,05518	21.707,78	-3,15147	21.023,66	-3,25402	20339,55	-4.104,68	-16,8	-684,11	-3,017
Romania	69.866,03	0,54286	70.245,31	0,53993	70.624,58	0,53703	71.003,86	0,53416	71.383,13	0,53132	71.762,41	0,52851	72141,68	2.275,65	3,3	379,27	0,536
Serbia	22.821,52	0,15437	22.856,75	0,15413	22.891,98	0,15390	22.927,21	0,15366	22.962,44	0,15342	22.997,67	0,15319	23032,9	211,38	0,9	35,23	0,154
Slovakia	20.017,12	0,24232	20.065,63	0,24173	20.114,13	0,24115	20.162,64	0,24057	20.211,14	0,23999	20.259,65	0,23942	20308,15	291,03	1,5	48,51	0,241
Slovenia	11.390,30	0,06176	11.397,34	0,06172	11.404,37	0,06169	11.411,41	0,06165	11.418,44	0,06161	11.425,48	0,06157	11432,51	42,21	0,4	7,04	0,062
Spain	92.871,41	3,41355	96.041,63	3,30088	99.211,84	3,19540	102.382,06	3,09646	105.552,27	3,00346	108.722,49	2,91588	111892,7	19.021,29	20,5	3.170,22	3,154
Sweden	252.545,35	-0,44461	251.422,50	-0,44660	250.299,65	-0,44860	249.176,81	-0,45062	248.053,96	-0,45266	246.931,11	-0,45472	245808,26	-6.737,09	-2,7	-1.122,85	-0,450
Switzerland	12.457,58	-0,16171	12.437,44	-0,16197	12.417,29	-0,16223	12.397,15	-0,16250	12.377,00	-0,16276	12.356,86	-0,16303	12336,71	-120,87	-1,0	-20,15	-0,162
Turkey	118.758,51	-0,33822	118.356,84	-0,33937	117.955,17	-0,34053	117.553,51	-0,34169	117.151,84	-0,34286	116.750,17	-0,34404	116348,5	-2.410,01	-2,0	-401,67	-0,341
United Kingdom	19.839,95	1,33717	20.105,24	1,31952	20.370,54	1,30234	20.635,83	1,28560	20.901,12	1,26928	21.166,42	1,25337	21431,71	1.591,76	8,0	265,29	1,295
	1.664.719,78	**0,1**	**1.666.991,14**	**0,1**	**1.669.262,49**	**-0,1**	**1.667.224,64**	**0,1**	**1.669.484,77**	**0,1**	**1.671.759,01**	**0,4**	**1678347,91**	**13.628,13**	**0,42**	**2.271,35**	**0,1**

Table 5-5 – CLC total forest area change 2006/2012 per country and year (interpolated).

Change per year CLC 2006/2012																
Country	CLC 2006		CLC 2007		CLC 2008		CLC 2009		CLC 2010		CLC 2011		CLC 2012	2006/2012		per year	
	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	Change	%	Change	Mean %
Albania	7.629,68	-0,21041	7.613,63	-0,21085	7.597,57	-0,21130	7.581,52	-0,21174	7.565,47	-0,21219	7.549,41	-0,21264	7533,36	-96,32	-1,3	-16,05	-0,212
Austria	37.109,87	-0,07464	37.082,17	-0,07469	37.054,47	-0,07475	37.026,78	-0,07481	36.999,08	-0,07486	36.971,38	-0,07492	36943,68	-166,19	-0,4	-27,70	-0,075
Belgium	6.110,62	-0,04879	6.107,64	-0,04882	6.104,66	-0,04884	6.101,68	-0,04887	6.098,69	-0,04889	6.095,71	-0,04891	6092,73	-17,89	-0,3	-2,98	-0,049
Bosnia and Herzegovina	23.208,49	0,03384	23.216,34	0,03383	23.224,20	0,03382	23.232,05	0,03380	23.239,90	0,03379	23.247,76	0,03378	23255,61	47,12	0,2	7,85	0,034
Bulgaria	34.961,31	-0,04822	34.944,45	-0,04824	34.927,59	-0,04827	34.910,74	-0,04829	34.893,88	-0,04831	34.877,02	-0,04834	34860,16	-101,15	-0,3	-16,86	-0,048
Croatia	20.435,45	-0,13671	20.407,51	-0,13689	20.379,58	-0,13708	20.351,64	-0,13727	20.323,70	-0,13746	20.295,77	-0,13765	20267,83	-167,62	-0,8	-27,94	-0,137
Cyprus	1.538,05	-0,03522	1.537,51	-0,03523	1.536,97	-0,03524	1.536,43	-0,03526	1.535,88	-0,03527	1.535,34	-0,03528	1534,8	-3,25	-0,2	-0,54	-0,035
Czech Republic	26.181,98	0,07523	26.201,68	0,07517	26.221,37	0,07512	26.241,07	0,07506	26.260,77	0,07500	26.280,46	0,07495	26300,16	118,18	0,5	19,70	0,075
Denmark	3.924,46	-0,37513	3.909,74	-0,37654	3.895,02	-0,37796	3.880,30	-0,37940	3.865,57	-0,38084	3.850,85	-0,38230	3836,13	-88,33	-2,3	-14,72	-0,379
Estonia	20.665,60	0,36864	20.741,78	0,36729	20.817,96	0,36594	20.894,15	0,36461	20.970,33	0,36328	21.046,51	0,36197	21122,69	457,09	2,2	76,18	0,365
Finland	196.821,66	1,01630	198.821,95	1,00607	200.822,24	0,99605	202.822,53	0,98623	204.822,82	0,97660	206.823,11	0,96715	208823,4	12.001,74	6,1	2000,29	0,991
France (cont.)	142.506,71	-0,09156	142.376,24	-0,09164	142.245,76	-0,09172	142.115,29	-0,09181	141.984,82	-0,09189	141.854,34	-0,09198	141723,87	-782,84	-0,5	-130,47	-0,092
Germany	104.231,96	0,70645	104.968,31	0,70150	105.704,66	0,69661	106.441,02	0,69179	107.177,37	0,68704	107.913,72	0,68235	108650,07	4.418,11	4,2	736,35	0,694
Greece	25.542,53	-0,24149	25.480,85	-0,24208	25.419,16	-0,24266	25.357,48	-0,24325	25.295,80	-0,24385	25.234,11	-0,24444	25172,43	-370,10	-1,4	-61,68	-0,243
Hungary	17.223,96	0,00218	17.224,34	0,00218	17.224,71	0,00218	17.225,09	0,00218	17.225,46	0,00218	17.225,84	0,00218	17226,21	2,25	0,0	0,38	0,002
Iceland	422,47	0,11756	422,97	0,11742	423,46	0,11729	423,96	0,11715	424,46	0,11701	424,95	0,11688	425,45	2,98	0,7	0,50	0,117
Ireland	3.740,23	-0,04215	3.738,65	-0,04217	3.737,08	-0,04219	3.735,50	-0,04221	3.733,92	-0,04223	3.732,35	-0,04224	3730,77	-9,46	-0,3	-1,58	-0,042
Italy	79.473,04	-0,02176	79.455,75	-0,02176	79.438,45	-0,02177	79.421,16	-0,02177	79.403,87	-0,02178	79.386,57	-0,02178	79369,28	-103,76	-0,1	-17,29	-0,022
Kosovo	4.342,86	-0,08973	4.338,96	-0,08981	4.335,07	-0,08989	4.331,17	-0,08997	4.327,27	-0,09005	4.323,38	-0,09013	4319,48	-23,38	-0,5	-3,90	-0,090
Latvia	25.978,54	-1,20411	25.665,73	-1,21878	25.352,92	-1,23382	25.040,11	-1,24924	24.727,30	-1,26504	24.414,49	-1,28125	24101,68	-1.876,86	-7,2	-312,81	-1,242
Liechtenstein	73,92	0,00000	73,92	0,00000	73,92	0,00000	73,92	0,00000	73,92	0,00000	73,92	0,00000	73,92	0,00	0,0	0,00	0,000
Lithuania	18.922,03	-0,04431	18.913,65	-0,04433	18.905,26	-0,04435	18.896,88	-0,04437	18.888,49	-0,04439	18.880,11	-0,04441	18871,72	-50,31	-0,3	-8,38	-0,044
Luxembourg	933,01	-0,02090	932,82	-0,02090	932,62	-0,02091	932,43	-0,02091	932,23	-0,02092	932,04	-0,02092	931,84	-1,17	-0,1	-0,19	-0,021
Macedonia	8.299,88	-0,11239	8.290,55	-0,11252	8.281,22	-0,11264	8.271,90	-0,11277	8.262,57	-0,11290	8.253,24	-0,11303	8243,91	-55,97	-0,7	-9,33	-0,113
Malta	2,10	0,00000	2,10	0,00000	2,10	0,00000	2,10	0,00000	2,10	0,00000	2,10	0,00000	2,1	0,00	0,0	0,00	0,000
Montenegro	5.797,49	-0,07506	5.793,14	-0,07512	5.788,79	-0,07517	5.784,44	-0,07523	5.780,08	-0,07529	5.775,73	-0,07534	5771,38	-26,11	-0,5	-4,35	-0,075
Netherlands	3.154,84	-0,04776	3.153,33	-0,04778	3.151,83	-0,04780	3.150,32	-0,04783	3.148,81	-0,04785	3.147,31	-0,04787	3145,8	-9,04	-0,3	-1,51	-0,048
Norway	108.444,33	-0,07557	108.362,38	-0,07563	108.280,43	-0,07568	108.198,48	-0,07574	108.116,52	-0,07580	108.034,57	-0,07586	107952,62	-491,71	-0,5	-81,95	-0,076
Poland	95.598,17	0,11613	95.709,19	0,11600	95.820,21	0,11586	95.931,23	0,11573	96.042,24	0,11559	96.153,26	0,11546	96264,28	666,11	0,7	111,02	0,116
Portugal	20.339,55	0,34154	20.409,02	0,34038	20.478,49	0,33923	20.547,96	0,33808	20.617,42	0,33694	20.686,89	0,33581	20756,36	416,81	2,0	69,47	0,339
Romania	72.141,68	-0,05790	72.099,91	-0,05793	72.058,14	-0,05797	72.016,37	-0,05800	71.974,60	-0,05803	71.932,83	-0,05807	71891,06	-250,62	-0,3	-41,77	-0,058
Serbia	23.032,90	-0,01503	23.029,44	-0,01503	23.025,98	-0,01503	23.022,52	-0,01504	23.019,05	-0,01504	23.015,59	-0,01504	23012,13	-20,77	-0,1	-3,46	-0,015
Slovakia	20.308,15	-0,25587	20.256,19	-0,25652	20.204,23	-0,25718	20.152,27	-0,25785	20.100,30	-0,25851	20.048,34	-0,25918	19996,38	-311,77	-1,5	-51,96	-0,258
Slovenia	11.432,51	-0,00741	11.431,66	-0,00741	11.430,82	-0,00741	11.429,97	-0,00741	11.429,12	-0,00741	11.428,28	-0,00741	11427,43	-5,08	0,0	-0,85	-0,007
Spain	111.892,70	-0,09406	111.787,46	-0,09415	111.682,21	-0,09423	111.576,97	-0,09432	111.471,73	-0,09441	111.366,48	-0,09450	111261,24	-631,46	-0,6	-105,24	-0,094
Sweden	245.808,26	1,28936	248.977,63	1,27295	252.146,99	1,25695	255.316,36	1,24135	258.485,72	1,22613	261.655,09	1,21128	264824,45	19.016,19	7,7	3169,37	1,250
Switzerland	12.336,71	0,01537	12.338,61	0,01537	12.340,50	0,01537	12.342,40	0,01537	12.344,30	0,01536	12.346,19	0,01536	12348,09	11,38	0,1	1,90	0,015
Turkey	116.348,50	-0,06171	116.276,70	-0,06175	116.204,90	-0,06179	116.133,10	-0,06183	116.061,29	-0,06187	115.989,49	-0,06190	115917,69	-430,81	-0,4	-71,80	-0,062
United Kingdom	21.431,71	-0,59943	21.303,24	-0,60305	21.174,77	-0,60670	21.046,31	-0,61041	20.917,84	-0,61416	20.789,37	-0,61795	20660,9	-770,81	-3,6	-128,47	-0,609
	1.678.347,91	**0,3**	**1.683.397,11**	**0,3**	**1.688.446,30**	**0,0**	**1.689.164,33**	**0,3**	**1.694.217,42**	**0,3**	**1.699.270,32**	**0,6**	**1708643,09**	**30.295,18**	**1,25**	**5.049,20**	**0,3**

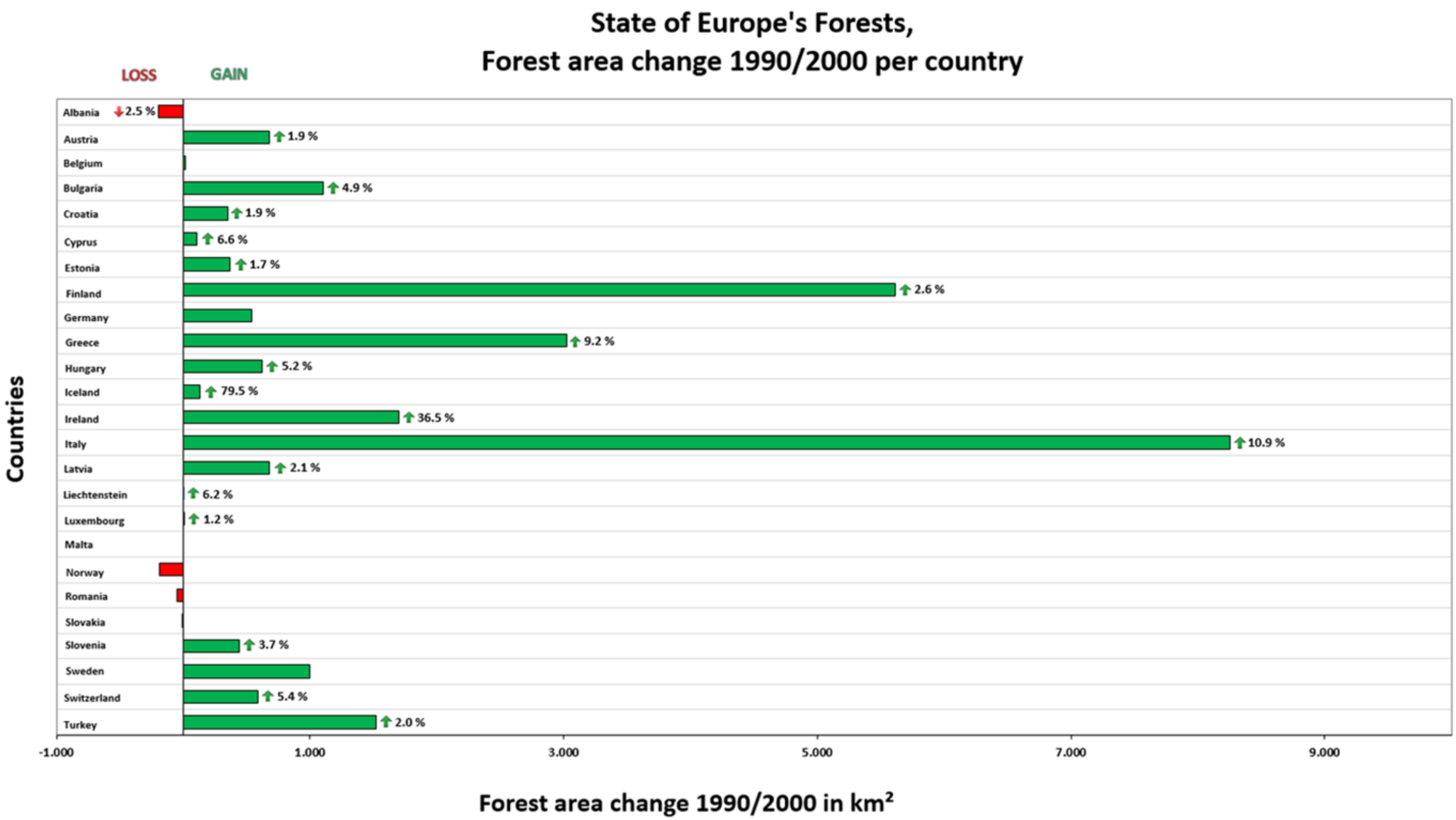

Figure 5-4 – State of Europe's Forests, forest area change without other wooded land 1990/2000 per country in km². Changes, greater or equal 1 % are given in percent (FAO, 2015c).

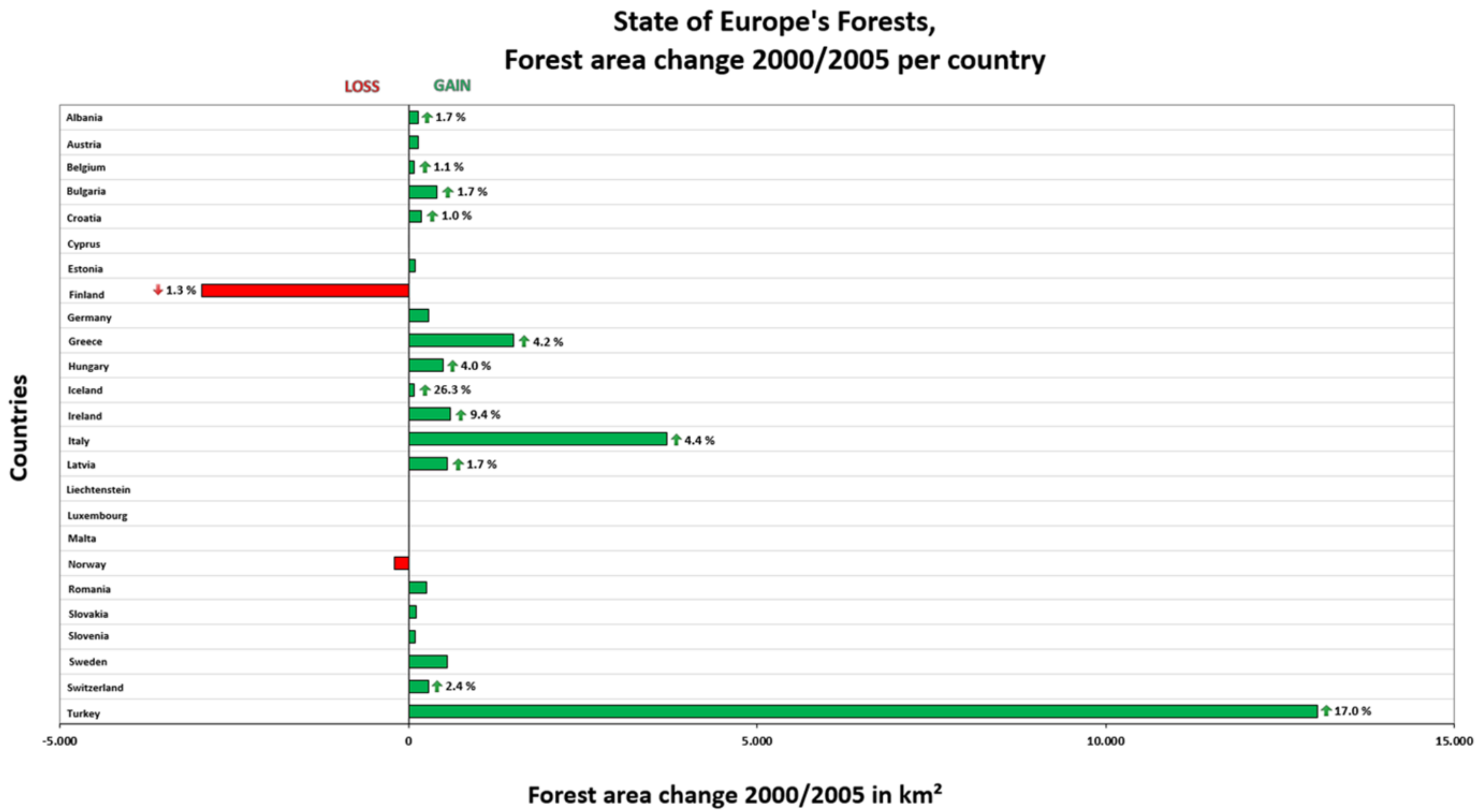

Figure 5-5 – State of Europe's Forests, forest area change without other wooded land 2000/2005 per country in km². Changes, greater or equal 1 % are given in percent (FAO, 2015c).

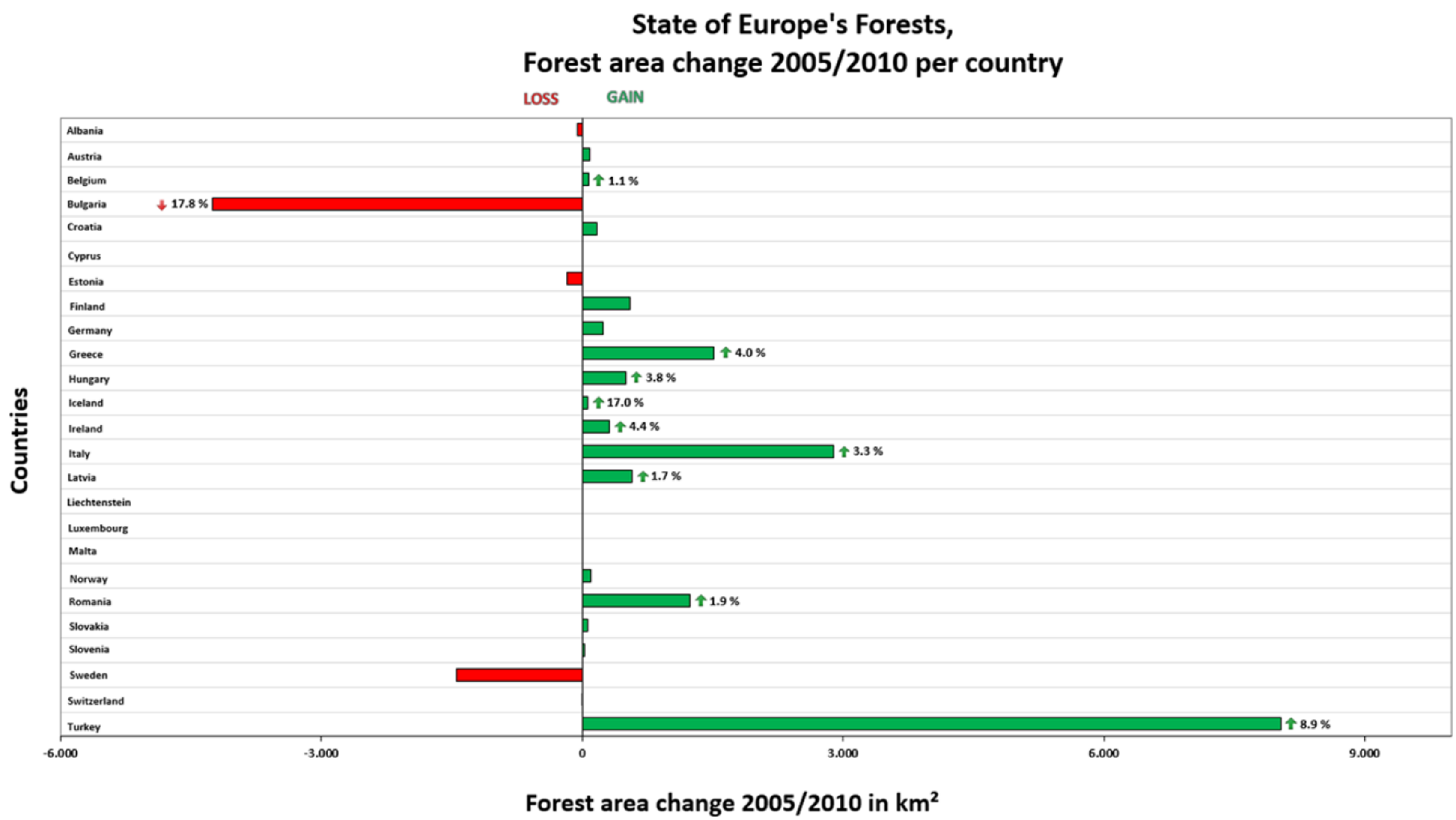

Figure 5-6 – State of Europe's Forests, forest area change without other wooded land 2005/2010 per country in km². Changes, greater or equal 1 % are given in percent (FAO, 2015c).

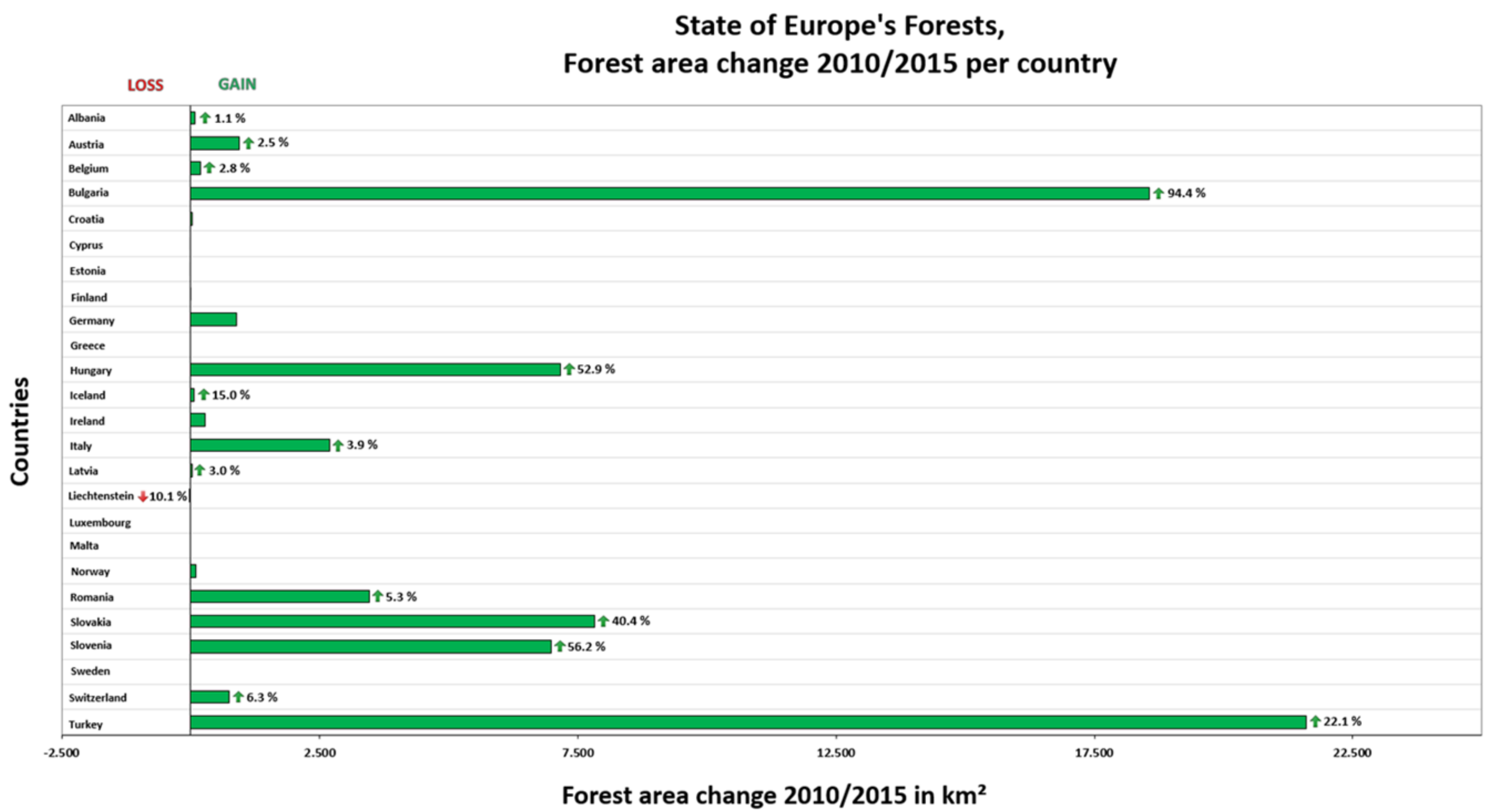

Figure 5-7 – State of Europe's Forests, forest area change without other wooded land 2010/2015 per country in km². Changes, greater or equal 1 % are given in percent (FAO, 2015c).

Table 5-6 – State of Europe's Forests, interpolated forest area change without other wooded land 1990/2000 per country (FAO, 2015c).

Change per year SoEF 1990/2000

Country	SoEF 1990 Forest [km²]	SoEF 1990 %	SoEF 1991 Forest [km²]	SoEF 1991 %	SoEF 1992 Forest [km²]	SoEF 1992 %	SoEF 1993 Forest [km²]	SoEF 1993 %	SoEF 1994 Forest [km²]	SoEF 1994 %
Albania	7888	-0,24848	7868,4	-0,24910	7848,8	-0,24972	7829,2	-0,25034	7809,6	-0,25097
Austria	36845	0,18510	36913,2	0,18476	36981,4	0,18442	37049,6	0,18408	37117,8	0,18374
Belgium	6488	0,02466	6489,6	0,02465	6491,2	0,02465	6492,8	0,02464	6494,4	0,02464
Bulgaria	22410	0,49085	22520	0,48845	22630	0,48608	22740	0,48373	22850	0,48140
Croatia	18500	0,18919	18535	0,18883	18570	0,18848	18605	0,18812	18640	0,18777
Cyprus	1611	0,65798	1621,6	0,65368	1632,2	0,64943	1642,8	0,64524	1653,4	0,64110
Estonia	22060	0,16591	22096,6	0,16564	22133,2	0,16536	22169,8	0,16509	22206,4	0,16482
Finland	218968	0,25652	219529,7	0,25587	220091,4	0,25521	220653,1	0,25456	221214,8	0,25392
Germany	112250	0,04811	112304	0,04808	112358	0,04806	112412	0,04804	112466	0,04801
Greece	32990	0,91543	33292	0,90712	33594	0,89897	33896	0,89096	34198	0,88309
Hungary	11922	0,51753	11983,7	0,51487	12045,4	0,51223	12107,1	0,50962	12168,8	0,50703
Iceland	161	7,95031	173,8	7,36479	186,6	6,85959	199,4	6,41926	212,2	6,03205
Ireland	4650	3,65376	4819,9	3,52497	4989,8	3,40495	5159,7	3,29283	5329,6	3,18786
Italy	75440	1,09358	76265	1,08175	77090	1,07018	77915	1,05885	78740	1,04775
Latvia	31730	0,21431	31798	0,21385	31866	0,21339	31934	0,21294	32002	0,21249
Liechtenstein	65	0,61538	65,4	0,61162	65,8	0,60790	66,2	0,60423	66,6	0,60060
Luxembourg	858	0,11655	859	0,11641	860	0,11628	861	0,11614	862	0,11601
Malta	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0,00000
Norway	121320	-0,01566	121301	-0,01566	121282	-0,01567	121263	-0,01567	121244	-0,01567
Romania	63710	-0,00785	63705	-0,00785	63700	-0,00785	63695	-0,00785	63690	-0,00785
Slovakia	19220	-0,00520	19219	-0,00520	19218	-0,00520	19217	-0,00520	19216	-0,00520
Slovenia	11830	0,37131	11894	0,36993	11938	0,36857	11982	0,36722	12026	0,36587
Sweden	280630	0,03563	280730	0,03562	280830	0,03561	280930	0,03560	281030	0,03558
Switzerland	10940	0,53931	10999	0,53641	11058	0,53355	11117	0,53072	11176	0,52792
Turkey	75242	0,20175	75393,8	0,20134	75545,6	0,20094	75697,4	0,20054	75849,2	0,20013
	1.187.751,00	**0,2**	**1.190.379,70**	**0,2**	**1.193.008,40**	**0,2**	**1.195.637,10**	**0,2**	**1.198.265,80**	**0,21938**

Country	SoEF 1995 Forest [km²]	SoEF 1995 %	SoEF 1996 Forest [km²]	SoEF 1996 %	SoEF 1997 Forest [km²]	SoEF 1997 %	SoEF 1998 Forest [km²]	SoEF 1998 %	SoEF 1999 Forest [km²]	SoEF 1999 %	SoEF 2000 Forest [km²]	1990/2000 Change	1990/2000 %	per year Change	per year Mean %
Albania	7790	-0,25160	7770,4	-0,25224	7750,8	-0,25288	7731,2	-0,25352	7711,6	-0,25416	7692	-196	-2,48	-19,6	-0,251
Austria	37186	0,18340	37254,2	0,18307	37322,4	0,18273	37390,6	0,18240	37458,8	0,18207	37527	682	1,85	68,2	0,184
Belgium	6496	0,02463	6497,6	0,02462	6499,2	0,02462	6500,8	0,02461	6502,4	0,02461	6504	16	0,25	1,6	0,025
Bulgaria	22960	0,47909	23070	0,47681	23180	0,47455	23290	0,47231	23400	0,47009	23510	1100	4,91	110	0,480
Croatia	18675	0,18742	18710	0,18707	18745	0,18672	18780	0,18637	18815	0,18602	18850	350	1,89	35	0,188
Cyprus	1664	0,63702	1674,6	0,63299	1685,2	0,62901	1695,8	0,62507	1706,4	0,62119	1717	106	6,58	10,6	0,639
Estonia	22243	0,16455	22279,6	0,16428	22316,2	0,16401	22352,8	0,16374	22389,4	0,16347	22426	366	1,66	36,6	0,165
Finland	221776,5	0,25327	222338,2	0,25263	222899,9	0,25200	223461,6	0,25136	224023,3	0,25073	224585	5617	2,57	561,7	0,254
Germany	112520	0,04799	112574	0,04797	112628	0,04795	112682	0,04792	112736	0,04790	112790	540	0,48	54	0,048
Greece	34500	0,87536	34802	0,86777	35104	0,86030	35406	0,85296	35708	0,84575	36010	3020	9,15	302	0,880
Hungary	12230,5	0,50448	12292,2	0,50194	12353,9	0,49944	12415,6	0,49696	12477,3	0,49450	12539	617	5,18	61,7	0,506
Iceland	225	5,68889	237,8	5,38267	250,6	5,10774	263,4	4,85953	276,2	4,63432	289	128	79,50	12,8	6,030
Ireland	5499,5	3,08937	5669,4	2,99679	5839,3	2,90960	6009,2	2,82733	6179,1	2,74939	6349	1699	36,54	169,9	3,164
Italy	79565	1,03689	80390	1,02625	81215	1,01582	82040	1,00561	82865	0,99560	83690	8250	10,94	825	1,043
Latvia	32070	0,21204	32138	0,21159	32206	0,21114	32274	0,21070	32342	0,21025	32410	680	2,14	68	0,212
Liechtenstein	67	0,59701	67,4	0,59347	67,8	0,58997	68,2	0,58651	68,6	0,58309	69	4	6,15	0,4	0,599
Luxembourg	863	0,11587	864	0,11574	865	0,11561	866	0,11547	867	0,11534	868	10	1,17	1	0,116
Malta	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0	0,00	0	0,000
Norway	121225	-0,01567	121206	-0,01568	121187	-0,01568	121168	-0,01568	121149	-0,01568	121130	-190	-0,16	-19	-0,016
Romania	63685	-0,00785	63680	-0,00785	63675	-0,00785	63670	-0,00785	63665	-0,00785	63660	-50	-0,08	-5	-0,008
Slovakia	19215	-0,00520	19214	-0,00520	19213	-0,00520	19212	-0,00521	19211	-0,00521	19210	-10	-0,05	-1	-0,005
Slovenia	12070	0,36454	12114	0,36322	12158	0,36190	12202	0,36060	12246	0,35930	12290	440	3,71	44	0,365
Sweden	281130	0,03557	281230	0,03556	281330	0,03555	281430	0,03553	281530	0,03552	281630	1000	0,36	100	0,036
Switzerland	11235	0,52514	11294	0,52240	11353	0,51969	11412	0,51700	11471	0,51434	11530	590	5,39	59	0,527
Turkey	76001	0,19973	76152,8	0,19934	76304,6	0,19894	76456,4	0,19854	76608,2	0,19815	76760	1518	2,02	151,8	0,200
	1.200.894,50	**0,2**	**1.203.523,20**	**0,2**	**1.206.151,90**	**0,2**	**1.208.780,60**	**0,2**	**1.211.409,30**	**0,2**	**1214.038,00**	**26.287,00**	**2,2**	**2.628,70**	**0,2**

Table 5-7 – State of Europe's Forests, interpolated forest area change without other wooded land 2000/2005 per country (FAO, 2015c).

Change per year SoEF 2000/2005														
Country	SoEF 2000		SoEF 2001		SoEF 2002		SoEF 2003		SoEF 2004		SoEF 2005	2000/2005		per year	
	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	Change	%	Change	Mean %
Albania	7692	0,34321	7718,4	0,34204	7744,8	0,34087	7771,2	0,33972	7797,6	0,33857	7824	132	1,72	26,4	0,341
Austria	37527	0,07142	37553,8	0,07136	37580,6	0,07131	37607,4	0,07126	37634,2	0,07121	37661	134	0,36	26,8	0,071
Belgium	6504	0,22448	6518,6	0,22397	6533,2	0,22347	6547,8	0,22298	6562,4	0,22248	6577	73	1,12	14,6	0,223
Bulgaria	23510	0,34879	23592	0,34758	23674	0,34637	23756	0,34518	23838	0,34399	23920	410	1,74	82	0,346
Croatia	18850	0,19098	18886	0,19062	18922	0,19025	18958	0,18989	18994	0,18953	19030	180	0,95	36	0,190
Cyprus	1717	0,12813	1719,2	0,12797	1721,4	0,12780	1723,6	0,12764	1725,8	0,12748	1728	11	0,64	2,2	0,128
Estonia	22426	0,08472	22445	0,08465	22464	0,08458	22483	0,08451	22502	0,08444	22521	95	0,42	19	0,085
Finland	224585	-0,26404	223992	-0,26474	223399	-0,26544	222806	-0,26615	222213	-0,26686	221620	-2965	-1,32	-593	-0,265
Germany	112790	0,05054	112847	0,05051	112904	0,05049	112961	0,05046	113018	0,05043	113075	285	0,25	57	0,050
Greece	36010	0,83866	36312	0,83168	36614	0,82482	36916	0,81807	37218	0,81144	37520	1510	4,19	302	0,825
Hungary	12539	0,79592	12638,8	0,78963	12738,6	0,78345	12838,4	0,77736	12938,2	0,77136	13038	499	3,98	99,8	0,784
Iceland	289	5,25952	304,2	4,99671	319,4	4,75892	334,6	4,54274	349,8	4,34534	365	76	26,30	15,2	4,781
Ireland	6349	1,88691	6468,8	1,85197	6588,6	1,81829	6708,4	1,78582	6828,2	1,75449	6948	599	9,43	119,8	1,819
Italy	83690	0,88422	84430	0,87647	85170	0,86885	85910	0,86137	86650	0,85401	87390	3700	4,42	740	0,869
Latvia	32410	0,34557	32522	0,34438	32634	0,34320	32746	0,34203	32858	0,34086	32970	560	1,73	112	0,343
Liechtenstein	69	0,00000	69	0,00000	69	0,00000	69	0,00000	69	0,00000	69	0	0,00	0	0,000
Luxembourg	868	0,00000	868	0,00000	868	0,00000	868	0,00000	868	0,00000	868	0	0,00	0	0,000
Malta	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0	0,00	0	0,000
Norway	121130	-0,03467	121088	-0,03469	121046	-0,03470	121004	-0,03471	120962	-0,03472	120920	-210	-0,17	-42	-0,035
Romania	63660	0,07854	63710	0,07848	63760	0,07842	63810	0,07836	63860	0,07830	63910	250	0,39	50	0,078
Slovakia	19210	0,11452	19232	0,11439	19254	0,11426	19276	0,11413	19298	0,11400	19320	110	0,57	22	0,114
Slovenia	12290	0,16273	12310	0,16247	12330	0,16221	12350	0,16194	12370	0,16168	12390	100	0,81	20	0,162
Sweden	281630	0,03906	281740	0,03904	281850	0,03903	281960	0,03901	282070	0,03900	282180	550	0,20	110	0,039
Switzerland	11530	0,48569	11586	0,48334	11642	0,48102	11698	0,47871	11754	0,47643	11810	280	2,43	56	0,481
Turkey	76760	3,39578	79366,6	3,28425	81973,2	3,17982	84579,8	3,08182	87186,4	2,98969	89793	13033	16,98	2606,6	3,186
	1.214.038,00	**0,3**	**1.217.920,40**	**0,31877**	**1.221.802,80**	**0,3**	**1.225.685,20**	**0,3**	**1.229.567,60**	**0,3**	**1233450**	**19412**	**1,6**	**3882,4**	**0,3**

Table 5-8 – State of Europe's Forests, interpolated forest area change without other wooded land 2005/2010 per country (FAO, 2015c).

Change per year SoEF 2005/2010															
Country	SoEF 2005		SoEF 2006		SoEF 2007		SoEF 2008		SoEF 2009		SoEF 2010	2005/2010		per year	
	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	Change	%	Change	Mean %
Albania	7824	-0,15593	7811,8	-0,15617	7799,6	-0,15642	7787,4	-0,15666	7775,2	-0,15691	7763	-61	-0,78	-12,2	-0,156
Austria	37661	0,04673	37678,6	0,04671	37696,2	0,04669	37713,8	0,04667	37731,4	0,04665	37749	88	0,23	17,6	0,047
Belgium	6577	0,22199	6591,6	0,22149	6606,2	0,22100	6620,8	0,22052	6635,4	0,22003	6650	73	1,11	14,6	0,221
Bulgaria	23920	-3,55351	23070	-3,68444	22220	-3,82538	21370	-3,97754	20520	-4,14230	19670	-4250	-17,77	-850	-3,837
Croatia	19030	0,17867	19064	0,17835	19098	0,17803	19132	0,17771	19166	0,17740	19200	170	0,89	34	0,178
Cyprus	1728	0,00000	1728	0,00000	1728	0,00000	1728	0,00000	1728	0,00000	1728	0	0,00	0	0,000
Estonia	22521	-0,16074	22484,8	-0,16100	22448,6	-0,16126	22412,4	-0,16152	22376,2	-0,16178	22340	-181	-0,80	-36,2	-0,161
Finland	221620	0,05009	221731	0,05006	221842	0,05004	221953	0,05001	222064	0,04999	222175	555	0,25	111	0,050
Germany	113075	0,04157	113122	0,04155	113169	0,04153	113216	0,04151	113263	0,04150	113310	235	0,21	47	0,042
Greece	37520	0,80490	37822	0,79848	38124	0,79215	38426	0,78593	38728	0,77980	39030	1510	4,02	302	0,792
Hungary	13038	0,76085	13137,2	0,75511	13236,4	0,74945	13335,6	0,74387	13434,8	0,73838	13534	496	3,80	99,2	0,750
Iceland	365	3,39726	377,4	3,28564	389,8	3,18112	402,2	3,08304	414,6	2,99083	427	62	16,99	12,4	3,188
Ireland	6948	0,88659	7009,6	0,87879	7071,2	0,87114	7132,8	0,86362	7194,4	0,85622	7256	308	4,43	61,6	0,871
Italy	87390	0,66140	87968	0,65706	88546	0,65277	89124	0,64853	89702	0,64436	90280	2890	3,31	578	0,653
Latvia	32970	0,34577	33084	0,34458	33198	0,34339	33312	0,34222	33426	0,34105	33540	570	1,73	114	0,343
Liechtenstein	69	0,00000	69	0,00000	69	0,00000	69	0,00000	69	0,00000	69	0	0,00	0	0,000
Luxembourg	868	0,00000	868	0,00000	868	0,00000	868	0,00000	868	0,00000	868	0	0,00	0	0,000
Malta	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0	0,00	0	0,000
Norway	120920	0,01654	120940	0,01654	120960	0,01653	120980	0,01653	121000	0,01653	121020	100	0,08	20	0,017
Romania	63910	0,38805	64158	0,38655	64406	0,38506	64654	0,38358	64902	0,38211	65150	1240	1,94	248	0,385
Slovakia	19320	0,06211	19332	0,06207	19344	0,06203	19356	0,06200	19368	0,06196	19380	60	0,31	12	0,062
Slovenia	12390	0,04843	12396	0,04840	12402	0,04838	12408	0,04836	12414	0,04833	12420	30	0,24	6	0,048
Sweden	282180	-0,10277	281890	-0,10288	281600	-0,10298	281310	-0,10309	281020	-0,10320	280730	-1450	-0,51	-290	-0,103
Switzerland	11810	-0,01693	11808	-0,01694	11806	-0,01694	11804	-0,01694	11802	-0,01695	11800	-10	-0,08	-2	-0,017
Turkey	89793	1,78900	91399,4	1,75756	93005,8	1,72720	94612,2	1,69788	96218,6	1,66953	97825	8032	8,95	1606,4	1,728
	1.233.450,00	**0,2**	**1.235.543,40**	**0,2**	**1.237.636,80**	**0,2**	**1.239.730,20**	**0,2**	**1.241.823,60**	**0,2**	**1243917**	**10472**	**0,85**	**2094,4**	**0,2**

Table 5-9 – State of Europe's Forests, interpolated forest area change without other wooded land 2010/2015 per country (FAO, 2015c).

Change per year SoEF 2010/2015														
Country	SoEF 2010		SoEF 2011		SoEF 2012		SoEF 2013		SoEF 2014		SoEF 2015	2010/2015		per year	
	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	Change	%	Change	Mean %
Albania	7763	0,22414	7780,4	0,22364	7797,8	0,22314	7815,2	0,22264	7832,6	0,22215	7850	87	1,12	17,4	0,223
Austria	37749	0,49856	37937,2	0,49608	38125,4	0,49363	38313,6	0,49121	38501,8	0,48881	38690	941	2,49	188,2	0,494
Belgium	6650	0,55338	6686,8	0,55034	6723,6	0,54733	6760,4	0,54435	6797,2	0,54140	6834	184	2,77	36,8	0,547
Bulgaria	19670	18,87138	23382	15,87546	27094	13,70045	30806	12,04960	34518	10,75381	38230	18560	94,36	3712	14,250
Croatia	19200	0,02083	19204	0,02083	19208	0,02082	19212	0,02082	19216	0,02082	19220	20	0,10	4	0,021
Cyprus	1728	-0,01157	1727,8	-0,01158	1727,6	-0,01158	1727,4	-0,01158	1727,2	-0,01158	1727	-1	-0,06	-0,2	-0,012
Estonia	22340	-0,01791	22336	-0,01791	22332	-0,01791	22328	-0,01791	22324	-0,01792	22320	-20	-0,09	-4	-0,018
Finland	222175	0,00045	222176	0,00045	222177	0,00045	222178	0,00045	222179	0,00045	222180	5	0,00	1	0,000
Germany	113310	0,15533	113486	0,15509	113662	0,15485	113838	0,15461	114014	0,15437	114190	880	0,78	176	0,155
Greece	39030	0,00000	39030	0,00000	39030	0,00000	39030	0,00000	39030	0,00000	39030	0	0,00	0	0,000
Hungary	13534	10,57633	14965,4	9,56473	16396,8	8,72975	17828,2	8,02885	19259,6	7,43214	20691	7157	52,88	1431,4	8,866
Iceland	427	2,99766	439,8	2,91041	452,6	2,82810	465,4	2,75032	478,2	2,67670	491	64	14,99	12,8	2,833
Ireland	7256	0,78280	7312,8	0,77672	7369,6	0,77073	7426,4	0,76484	7483,2	0,75903	7540	284	3,91	56,8	0,771
Italy	90280	0,59592	90818	0,59239	91356	0,58890	91894	0,58546	92432	0,58205	92970	2690	2,98	538	0,589
Latvia	33540	0,01193	33544	0,01192	33548	0,01192	33552	0,01192	33556	0,01192	33560	20	0,06	4	0,012
Liechtenstein	69	-2,02899	67,6	-2,07101	66,2	-2,11480	64,8	-2,16049	63,4	-2,20820	62	-7	-10,14	-1,4	-2,117
Luxembourg	868	0,00000	868	0,00000	868	0,00000	868	0,00000	868	0,00000	868	0	0,00	0	0,000
Malta	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0,00000	3	0	0,00	0	0,000
Norway	121020	0,01653	121040	0,01652	121060	0,01652	121080	0,01652	121100	0,01652	121120	100	0,08	20	0,017
Romania	65150	1,06216	65842	1,05100	66534	1,04007	67226	1,02936	67918	1,01888	68610	3460	5,31	692	1,040
Slovakia	19380	8,07018	20944	7,46753	22508	6,94864	24072	6,49718	25636	6,10080	27200	7820	40,35	1564	7,017
Slovenia	12420	11,23994	13816	10,10423	15212	9,17697	16608	8,40559	18004	7,75383	19400	6980	56,20	1396	9,336
Sweden	280730	0,00000	280730	0,00000	280730	0,00000	280730	0,00000	280730	0,00000	280730	0	0,00	0	0,000
Switzerland	11800	1,25424	11948	1,23870	12096	1,22354	12244	1,20876	12392	1,19432	12540	740	6,27	148	1,224
Turkey	97825	4,41707	102146	4,23022	106467	4,05853	110788	3,90024	115109	3,75383	119430	21605	22,09	4321	4,072
	1.243.917,00	**1,2**	**1.258.230,80**	**1,1**	**1.272.544,60**	**1,1**	**1.286.858,40**	**1,1**	**1.301.172,20**	**1,1**	**1315486**	**71569**	**5,745**	**14313,8**	**1,1**

Table 5-10 – State of Europe's Forests, interpolated forest area change with other wooded land 2010/2015 per country (FAO, 2015c).

Change per year SoEF with other wooded land 2010/2015															
Country	SoEF 2010		SoEF 2011		SoEF 2012		SoEF 2013		SoEF 2014		SoEF 2015	2010/2015		per year	
	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	Change	%	Change	Mean %
Albania	10.310,00	4,0	10.722,40	3,85	11.134,80	3,70	11.547,20	3,57	11.959,60	3,45	12.372,00	2.062,00	20,0	412,4	3,7
Austria	39.910,00	0,2	39.972,00	0,31	40.034,00	0,15	40.096,00	0,15	40.158,00	0,15	40.220,00	310,00	0,8	62	0,2
Belgium	7.064,00	0,4	7.089,40	0,72	7.114,80	0,36	7.140,20	0,36	7.165,60	0,35	7.191,00	127,00	1,8	25,4	0,4
Bosnia and Herzegovina	30.210,00	-1,5	29.766,40	-2,98	29.322,80	-1,51	28.879,20	-1,54	28.435,60	-1,56	27.992,00	-2.218,00	-7,3	-443,6	-1,8
Bulgaria	39.270,00	-0,4	39.106,00	-0,84	38.942,00	-0,42	38.778,00	-0,42	38.614,00	-0,42	38.450,00	-820,00	-2,1	-164	-0,5
Croatia	24.740,00	0,1	24.774,00	0,27	24.808,00	0,14	24.842,00	0,14	24.876,00	0,14	24.910,00	170,00	0,7	34	0,2
Cyprus	3.870,00	0,0	3.868,40	-0,08	3.866,80	-0,04	3.865,20	-0,04	3.863,60	-0,04	3.862,00	-8,00	-0,2	-1,6	0,0
Czech Republic	26.570,00	0,1	26.590,80	0,16	26.611,60	0,08	26.632,40	0,08	26.653,20	0,08	26.674,00	104,00	0,4	20,8	0,1
Denmark	6.350,00	0,7	6.395,40	1,42	6.440,80	0,70	6.486,20	0,70	6.531,60	0,70	6.577,00	227,00	3,6	45,4	0,8
Estonia	23.370,00	1,1	23.627,20	2,18	23.884,40	1,08	24.141,60	1,07	24.398,80	1,05	24.656,00	1.286,00	5,5	257,2	1,3
Finland	231.160,00	-0,1	230.966,00	-0,17	230.772,00	-0,08	230.578,00	-0,08	230.384,00	-0,08	230.190,00	-970,00	-0,4	-194	-0,1
France (cont.)	175.720,00	0,0	175.734,00	0,02	175.748,00	0,01	175.762,00	0,01	175.776,00	0,01	175.790,00	70,00	0,0	14	0,0
Germany	110.760,00	0,6	111.446,00	1,23	112.132,00	0,61	112.818,00	0,61	113.504,00	0,60	114.190,00	3.430,00	3,1	686	0,7
Greece	65.390,00	0,0	65.390,00	0,00	65.390,00	0,00	65.390,00	0,00	65.390,00	0,00	65.390,00	0,00	0,0	0	0,0
Hungary	20.390,00	1,5	20.692,80	2,93	20.995,60	1,44	21.298,40	1,42	21.601,20	1,40	21.904,00	1.514,00	7,4	302,8	1,7
Iceland	1.160,00	13,3	1.314,60	23,52	1.469,20	10,52	1.623,80	9,52	1.778,40	8,69	1.933,00	773,00	66,6	154,6	13,1
Ireland	7.870,00	0,4	7.898,40	0,72	7.926,80	0,36	7.955,20	0,36	7.983,60	0,36	8.012,00	142,00	1,8	28,4	0,4
Italy	109.160,00	0,4	109.548,00	0,71	109.936,00	0,35	110.324,00	0,35	110.712,00	0,35	111.100,00	1.940,00	1,8	388	0,4
Kosovo						incl. in Serbia								incl. in Serbia	
Latvia	34.670,00	0,0	34.672,00	0,01	34.674,00	0,01	34.676,00	0,01	34.678,00	0,01	34.680,00	10,00	0,0	2	0,0
Liechtenstein	80,00	-3,2	77,40	-6,72	74,80	-3,48	72,20	-3,60	69,60	-3,74	67,00	-13,00	-16,3	-2,6	-4,2
Lithuania	22.490,00	0,3	22.560,00	0,62	22.630,00	0,31	22.700,00	0,31	22.770,00	0,31	22.840,00	350,00	1,6	70	0,4
Luxembourg	880,00	0,0	880,40	0,09	880,80	0,05	881,20	0,05	881,60	0,05	882,00	2,00	0,2	0,4	0,1
Macedonia	11.410,00	-0,2	11.389,00	-0,37	11.368,00	-0,18	11.347,00	-0,19	11.326,00	-0,19	11.305,00	-105,00	-0,9	-21	-0,2
Malta	3,50	-2,9	3,40	-5,88	3,30	-3,03	3,20	-3,13	3,10	-3,23	3,00	-0,50	-14,3	-0,1	-3,6
Montenegro	7.440,00	5,9	7.880,60	11,18	8.321,20	5,29	8.761,80	5,03	9.202,40	4,79	9.643,00	2.203,00	29,6	440,6	6,4
Netherlands	3.650,00	0,6	3.672,00	1,20	3.694,00	0,60	3.716,00	0,59	3.738,00	0,59	3.760,00	110,00	3,0	22	0,7
Norway	123.840,00	2,8	127.320,00	5,47	130.800,00	2,66	134.280,00	2,59	137.760,00	2,53	141.240,00	17.400,00	14,1	3480	3,2
Poland	93.190,00	0,2	93.422,00	0,50	93.654,00	0,25	93.886,00	0,25	94.118,00	0,25	94.350,00	1.160,00	1,2	232	0,3
Portugal	36.110,00	7,2	38.702,40	13,40	41.294,80	6,28	43.887,20	5,91	46.479,60	5,58	49.072,00	12.962,00	35,9	2592,4	7,7
Romania	67.330,00	0,6	67.766,00	1,29	68.202,00	0,64	68.638,00	0,64	69.074,00	0,63	69.510,00	2.180,00	3,2	436	0,8
Serbia	31.230,00	0,7	31.440,00	1,34	31.650,00	0,66	31.860,00	0,66	32.070,00	0,65	32.280,00	1.050,00	3,4	210	0,8
Slovakia	19.380,00	0,0	19.384,00	0,04	19.388,00	0,02	19.392,00	0,02	19.396,00	0,02	19.400,00	20,00	0,1	4	0,0
Slovenia	12.740,00	0,0	12.734,00	-0,09	12.728,00	-0,05	12.722,00	-0,05	12.716,00	-0,05	12.710,00	-30,00	-0,2	-6	-0,1
Spain	277.470,00	-0,1	277.229,40	-0,17	276.988,80	-0,09	276.748,20	-0,09	276.507,60	-0,09	276.267,00	-1.203,00	-0,4	-240,6	-0,1
Sweden	306.250,00	-0,1	306.010,00	-0,16	305.770,00	-0,08	305.530,00	-0,08	305.290,00	-0,08	305.050,00	-1.200,00	-0,4	-240	-0,1
Switzerland	13.110,00	0,2	13.136,00	0,40	13.162,00	0,20	13.188,00	0,20	13.214,00	0,20	13.240,00	130,00	1,0	26	0,2
Turkey	217.020,00	0,1	217.341,00	0,30	217.662,00	0,15	217.983,00	0,15	218.304,00	0,15	218.625,00	1.605,00	0,7	321	0,2
United Kingdom	29.010,00	1,8	29.536,00	3,56	30.062,00	1,75	30.588,00	1,72	31.114,00	1,69	31.640,00	2.630,00	9,1	526,00	2,1
	2.240.577,50	**0,4**	**2.250.057,40**	**0,84**	**2.259.537,30**	**0,42**	**2.269.017,20**	**0,42**	**2.278.497,10**	**0,42**	**2.287.977,00**	**47.399,50**	**2,1**	**9479,90**	**0,5**

Table 5-11 – Global Forest Resources Assessment, interpolated forest area change with other wooded land 2010/2015 per country (FAO, 2010 and FAO, 2015e).

Change per year GFRA with other wooded land 2010/2015															
Country	GFRA 2010		GFRA 2011		GFRA 2012		GFRA 2013		GFRA 2014		GFRA 2015	2010/2015		per year	
	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	%	Forest [km²]	Change	%	Change	Mean %
Albania	10.310,0	-0,058195926	10.304,0	-0,058229814	10.298,0	-0,058263741	10.292,0	-0,116595414	10.286,00	-0,058331713	10.280,00	-30,00	-0,3	-6	-0,07
Austria	40.060,0	0,07988018	40.092,0	0,079816422	40.124,0	0,079752766	40.156,0	0,159378424	40.188,00	0,079625759	40.220,00	160,00	0,4	32	0,10
Belgium	7.060,0	0,368271955	7.086,0	0,366920689	7.112,0	0,365579303	7.138,0	0,728495377	7.164,00	0,36292574	7.190,00	130,00	1,8	26	0,44
Bosnia and Herzegovina	27.340,0	0	27.340,0	0	27.340,0	0	27.340,0	0	27.340,00	0	27.340,00	0,00	0,0	0	0,00
Bulgaria	39.270,0	-0,417621594	39.106,0	-0,419372986	38.942,0	-0,42113913	38.778,0	-0,845840425	38.614,00	-0,424716424	38.450,00	-820,00	-2,1	-164	-0,51
Croatia	24.740,0	0,137429264	24.774,0	0,137240656	24.808,0	0,137052564	24.842,0	0,273729973	24.876,00	0,136677922	24.910,00	170,00	0,7	34	0,16
Cyprus	3.870,0	-0,051679587	3.868,0	-0,051706308	3.866,0	-0,051733057	3.864,0	-0,103519669	3.862,00	-0,051786639	3.860,00	-10,00	-0,3	-2	-0,06
Czech Republic	26.570,0	0,075272864	26.590,0	0,075216247	26.610,0	0,075159714	26.630,0	0,150206534	26.650,00	0,075046904	26.670,00	100,00	0,4	20	0,09
Denmark	5.910,0	2,267343486	6.044,0	2,217074785	6.178,0	2,168986727	6.312,0	4,245880862	6.446,00	2,078808563	6.580,00	670,00	11,3	134	2,60
Estonia	23.500,0	0,90212766	23.712,0	0,894062078	23.924,0	0,886139442	24.136,0	1,756711966	24.348,00	0,870708066	24.560,00	1.060,00	4,5	212	1,06
Finland	232.690,0	-0,214878164	232.190,0	-0,215340885	231.690,0	-0,215805602	231.190,0	-0,43254466	230.690,00	-0,216741081	230.190,00	-2.500,00	-1,1	-500	-0,26
France (cont.)	175.720,0	0,007967221	175.734,0	0,007966586	175.748,0	0,007965951	175.762,0	0,015930633	175.776,00	0,007964682	175.790,00	70,00	0,0	14	0,01
Germany	110.760,0	0,619357169	111.446,0	0,615544748	112.132,0	0,611778975	112.818,0	1,216117995	113.504,00	0,604383986	114.190,00	3.430,00	3,1	686	0,73
Greece	65.390,0	0,021410002	65.404,0	0,021405419	65.418,0	0,021400838	65.432,0	0,042792517	65.446,00	0,021391682	65.460,00	70,00	0,1	14	0,03
Hungary	20.290,0	1,586988664	20.612,0	1,562196779	20.934,0	1,538167574	21.256,0	3,029732781	21.578,00	1,492260636	21.900,00	1.610,00	7,9	322	1,84
Iceland	1.160,0	13,27586207	1.314,0	11,71993912	1.468,0	10,49046322	1.622,0	18,98890259	1.776,00	8,671171171	1.930,00	770,00	66,4	154	12,63
Ireland	7.890,0	0,30418251	7.914,0	0,303260045	7.938,0	0,302343159	7.962,0	0,602863602	7.986,00	0,30052592	8.010,00	120,00	1,5	24	0,36
Italy	109.160,0	0,355441554	109.548,0	0,354182641	109.936,0	0,352932615	110.324,0	0,703382763	110.712,00	0,350458848	111.100,00	1.940,00	1,8	388	0,42
Kosovo						n/a								n/a	
Latvia	34.670,0	0,005768676	34.672,0	0,005768343	34.674,0	0,005768011	34.676,0	0,011535356	34.678,00	0,005767345	34.680,00	10,00	0,03	2	0,01
Liechtenstein	80,0	0	80,0	0	80,0	0	80,0	0	80,00	0	80,00	0,00	0	0	0,00
Lithuania	22.400,0	0,392857143	22.488,0	0,391319815	22.576,0	0,389794472	22.664,0	0,776561948	22.752,00	0,386779184	22.840,00	440,00	2,0	88	0,47
Luxembourg	880,0	0	880,0	0	880,0	0	880,0	0	880,00	0	880,00	0,00	0,0	0	0,00
Macedonia						n/a								n/a	
Malta						n/a								n/a	
Montenegro	7.180,0	6,852367688	7.672,0	6,412930136	8.164,0	6,026457619	8.656,0	11,36783734	9.148,00	5,378224749	9.640,00	2.460,00	34,3	492	7,21
Netherlands	3.650,0	0,602739726	3.672,0	0,59912854	3.694,0	0,595560368	3.716,0	1,184068891	3.738,00	0,588550027	3.760,00	110,00	3,0	22	0,71
Norway	127.680,0	2,12406015	130.392,0	2,079882201	133.104,0	2,037504508	135.816,0	3,993638452	138.528,00	1,957726958	141.240,00	13.560,00	10,6	2712	2,44
Poland	93.370,0	0,209917532	93.566,0	0,209477802	93.762,0	0,20903991	93.958,0	0,417207689	94.154,00	0,208169594	94.350,00	980,00	1,0	196	0,25
Portugal	36.110,0	7,178067017	38.702,0	6,697328303	41.294,0	6,27694096	43.886,0	11,8124231	46.478,00	5,57683205	49.070,00	12.960,00	35,9	2592	7,51
Romania	67.330,0	0,64755681	67.766,0	0,643390491	68.202,0	0,639277441	68.638,0	1,270433288	69.074,00	0,631207111	69.510,00	2.180,00	3,2	436	0,77
Serbia	31.230,0	0,672430355	31.440,0	0,667938931	31.650,0	0,663507109	31.860,0	1,31826742	32.070,00	0,654817587	32.280,00	1.050,00	3,4	210	0,80
Slovakia	19.330,0	0,07242628	19.344,0	0,072373863	19.358,0	0,072321521	19.372,0	0,144538509	19.386,00	0,072217064	19.400,00	70,00	0,4	14	0,09
Slovenia	12.740,0	-0,047095761	12.734,0	-0,047117952	12.728,0	-0,047140163	12.722,0	-0,094324792	12.716,00	-0,047184649	12.710,00	-30,00	-0,2	-6	-0,06
Spain	277.470,0	-0,086495837	277.230,0	-0,086570717	276.990,0	-0,086645727	276.750,0	-0,173441734	276.510,00	-0,086796138	276.270,00	-1.200,00	-0,4	-240	-0,10
Sweden	312.470,0	-0,474925593	310.986,0	-0,477191899	309.502,0	-0,479479939	308.018,0	-0,963580051	306.534,00	-0,484122479	305.050,00	-7.420,00	-2,4	-1484	-0,58
Switzerland	13.110,0	0,198321892	13.136,0	0,197929354	13.162,0	0,197538368	13.188,0	0,394297847	13.214,00	0,196761011	13.240,00	130,00	1,0	26	0,24
Turkey	217.020,0	0,131785089	217.306,0	0,131611644	217.592,0	0,131438656	217.878,0	0,262532243	218.164,00	0,131094039	218.450,00	1.430,00	0,7	286	0,16
United Kingdom	29.010,0	1,813167873	29.536,0	1,780877573	30.062,0	1,749717251	30.588,0	3,439257225	31.114,00	1,690557305	31.640,00	2.630,00	9,1	526	2,09
	2.237.420,00	**0,3**	**2.244.680,00**	**0,3**	**2.251.940,00**	**0,3**	**2.259.200,00**	**0,3**	**2.266.460,00**	**0,3**	**2.273.720,00**	**36.300,00**	**1,6**	**7260,00**	**0,3**

Grasslands

Table 5-12 - Permanent meadows and pastures in European countries 2000-2017 in 1000 km2 and annual change rate in % (FAOSTAT 2010 and 2015e)

state	2000	2001	change %	2002	change %	2003	change %	2004	change %	2005	change %	2006	change %	2007	change %	2008	change %
Albania	4,45	4,40	-1,12	4,41	0,23	4,22	-4,31	4,23	0,24	4,18	-1,18	4,15	-1,43	4,21	1,45	4,84	14,96
Austria	14,70	14,58	-0,82	14,46	-0,82	14,34	-0,83	14,22	-0,84	14,10	-0,84	13,98	-1,69	13,86	-0,86	13,74	-0,87
Bosnia + Herzeg	10,30	10,19	-1,07	10,30	1,08	10,57	2,62	10,44	-1,23	10,37	-0,67	10,36	-0,19	10,32	-0,39	10,32	0,00
Belgium	5,07	5,21	2,76	5,36	2,88	5,36	0,00	5,30	-1,12	5,19	-2,08	5,17	-0,77	5,07	-1,93	5,00	-1,38
Bulgaria	18,04	17,86	-1,00	17,42	-2,46	17,89	2,70	18,06	0,95	19,04	5,43	18,76	-2,93	18,42	-1,81	18,29	-0,71
Croatia	2,58	2,55	-1,16	2,53	-0,78	2,61	3,16	2,59	-0,77	2,65	2,32	2,73	6,01	2,70	-1,10	3,42	26,81
Cyprus	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Czech Republic	9,61	9,66	0,52	9,68	0,21	9,71	0,31	9,72	0,10	9,74	0,21	9,76	0,41	9,78	0,20	9,80	0,20
Denmark	3,58	3,76	5,03	3,82	1,60	3,84	0,52	3,70	-3,65	3,68	-0,54	3,57	-5,95	3,50	-1,96	2,61	-25,43
Estonia	1,31	1,94	48,09	0,67	-65,46	2,68	300,00	2,36	-11,83	2,79	18,07	3,31	36,73	3,07	-7,11	3,01	-1,95
Finland	0,26	0,25	-3,85	0,27	8,00	0,28	3,70	0,28	0,00	0,33	17,86	0,36	18,09	0,34	-5,56	0,33	-2,94
France	103,12	102,33	-0,77	101,11	-1,19	100,64	-0,47	99,80	-0,84	99,02	-0,78	98,77	-0,50	98,48	-0,30	97,91	-0,58
Germany	50,48	50,13	-0,69	49,70	-0,86	49,68	-0,04	49,13	-1,11	49,29	0,33	48,82	-1,90	48,75	-0,14	47,89	-1,76
Greece	46,75	45,86	-1,90	44,97	-1,94	44,08	-1,98	43,19	-2,02	42,30	-2,06	41,41	-4,19	40,52	-2,15	39,63	-2,20
Hungary	10,51	10,61	0,95	10,63	0,19	10,62	-0,09	10,60	-0,19	10,57	-0,28	10,15	-7,91	10,17	0,20	10,10	-0,69
Iceland	17,60	17,60	0,00	17,58	-0,11	17,56	-0,11	17,55	-0,06	17,53	-0,11	17,52	-0,11	17,51	-0,06	17,51	0,00
Ireland	33,33	32,20	-3,39	31,94	-0,81	31,86	-0,25	30,98	-2,76	31,15	0,55	31,04	-0,70	32,13	3,51	30,96	-3,63
Italy	43,53	43,65	0,28	43,79	0,32	43,68	-0,25	43,54	-0,32	44,02	1,10	42,82	-5,42	44,60	4,16	44,16	-0,99
Kosovo	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Latvia	6,06	6,11	0,83	6,10	-0,16	6,13	0,49	6,21	1,31	6,29	1,29	6,37	2,53	6,41	0,63	6,48	1,09
Liechtenstein	0,03	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00
Lithuania	4,97	12,22	145,88	12,03	-1,55	9,73	-19,12	9,55	-1,84	8,91	-6,74	8,76	-3,22	8,30	-5,24	7,83	-5,68
Luxembourg	0,65	0,65	0,00	0,65	0,00	0,65	0,00	0,65	0,00	0,67	3,08	0,67	0,00	0,68	1,49	0,67	-1,47
Macedonia	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Malta	0	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Montenegro	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Netherlands	10,12	9,93	-1,88	10,00	0,70	9,85	-1,50	7,91	-19,72	7,95	0,52	8,17	5,56	8,21	0,44	8,28	0,87
Norway	1,58	1,61	1,90	1,63	1,24	1,64	0,61	1,66	1,22	1,69	1,81	1,72	3,53	1,75	1,51	1,75	0,29
Poland	40,83	38,64	-5,36	35,62	-7,82	32,68	-8,25	33,65	2,97	33,87	0,65	32,16	-10,05	32,71	1,71	31,84	-2,66
Portugal	14,33	14,29	-0,28	14,68	2,73	15,07	2,66	15,07	0,00	17,69	17,39	17,32	-4,16	17,82	2,87	17,83	0,06
Romania	49,49	49,36	-0,26	49,59	0,47	49,58	-0,02	47,86	-3,47	46,85	-2,11	46,31	-2,29	44,94	-2,96	44,50	-0,98
Serbia	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Slovakia	8,65	7,84	-9,36	7,99	1,91	7,95	-0,50	5,14	-35,35	5,24	1,95	5,36	4,56	5,28	-1,49	5,32	0,76
Slovenia	3,14	3,07	-2,23	3,07	0,00	3,08	0,33	2,87	-6,82	3,05	6,27	2,85	-13,05	2,97	4,21	3,85	29,66
Spain	114,62	114,76	0,12	115,33	0,50	111,72	-3,13	111,14	-0,52	113,20	1,85	110,35	-5,01	106,08	-3,87	108,70	2,47
Sweden	4,47	4,60	2,91	4,90	6,52	4,94	0,82	5,23	5,87	5,13	-1,91	5,03	-3,88	4,89	-2,78	4,58	-6,34
Switzerland	11,33	11,29	-0,35	11,27	-0,19	11,26	-0,10	11,23	-0,24	11,20	-0,27	11,17	-0,69	11,14	-0,27	11,11	-0,24
Turkey	141,00	146,17	3,67	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00
United Kingdom	110,36	112,51	1,95	111,40	-0,99	112,48	0,97	111,83	-0,58	111,80	-0,03	116,99	9,24	115,16	-1,56	116,33	1,02
EEA39 countries	896,86	905,86	1,00	899,10	-0,75	892,58	-0,73	881,89	-1,20	885,69	0,43	882,11	-0,81	875,96	-0,70	874,80	-0,13

state	2009	change %	2010	change %	2011	change %	2012	change %	2013	change %	2014	change %	2015	change %	2016	change %	2017	change %
Albania	5,05	4,40	5,05	0,00	5,05	-0,06	5,05	0,06	4,91	-2,83	4,78	-2,59	4,78	-0,02	4,78	0,00	4,78	-0,03
Austria	13,62	-0,87	13,50	-0,88	13,32	-1,31	13,15	-1,32	12,97	-1,35	12,97	0,00	13,07	0,75	12,59	-3,68	12,59	0,00
Bosnia + Herzeg	10,29	-0,29	10,35	0,58	10,44	0,87	10,48	0,38	10,45	-0,29	10,45	0,00	10,49	0,38	10,79	2,86	10,61	-1,67
Belgium	5,02	0,40	5,00	-0,40	4,89	-2,20	5,07	3,68	4,98	-1,74	4,92	-1,24	4,76	-3,25	4,78	0,50	4,68	-2,17
Bulgaria	17,19	-6,01	17,02	-0,99	16,78	-1,41	16,47	-1,85	13,81	-16,15	13,64	-1,23	13,69	0,34	13,84	1,12	13,92	0,60
Croatia	3,43	0,26	3,45	0,61	3,46	0,29	3,46	-0,23	6,18	78,82	6,18	0,00	6,18	0,00	6,00	-2,91	6,08	1,33
Cyprus	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Czech Republic	9,83	0,31	9,86	0,31	9,89	0,30	9,92	0,30	9,94	0,20	9,97	0,30	10,01	0,40	9,49	-5,19	9,78	3,06
Denmark	1,97	-24,52	2,00	1,52	1,87	-6,50	2,00	6,95	1,95	-2,50	1,93	-1,03	2,55	32,12	2,26	-11,37	2,35	3,84
Estonia	3,27	8,74	2,97	-9,35	3,07	3,34	3,29	7,18	3,27	-0,49	3,20	-2,14	3,18	-0,69	3,04	-4,34	3,14	3,29
Finland	0,34	3,03	0,33	-2,94	0,32	-3,03	0,32	0,00	0,31	-3,13	0,33	6,45	0,28	-15,76	0,26	-6,47	0,25	-3,85
France	97,37	-0,56	96,15	-1,25	95,97	-0,18	95,59	-0,39	94,72	-0,92	94,38	-0,35	92,62	-1,87	93,70	1,17	92,34	-1,45
Germany	47,41	-1,00	46,55	-1,81	46,44	-0,24	46,30	-0,30	46,21	-0,19	46,51	0,65	46,77	0,56	46,94	0,36	47,15	0,45
Greece	38,74	-2,25	37,85	-2,30	36,96	-2,35	36,07	-2,41	35,19	-2,44	28,73	-18,36	29,17	1,53	28,82	-1,20	28,82	0,00
Hungary	10,04	-0,59	7,63	-24,00	7,59	-0,52	7,59	0,00	7,59	0,00	7,61	0,26	7,62	0,13	7,83	2,76	8,04	2,68
Iceland	17,51	0,00	17,51	0,00	17,51	0,00	17,51	0,00	17,51	0,00	17,51	0,00	17,51	0,00	17,51	0,00	17,51	0,00
Ireland	30,97	0,02	35,55	14,79	34,92	-1,77	33,62	-3,72	33,63	0,03	34,07	1,31	34,00	-0,21	39,99	17,62	40,29	0,75
Italy	44,23	0,16	46,98	6,22	46,12	-1,83	41,69	-9,61	45,43	8,97	40,41	-11,05	38,97	-3,56	36,63	-6,00	36,08	-1,49
Kosovo	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Latvia	6,59	1,70	6,25	-5,16	6,51	4,16	6,57	0,92	6,63	0,91	6,57	-0,90	6,48	-1,37	6,35	-2,01	6,35	0,00
Liechtenstein	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00	0,03	0,00
Lithuania	6,08	-22,42	6,14	1,09	5,89	-4,05	5,50	-6,69	5,68	3,36	5,68	-0,05	7,99	40,63	7,77	-2,79	7,96	2,51
Luxembourg	0,67	0,55	0,68	0,33	0,68	0,07	0,67	-0,52	0,67	-0,58	0,67	-0,10	0,67	0,13	0,67	0,30	0,67	0,43
Macedonia	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Malta	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0,00	0,00	0,00	0,00
Montenegro	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Netherlands	8,27	-0,07	8,13	-1,68	8,16	0,33	7,95	-2,59	7,73	-2,74	7,58	-1,98	7,66	1,08	7,30	-4,70	7,15	-2,05
Norway	1,75	-0,17	1,76	0,57	1,77	0,46	1,77	-0,06	1,76	-0,06	1,76	-0,45	1,76	0,17	1,76	-0,23	1,81	2,91
Poland	31,80	-0,13	32,30	1,57	32,91	1,89	32,06	-2,58	32,06	0,00	31,20	-2,68	30,93	-0,87	31,75	2,65	31,71	-0,13
Portugal	17,85	0,11	17,93	0,45	18,01	0,45	18,09	0,44	18,17	0,44	18,17	0,00	18,17	0,00	18,76	3,26	18,76	0,00
Romania	43,72	-1,75	45,47	4,00	45,43	-0,09	44,89	-1,19	47,17	5,08	46,27	-1,91	46,55	0,61	45,21	-2,88	44,20	-2,23
Serbia	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Slovakia	5,24	-1,50	5,27	0,63	5,18	-1,73	5,15	-0,64	5,14	-0,23	5,11	-0,45	5,21	1,80	5,21	0,08	5,18	-0,58
Slovenia	3,90	1,27	3,88	-0,62	3,84	-0,99	3,76	-1,98	3,73	-0,85	3,78	1,28	3,79	0,38	3,80	0,16	3,77	-0,73
Spain	107,54	-1,07	103,24	-4,00	100,22	-2,93	94,03	-6,18	96,00	2,10	93,90	-2,19	92,32	-1,68	92,33	0,01	93,10	0,84
Sweden	4,36	-4,80	4,51	3,44	4,47	-0,89	4,41	-1,43	4,43	0,52	4,36	-1,63	4,50	3,24	4,52	0,47	4,53	0,24
Switzerland	11,08	-0,30	11,06	-0,13	11,04	-0,23	11,01	-0,28	10,97	-0,28	10,97	-0,04	10,85	-1,09	10,92	0,67	10,90	-0,21
Turkey	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00	146,17	0,00
United Kingdom	112,33	-3,44	112,08	-0,22	110,57	-1,35	109,24	-1,20	109,40	0,15	109,54	0,13	110,78	1,13	112,77	1,80	113,36	0,52
EEA39 countries	863,66	-1,27	862,64	-0,12	855,47	-0,83	838,86	-1,94	844,79	0,71	829,34	-1,83	829,49	0,02	834,56	0,61	834,06	-0,06

Table 5-13 – Pastures and Natural Grasslands in European countries 1990-2012 (CLC data 2012)

CORINE LAND COVER (CLC) DATA - GRASSLAND											
Country		1990		2000		2006		2012		2018	
Cod	Name	231_pastures	321_natural grasland	2000 231_pastu	2000 321_natural grasla	231_pastures3	321_natural grasland3	231_pastures4	321_natural grasland4	2018 231_pastu	2018 321_natural grasla
AL	Albania	no data	no data	432,62	2.947,60	616,12	3.209,17	615,66	3.208,32	774,50	3.087,52
AT	Austria	8.262,62	5.440,91	7.474,38	5.997,47	6.925,98	6.065,75	6.923,00	6.092,43	7.042,75	6.212,83
BA	Bosina+Herzegowina	54,12	43,71	4.083,10	2.485,69	3.404,39	3.011,95	3.403,40	3.009,76	3.241,77	2.883,42
BE	Belgium	3.608,01	9,89	3.550,78	9,10	3.547,75	8,88	3.542,82	8,88	3.522,57	9,32
BG	Bulgaria	4.150,24	3.993,39	4.126,49	3.928,33	3.985,63	4.059,49	3.940,72	4.054,33	3.913,56	4.084,48
CH	Switzerland	1.797,59	5.951,75	3.743,36	4.490,46	3.720,31	4.475,27	3.719,86	4.475,15	3.383,23	4.137,35
CY	Cyprus	no data	no data	11,64	296,52	8,85	260,76	8,85	260,23	11,06	253,91
CZ	Czech Republic	2.528,23	404,40	6.446,48	280,39	7.185,74	261,98	7.944,47	256,64	8.067,94	251,86
DE	Germany	44.350,72	1.976,28	45.365,24	1.763,88	43.940,02	1.681,35	64.429,20	1.517,86	64.551,10	1.642,59
DK	Denmark	562,95	269,02	568,69	261,92	603,33	253,59	587,76	250,06	695,72	257,21
EE	Estonia	no data	no data	2.579,86	390,81	3.085,18	355,26	3.049,64	357,02	3.004,36	363,52
EL	Greece	734,04	12.069,84	700,19	11.934,80	1.042,48	10.619,78	1.004,64	10.624,43	1.406,26	9.789,13
ES	Spain	6.594,58	27.009,78	6.511,49	26.170,60	8.903,01	39.478,93	8.758,24	39.407,80	11.934,59	34.464,55
FI	Finland	no data	no data	43,60	35,62	43,13	35,62	64,63	159,95	40,18	160,27
FR	France	88.091,52	13.512,41	87.200,27	12.486,42	86.240,46	12.599,69	85.729,86	12.329,98	85.208,16	12.062,06
HR	Croatia	4.758,34	776,59	3.070,83	2.517,52	2.861,82	2.528,64	2.837,33	2.543,49	2.803,69	2.566,13
HU	Hungary	6.809,47	2.257,59	6.782,89	2.283,76	6.849,68	2.282,01	6.883,07	2.285,62	6.923,49	2.307,64
IE	Ireland	38.156,07	936,45	35.972,55	896,96	38.445,15	444,46	38.614,28	449,88	38.943,00	484,68
IT	Italy	4.551,46	14.496,37	4.271,20	14.690,18	4.292,98	13.816,40	4.286,45	13.796,22	4.135,36	7.606,41
LI	Liechtenstein	no data	no data	14,03	22,25	5,13	22,18	5,13	22,18	5,16	22,26
LT	Lithuania	4.891,58	8,57	4.235,89	9,94	3.991,46	10,65	3.834,12	10,40	4.531,83	26,48
LU	Luxembourg	306,35	1,83	303,16	1,80	375,96	0,00	375,09	0,00	405,03	0,00
LV	Latvia	9.334,08	64,37	8.545,90	53,50	7.709,06	80,26	7.430,64	82,15	6.390,01	87,52
ME	Montenegro	343,41	1.222,59	210,57	1.323,80	269,05	1.018,36	266,54	1.017,93	267,05	1.025,24
MK	Macedonia	no data	no data	2.095,40	1.683,56	1.972,83	2.002,15	1.975,01	1.999,84	1.966,54	2.001,71
NL	Netherlands	11.380,65	260,03	10.714,20	322,47	10.245,02	425,99	10.131,14	479,42	9.969,64	511,15
NO	Norway	no data	no data	251,09	0,31	251,06	0,09	250,90	0,09	249,49	0,39
PL	Poland	27.682,55	453,03	27.168,07	377,40	27.708,31	348,80	27.453,06	324,67	28.007,57	266,11
PT	Portugal	1.118,22	2.205,21	1.001,46	2.017,82	1.392,59	1.223,31	1.379,65	1.222,48	2.868,61	662,87
RO	Romania	25.349,30	3.484,77	25.258,39	3.491,87	24.784,42	5.917,51	24.738,16	5.919,51	26.264,88	5.792,02
RS	Repubic of Serbia	1.873,11	2.209,12	1.612,21	2.040,44	1.659,67	2.052,05	1.650,74	2.047,27	1.510,38	1.969,64
SE	Sweden	no data	no data	2.675,63	1.921,46	2.652,81	1.925,90	2.655,50	1.926,26	2.634,20	1.929,42
SI	Slovenia	no data	no data	1.161,99	206,56	1.152,89	206,16	1.153,10	206,21	1.069,96	196,53
SK	Slovakia	3.186,97	319,98	2.733,81	285,99	2.598,32	275,15	2.580,63	274,04	2.699,34	264,70
TR	Turkey	16.324,22	91.609,60	15.802,75	91.310,51	19.753,71	89.294,94	19.534,38	88.937,45	20.088,41	88.776,19
UK	United Kingdom	no data	no data	67.371,42	19.642,36	70.017,68	14.293,58	69.953,46	14.314,62	68.741,24	14.373,01
KS	Kosovo									*166,77*	*705,14*
MT	Malta									*0,00*	*0,00*
IS	Iceland									*2.585,48*	*3.377,26*
EEA		**316.800,40**	**190.987,48**	**394.091,63**	**218.580,07**	**402.241,98**	**224.546,06**	**421.711,13**	**223.872,57**	**427.272,59**	**210.530,11**
EEA total grassland area			**507.787,88**		**612.671,70**		**626.788,04**		**645.583,70**		**637.802,70**

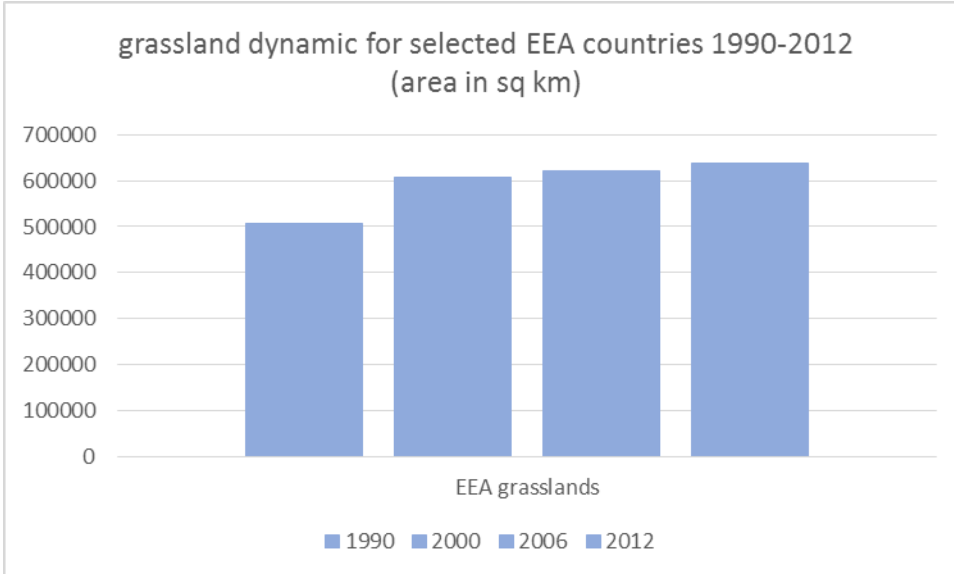

Figure 5-8 – Grassland (permanent pastures and natural grassland) dynamic for selected EEA countries (countries providing data for the whole period of time) (CLC 2012)