Copernicus Land Monitoring Service – High Resolution Layer Forest

Product Specifications

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Copernicus Land Monitoring Service – High Resolution Layer Forest: Product Specifications Document

Title	Copernicus Land Monitoring Service – High Resolution Layer Forest: Product Specifications Document
Creator	Tobias LANGANKE
Creation date	2017-03-15
Subject	Definitions and product specifications of Copernicus High Resolution Layer Forest products
Status	Final
Publisher	Copernicus team at EEA
Type	Text
Description	This document contains detailed product definitions and specifications for the pan-European Copernicus High Resolution Layer Forest. It was created in close collaboration and with contributions from the implementing service providers in a consultative process.
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Format	Microsoft Word document
Source	European Environment Agency and HRL Forest service providers
Rights	European Environment Agency
Identifier	This is version 11 of 2018-08-14
Language	EN
Relation	Copernicus regulation
Coverage	2018

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LIST OF ACRONYMS

CLC	CORINE Land Cover
CLMS	Copernicus Land Monitoring Service
CRS	Coordinate Reference System
DLT	Dominant Leaf Type
DLTC	Dominant Leaf Type Change
DWH	Data Warehouse
EEA	European Environment Agency
EO	Earth Observation
EPSG	European Petroleum Survey Group
ESA	European Space Agency
FADSL	Forest Additional Support Layer
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment
FTY	Forest Type
GIO	GMES Initial Operations
GIS	Geographic Information System
HR	High Resolution
HRL	High Resolution Layer
IMD	Impervious Degree
INSPIRE	INfrastructure for SPatial InfoRmation in Europe
LAEA	Lambert Azimuthal Equal Area Projection
LUCAS	Land Use and Coverage Area frame Survey
MMU	Minimum Mapping Unit
MMW	Minimum Mapping Width
MSGI	Metadata Standard for Geographic Information
QC	Quality Control
SVM	Support Vector Machine
TCD	Tree Cover Density
TCDC	Tree Cover Density Change
TCM	Tree Cover Mask
USGS	United States Geological Survey
VHR	Very High Resolution

1. Background

This document captures the detailed definitions and product specifications for the High Resolution Layer (HRL) Forest products as part of the Copernicus Land Monitoring Service (CLMS), coordinated by the European Environment Agency (EEA). The document evolved during the production period as a specification document, and was then adopted for the final users of the datasets.

The HRL Forest with reference year 2015 (± 1 year) has been fully produced in the European Terrestrial Reference System 1989 (ETRS89) and in Lambert Azimuthal Equal Area (LAEA) projection with one harmonised set of products (no split in different service elements and geographic lots) by a consortium of well-established European service providers. For the first time, the product portfolio includes a set of new change products at pan-European scale. Multitemporal satellite data in 20m spatial resolution, mainly Sentinel-2A data from the European Space Agency (ESA) as well as Landsat 8 data from the United States Geological Survey (USGS), represent the primary input data source for the 2015 products. Additionally, the 2015 production includes the correction and re-processing of the historical 2012 HRL Forest products to allow a full harmonisation across Europe. The two primary status layers Dominant Leaf Type (DLT) and Tree Cover Density (TCD) at 20m spatial resolution are sharing the same spatial extent and provide information on the leaf type (broadleaved /coniferous) and the proportional tree cover at pixel level. This allows users to apply a (national) forest definition, taking any canopy crown cover into account, which fits best to their specific needs.

2. Product Overview

Figure 1 summarizes the limited amount of products in the GMES Initial Operations (GIO) phase 2012, and the new products in the frame of the 2015 reference year production. New are in particular the separation between the pixel-based Dominant Leaf Type (DLT) and the Forest Type (FTY) following a forest definition, and new change products, namely the Dominant Leaf Type Change (DLTC) as well as the Tree Cover Density Change (TCDC).

TCD - Tree Cover Density
FTY - Forest Type
FADSL - Forest Additional Support Layer
DLT - Dominant Leaf Type
TCDC - Tree Cover Density Change
DLTC - Dominant Leaf Type Change

Figure: 1: Product portfolio of the GIO-land production phase for the reference year 2012 and extended range of products for the reference year 2015 production, including a correction and re-processing of the 2012 products for full European-wide harmonisation.

Table 1 provides an overview of the HRL Forest raster products in a tabular way.

Table 1: Overview on HRL Forest raster products

No	Product name	Rfr. year	Abbreviation	Pixel size	MMU	TCD threshold	Classified feature
1	Tree Cover Density 2015	2015	TCD_2015_020m	20m	N/A	N/A	Tree cover; tree cover density from 1-100%
2	Dominant Leaf Type 2015	2015	DLT_2015_020m	20m	N/A	N/A	Dominant leaf type: broadleaved or coniferous
3	Forest Type 2015	2015	FTY_2015_020m	20m	0.5 ha	10%	Forest Type: broadleaved or coniferous, largely following the FAO forest definition
4	Forest Additional Support Layer 2015	2015	FADSL_2015_020	20m	N/A	10%	Trees in urban context, trees predominantly used for agricultural practices
5	Tree Cover Density 2015	2015	TCD_2015_100m	100m	N/A	N/A	Aggregated tree cover; tree cover density from 1-100%
6	Forest Type 2015	2015	FTY_2015_100m	100m	N/A	10%	Aggregated Forest Type (broadleaved, coniferous, mixed), following the FAO forest definition
7	Tree Cover Density 2012	2012	TCD_2012_020m	20m	N/A	N/A	Tree cover; tree cover density from 1-100%
8	Dominant Leaf Type 2012	2012	DLT_2012_020m	20m	N/A	N/A	Dominant leaf type: broadleaved or coniferous
9	Forest Type 2012	2012	FTY_2012_020m	20m	0.5 ha	10%	Forest Type: broadleaved or coniferous, largely following the FAO forest definition
10	Forest Additional Support Layer 2012	2012	FADSL_2012_020m	20m	N/A	10%	Trees in urban context, trees predominantly used for agricultural practices
11	Tree Cover Density 2012	2012	TCD_2012_100m	100m	N/A	N/A	Aggregated tree cover; tree cover density from 1-100%
12	Forest Type 2012	2012	FTY_2012_100m	100m	N/A	10%	Aggregated Forest Type (broadleaved, coniferous, mixed), following the FAO forest definition
13	Tree Cover Density Change	2012-2015	TCDC_1215_100m	100m	N/A	30%	Tree cover density changes between two reference years

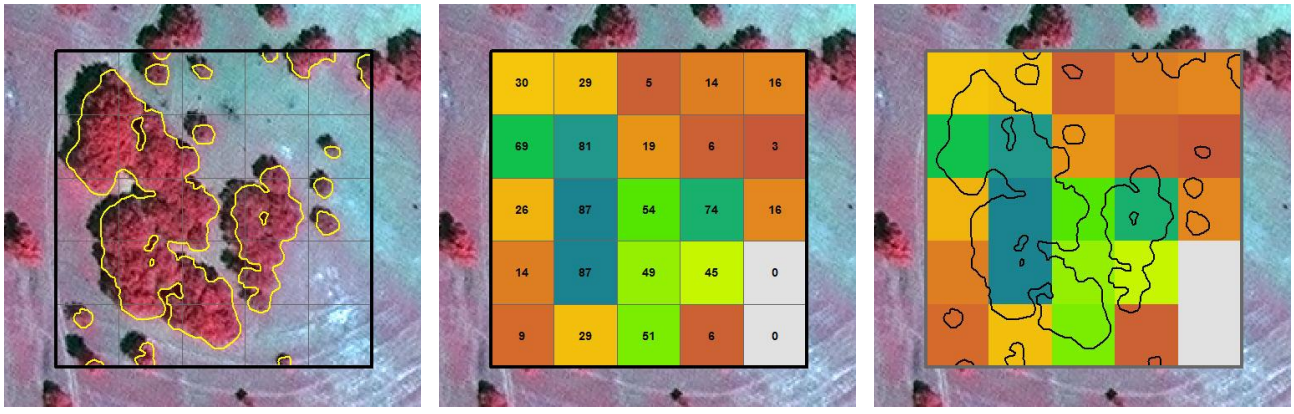
No	Product name	Rfr. year	Abbreviation	Pixel size	MMU	TCD threshold	Classified feature
14	Dominant Leaf Type Change	2012-2015	DLTC_1215_020m	20m	0.5 ha	30%	Various possible leaf type changes between two reference years

In the following, definitions for the primary status layers Tree Cover Density and Dominant Leaf Type as well as of the secondary status layer Forest Type and associated change layers will be given. Detailed product specifications are provided in Annex II.

2.1 Tree Cover Density (TCD)

The Copernicus HRL Forest defines Tree Cover Density as the ***„vertical projection of tree crowns to a horizontal earth's surface"*** and provides information on the proportional crown coverage per pixel. This information is derived from multispectral High Resolution (HR) satellite data using Very High Resolution (VHR) satellite data and/or aerial ortho-imagery as reference data. Tree Cover Density is assessed on VHR sources by visual interpretation following a point grid approach and subsequently transferred to the HR data by a linear function.

Figure 2 below presents an ideal-typical delineation of tree cover on a VHR satellite scene and the thereof derived Tree Cover Density in a red-yellow-green-blue colour scheme (no tree cover is displayed in light grey) within a 20m raster grid, being fully in line with the nominal spatial resolution of the final product. Even though tree cover is not derived from VHR data, but from multispectral HR satellite data in form of a binary mask (and subsequently filled with tree cover density values and leaf type information) this example helps to understand the character of the product.



Visually delineated Tree Cover Mask on VHR data with 20m raster grid

Translated Tree Cover Density of 0-100% to a 20m raster grid

20m Tree Cover Density raster overlaid with VHR Tree Cover Mask

Figure 2: Ideal-typical illustration of the Tree Cover Density product, delineated from a VHR satellite scene. Please note that the visual delineation on the left is only included for illustration purposes: it is not a product of the HRL Forest.

Table 2 provides an overview of the Land Cover (LC) and Land Use (LU) features that shall be included or excluded in the "tree cover" mapping, if detectable from the satellite imagery. The resulting binary Tree Cover Mask (TCM) has been semi-automatically enhanced by means of various processing steps and subsequently filled with the relevant information on Tree Cover Density. This is done using a multiple linear regression estimator correlating the assessed Tree Cover Density (VHR-based) with the spectral reflection values of the best available underlying HR satellite scene. Tree Cover Density shows a natural sensitivity towards phenology and radiometric influences (e.g. haze). Consequently, the magnitude of tree cover density values strongly relies on the availability and quality of adequate satellite data and reference data.

Table 2: LC/LU elements to be included/excluded in the Tree Cover Mask

Elements to be included in the tree covered area *(if tree cover can be detected from the 20m imagery)*	**Elements to be excluded from tree covered area** *(if no tree cover can be detected from the 20m imagery)*
• Evergreen/deciduous broadleaved, sclerophyllous and coniferous trees of any use • Forests (grown-up and under development) • Orchards, olive groves, fruit and other tree plantations, agro-forestry areas • Transitional woodland, forests in regeneration • Groups of trees within urban areas (alleys, wooded parks and gardens) • Forest management/use features inside forests (forest roads, firebreaks, thinnings, forest nurseries, etc.) • Forest damage features inside forests (partially burnt areas, storm damages, insect-infested damages, etc.)	• Open areas within forests (roads, permanently open vegetated areas, clear cuts, fully burnt areas, other severe forest damage areas, etc.) • Dwarf shrub-covered areas, such as moors and heathland • Vineyards • Dwarf pine / green alder in alpine areas • Mediterranean shrublands (macchia, garrigue etc.) • Shrubland

The Tree Cover Density represents one of the primary status layers of the HRL Forest product portfolio and has the following main specifications:

- 20m spatial resolution
- Tree Cover Density range of 0-100%
- No Minimum Mapping Unit (MMU); pixel-based
- Minimum Mapping Width (MMW) of 20m
- Monotemporal coverage

In particular, information on crown cover, which is provided with the continuous-scale (0-100%) Tree Cover Density product for the whole of Europe (see Figure 3), can be generally used by different countries, even if different national forest definition regards the crown/canopy cover exist (e.g. Austria with 3%, Spain with 5%). In this sense, the TCD product largely supports the user-specific derivation of forest-related products according to the European-wide different understandings of forest.

The Tree Cover Density product is also available as aggregated version in 100m spatial resolution, fully aligned to the EEA 100m reference grid. Aggregation rules to the 100m product are described in Annex VI.

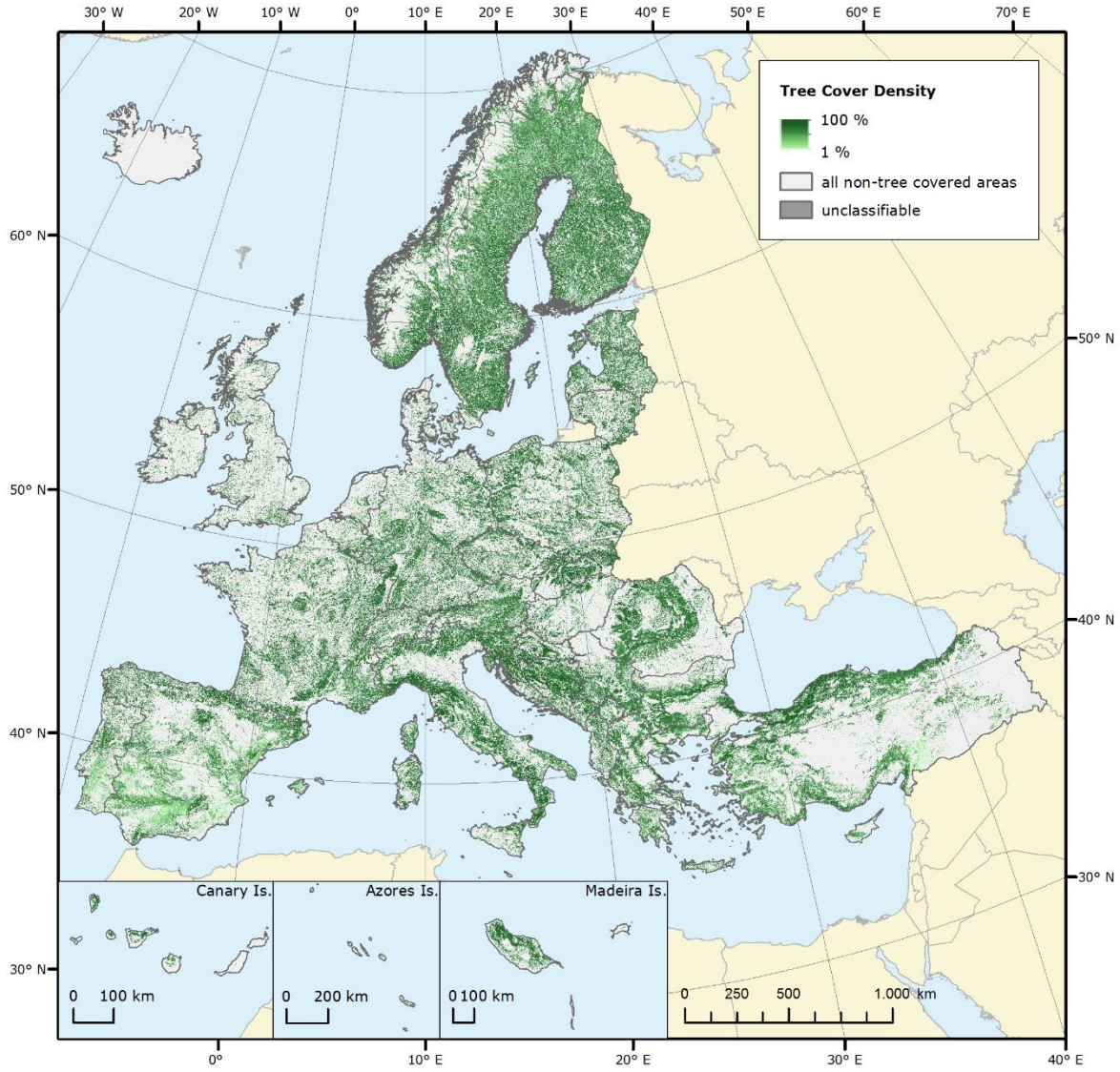


Figure 3: Pan-European illustration of the Tree Cover Density 2015
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2.2 Dominant Leaf Type (DLT)

The Dominant Leaf Type is another primary status layer of the HRL Forest, derived from multitemporal satellite image data using Support Vector Machine (SVM), and has the following main specifications:

- 20m spatial resolution
- Fully identical in its outline extent with the Tree Cover Density product
- Providing information on the dominant leaf type: broadleaved or coniferous
- No Minimum Mapping Unit (MMU); pixel-based

- Minimum Mapping Width (MMW) of 20m
- Multitemporal coverage

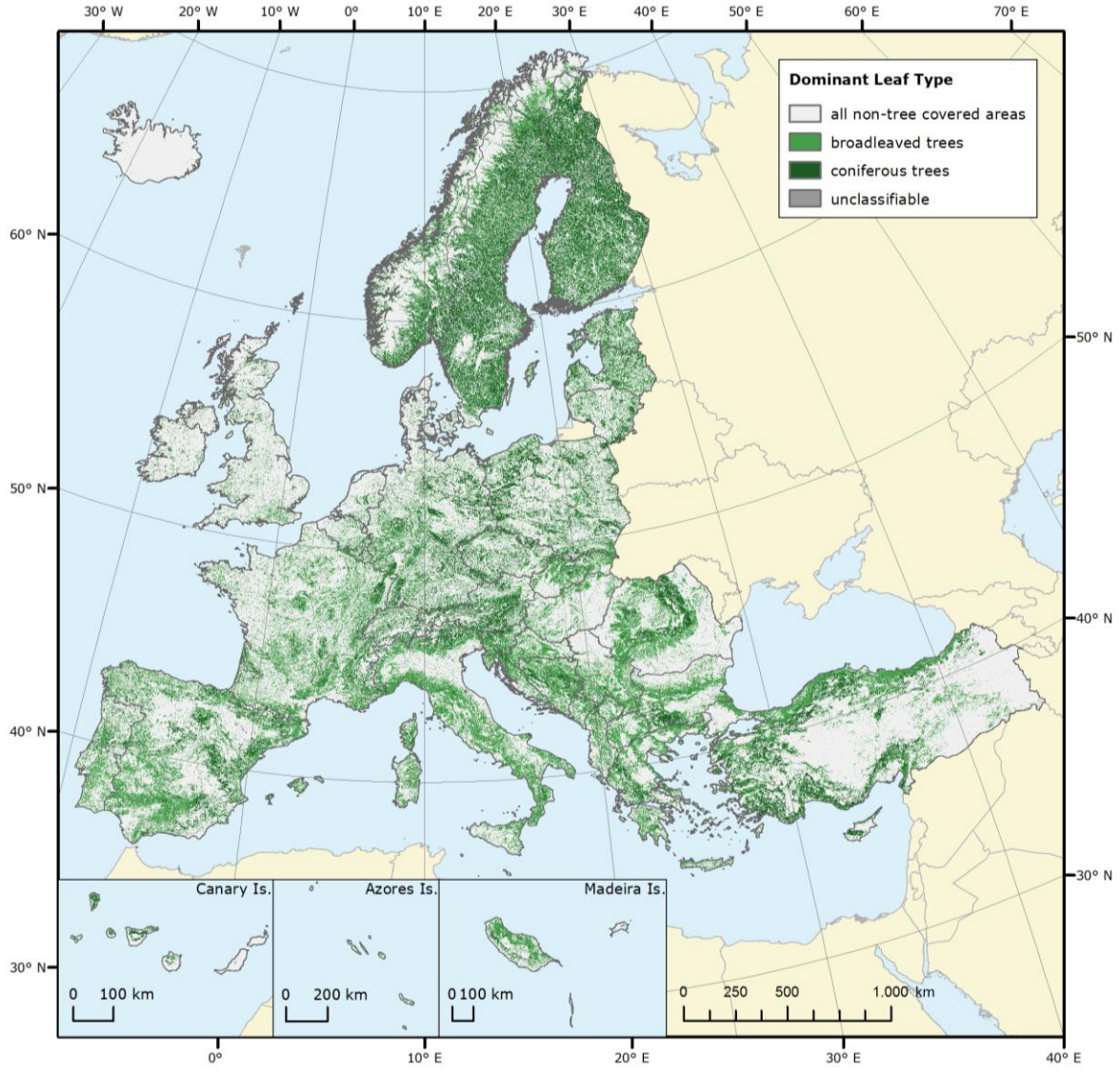

Figure 4: Pan-European illustration of the Dominant Leaf Type 2015

© EuroGeographics for the administrative boundaries

In combination with the Tree Cover Density product, the Dominant Leaf Type is suitable to serve various national forest definitions.

2.3 Forest Type (FTY)

With the Forest Type product the HRL Forest already provides one type of forest products following a forest definition. Contrary to the Tree Cover Density product non-forest trees are excluded following the forest definition of the Food and Agriculture Organization (FAO). This is e.g. specified in the terms and definitions of the Global Forest Resources Assessment (FRA) Working Paper 1, which is accessible online via www.fao.org/docrep/006/ad665e/ad665e06.htm. The forest definition of the FAO includes and excludes the following features/elements:

Includes (FAO): forest nurseries and seed orchards that constitute an integral part of the forest; as well as forest roads, cleared tracts, firebreaks and other small open areas < 0.5 ha and/or < 20m width. Forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5 ha and width of more or equal than 20m; plantations primarily used for forestry purposes, including cork oak stands.

Excludes (FAO): land predominantly used for agricultural practices. In this sense fruit trees and olive groves are also excluded. Gardens and urban parks are also not considered as forest.

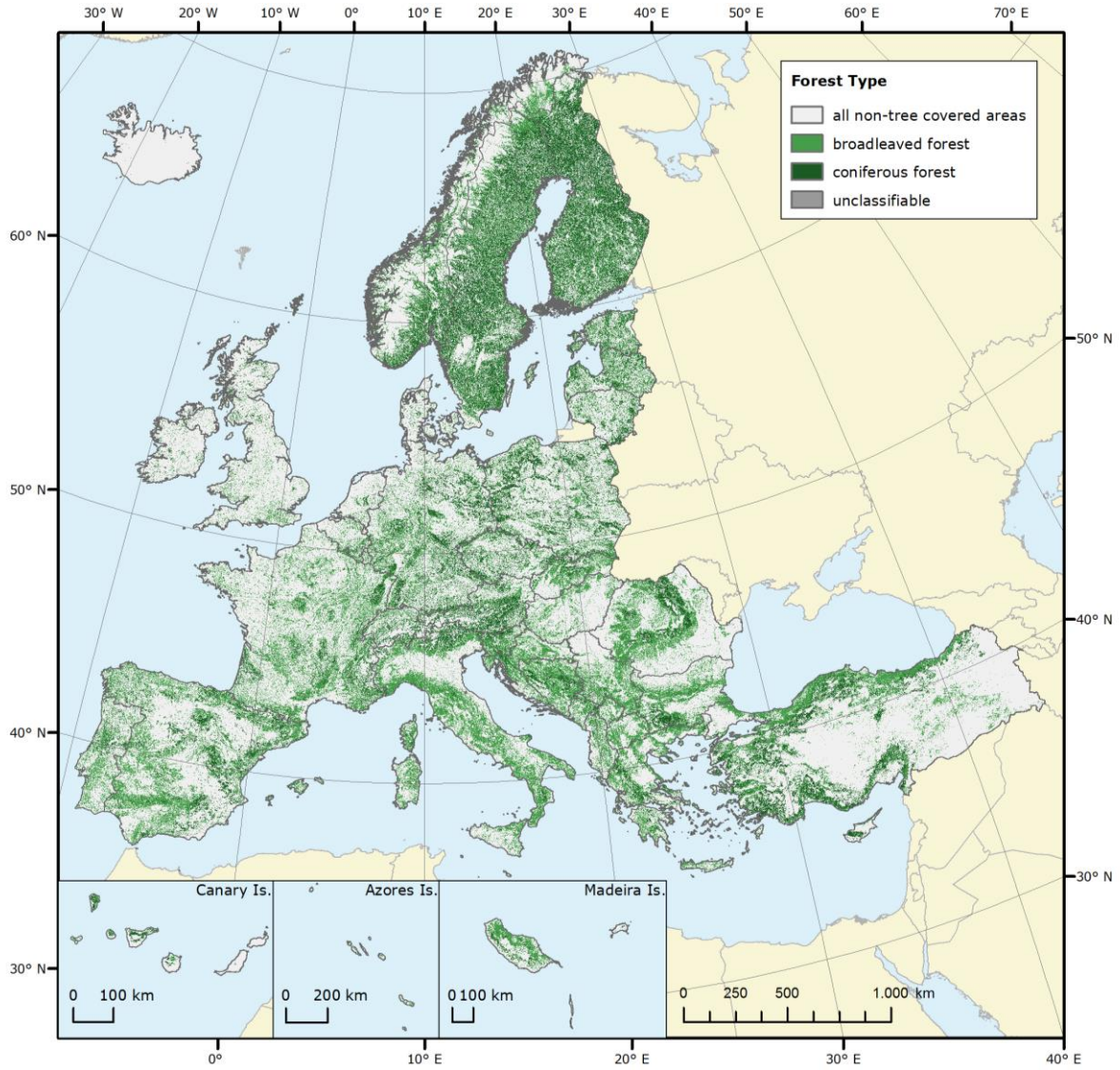

Figure 5: Pan-European illustration of the Forest Type 2015
© EuroGeographics for the administrative boundaries

The 20m Forest Type products are produced applying a minimum „Forest“ definition, largely following the FAO definition, whereas tree cover in traditional agroforestry systems such as Dehesa / Montado is explicitly included for EEA purposes. The product is derived through a spatial intersection of the

two primary status layers Tree Cover Density and Dominant Leaf Type and has the following main specifications:

- 20m spatial resolution
- Tree Cover Density range of ≥10-100%
- Minimum Mapping Unit (MMU; minimum number of pixels to form a patch) of 0.52 ha (equivalent to 13 pixels); applicable both for tree-covered areas and for non-tree-covered areas in a 4-pixel connectivity mode, but not for the distinction of dominant leaf type within the tree-covered area for which no such minimum is set. The potentially available leaf type information for areas below 10% density within non-forest patches smaller the MMU is explicitly kept from the pixel-based DLT product to ensure consistency.
- Minimum Mapping Width (MMW) of 20m

The relevant processing steps to derive the 20m Forest Type product are described in Annex IV.

In order to separate real "forest" areas from non-forest areas (i.e. trees predominantly used for agricultural practices, trees in an urban context), an additional raster product is provided named Forest Additional Support Layer. This 20m layer differentiates between forest areas and non-forest areas using a specific labelling approach and is briefly described below.

The Forest Type product is also available as aggregated version in 100m spatial resolution, fully aligned to the EEA 100m reference grid. Trees predominantly used for agricultural practices and trees in urban context (as presented by the Forest Additional Support Layer) are explicitly excluded in the aggregated version.

This means that the 20m FTY and 100m aggregated FTY product differ in that:

- The 20m FTY product **includes** trees predominantly used for agricultural practices and trees in urban context (as distinguished in the FADSL)
- The 100m FTY product has those areas (trees predominantly used for agricultural practices and trees in urban context), from the FADSL layer **excluded.**

2.3.1 Forest Additional Support Layer (FADSL)

The Forest Additional Support Layer (FADSL) provides information on trees under agricultural or urban use by utilization of CORINE Land Cover (CLC) 2012 information and HRL Imperviousness products 2012/2015. The layer is derived through a spatial intersection of the Forest Type product with additional sources and has the following main specifications:

- 20m spatial resolution
- Tree Cover Density range of ≥ 10-100%
- No Minimum Mapping Unit (MMU); pixel-based
- Minimum Mapping Width (MMW) of 20m
- Providing information on:
  - trees predominantly used for agricultural practices – broadleaved (from CLC)
  - trees in urban context – broadleaved and coniferous (from CLC)
  - trees in urban context – broadleaved and coniferous (from HRL Imperviousness)

A detailed description of the Forest Additional Support Layer is given in Annex V.

2.4 Change Products

The HRL Forest product portfolio includes for the first time dedicated change products. Both change products cover the time period between the 2012 and 2015 reference years and are briefly described in the sections below. Detailed product specifications are provided in Annex II.

2.4.1 Dominant Leaf Type Change (DLTC)

The Dominant Leaf Type Change product is a pixel-based 20m layer covering the time period of 2012 (+/- 1 year) to 2015 (+/- 1 year). It is derived by dedicated GIS operations of the primary status layers Tree Cover Density and Dominant Leaf Type for both time steps. It includes 14 thematic classes, thereof 10 change classes. The layer has a "noise" filter applied to address geometric, radiometric as well as phenological differences between the reference years 2012/2015 using a 30% density threshold and a 1 ha boundary filter. Changes in the tree cover extent and leaf type are indicated, if the difference between TCD 2012 and 2015 products is exceeded by the defined significance threshold of 30%, whilst considering a Minimum Mapping Unit of 1 ha. Due to its complexity and the fundamentally different data baseline of the 2012 and 2015 status layers, this product has actually a more experimental character.

The Dominant Leaf Type Change product has the following main specifications:

- 20m spatial resolution
- Tree Cover Density range of 0-100%
- Tree Cover Density significance difference threshold of 30%
- Boundary filter of 1 ha (25 pixels) to address geometric differences
- Minimum Mapping Unit (MMU) of 1 ha (25 pixels) for change classes

2.4.2 Tree Cover Density Change (TCDC)

The Tree Cover Density Change product is a pixel-based 100m layer based on the aggregated TCD status layers 2012 and 2015. It summarizes the extent and magnitude of tree cover density increases and decreases over time. A filtering approach with a 30% density significance threshold has been applied to differentiate between "noise" and the expected real change between both time steps. Changes in the magnitude of tree cover density will be derived, if the difference between TCD 2012 and 2015 products is exceeded by the defined significance threshold of 30%.

The Tree Cover Density Change product has the following main specifications:

- 100m spatial resolution
- Tree Cover Density range of -30 to -100% and +30 to +100%
- Tree Cover Density significance difference threshold of 30%
- No Minimum Mapping Unit (MMU); pixel-based

3. Data Used for HRL Forest Generation

A variety of high to very high resolution satellite data with multiple spatial resolutions were utilized for the production of the Forest layers. These include primarily multispectral time series of Sentinel-2A from the Copernicus programme and Landsat 8 from the Landsat programme, both resampled to 20m spatial resolution. These sources were complemented by the SPOT-5 and ResourceSat-2 satellite data of the HR_IMAGE_2015 dataset, available in 20m spatial resolution. For the reference sampling of Tree Cover Density values and the creation of an European-wide HRL Forest Reference Database, the VHR_IMAGE_2015 dataset provided by the ESA Data Warehouse (DWH) was of vital importance.

For the correction and re-processing of the historical HRL Forest 2012 products, the pan-European ESA DWH datasets DWH_MG2_CORE_01 (HR_IMAGE_2012) and DWH_MG2b_CORE_03 also referred to as VHR_IMAGE_2012 have been used.

Besides the EO data, a series of available ancillary datasets proved to be suitable to support training sample selection, plausibility checks and final Quality Control (QC) steps. Table 3 provides an overview on the utilized data.

Table 3: List of ancillary datasets used in HRL Forest production

Dataset	Characteristics
VHR_IMAGE_2015	• Resolution: 0.3m to 1.0m • Coverage: EEA-39
VHR_IMAGE_2012	• Resolution: 1.5m to 2.5m • Coverage: EEA-39
National Ortho-Imagery Web Map Services (e.g. Poland)	• Resolution: 0.1m to 0.5m • Coverage: national
HRL Tree Cover Density 2012	• Resolution: 20m • Coverage: EEA-39
HRL Forest Type 2012	• Resolution: 20m • Coverage: EEA-39
HRL Impervious Degree 2012 & 2015	• Resolution: 20m • Coverage: EEA-39
HRL Water & Wetness 2012 & 2015	• Resolution: 20m • Coverage: EEA-39
HRL Grassland 2012 & 2015	• Resolution: 20m • Coverage: EEA-39
JRC Forest Type Map 2006	• Resolution: 25m • Coverage: EU-27 plus various cooperating countries
Global Forest Change 2000–2014 (Hansen et al. 2013)	• Resolution: 30m • Coverage: global
CORINE Land Cover 2012 v18.5.1	• Thematic Land Cover data • Minimum Mapping Unit: 25 ha • Coverage: EEA-39
National thematic Land Cover maps (e.g. Sweden)	• Thematic Land Cover map • Minimum Mapping Unit: ≥1ha • Coverage: national
EuroBoundaryMap v11	• Scale: 1:100,000 • Coverage: Europe

4. File Naming Convention

The proposed file naming convention will be applied both to raster and vector products for all High Resolution Layer products. All letters except the THEME descriptor are in small (not capital) letters, and no points (“.”) and/or minus (“-“) within file names. The file naming is based on the following descriptors:

THEME YEAR RESOLUTION EXTENT EPSG VERSION

THEME:

- 3 letter abbreviation for main products (green)
- 4 letter abbreviation for change products (blue)
- 5 letter abbreviation for additional and expert products (orange)

REFERENCE YEAR

- 2012 and 2015 in four digits
- Change products in four digits (e.g. 0609)

RESOLUTION

- Four-digit (020m and 100m)

EXTENT

- 2-digit country code for country deliveries in national projection
- “eu” for all deliveries in European Projection (partial and full lot mosaics)

EPSG

- 5-digit EPSG code (geodetic parameter dataset code by the European Petroleum Survey Group), see http://www.epsg-registry.org/
- e.g. “03035” for the European LAEA projection

VERSION

- 4-digit qualifier of the version number, starting with “V1_1” for a first full final version, and allowing to capture re-processing/calculation of small changes as (“V1_2”, “V1_3” etc.). In case of major changes a second version should be used (“V2_1”)

Table 4: File naming descriptors for HRL products

Descriptor	To be written as	Meaning	Comments
THEME	TCD	Tree Cover Density	Three letter abbreviation for main products
	DLT	Dominant Leaf Type	
	FTY	Forest Type	
	FADSL	Forest Additional Support Layer	
	DLTC	Dominant Leaf Type Change	
	TCDC	Tree Cover Density Change	
	TCDRP	Tree Cover Density Reference Product (Vector data)	Reference product: Vector product with selected 100mx100m cells with density information
	TCDRG	Tree Cover Density Reference Grid	Reference product: Tree cover point grid
	NDVI	Biophysical variables delivery	Scene-based results
	NDWI		
REFERENCE YEAR	2012	Reference year 2012 (+/- 1 year)	
	2015	Reference year 2015 (+/- 1 year)	
	1215	Change 2012-2015	
RESOLUTION	020m	20m spatial (pixel) resolution	
	100m	100m spatial (pixel) resolution	
EXTENT	al	Albania	2-letter abbreviation for the country (in national projections), and “eu” for deliveries in European projection
	at	Austria	
	ba	Bosnia and Herzegovina	
	be	Belgium	
	bg	Bulgaria	
	ch	Switzerland	
	cy	Cyprus	
	cz	Czech Republic	
	de	Germany	
	dk	Denmark	
	ee	Estonia	
	es	Spain (including Andorra)	
	eu	Europe (full lot mosaic)	
	fi	Finland	
	fr	France	
	gb	United Kingdom	
	gf	French Guiana	
	gp	Guadeloupe	
	gr	Greece	

Descriptor	To be written as	Meaning	Comments
	hr	Croatia	
	hu	Hungary	
	ie	Ireland	
	im	Isle of Man	
	is	Iceland	
	it	Italy	
	li	Liechtenstein	
	lt	Lithuania	
	lu	Luxembourg	
	lv	Latvia	
	me	Montenegro	
	mk	Macedonia, FYR of	
	mq	Martinique	
	mt	Malta	
	ni	Northern Ireland	
	nl	Netherlands	
	no	Norway	
	pl	Poland	
	pt	Portugal	
	re	Réunion	
	ro	Romania	
	rs	Serbia	
	se	Sweden	
	si	Slovenia	
	sk	Slovakia	
	tr	Turkey	
	xk	Kosovo	
	yt	Mayotte	
EPSG	e.g. 03035	ETRS89 LAEA (European Projection)	5-digit EPSG code (geodetic parameter dataset code by the European Petroleum Survey Group)
VERSION	V1_1	First full final version	4-digit qualifier of the version number, starting with “V1_1” for a first full final version, and allowing to capture re-processing/calculation of small changes as (“V1_2”, “V1_3” etc.). In case of major changes a second version should be introduced (“V2_1”).
	V1_2	Re-delivery of first full final version with small changes	
	V2_1	Second full final version	
	etc.	etc.	

Examples and meaning of full product names for final products:

DLT_2015_020m_eu_03035_V1_1.tif

Dominant Leaf Type, 2015 reference year, 20m spatial resolution, pan-european product in European projection (EPSG: 3035), first final version (fully accepted).

DLT_2015_020m_eu_03035_V1_2.tif

Dominant Leaf Type, 2015 reference year, 20m spatial resolution, pan-european product in European projection (EPSG: 3035), first final version (fully accepted), second delivery after small changes.

DLT_2015_020m_fr_02154_V1_1.tif

Dominant Leaf Type, 2015 reference year, 20m spatial resolution, France mainland, national projection (EPSG: 2154), first final version (fully accepted).

5. INSPIRE Metadata and Mapping Tables

Metadata are provided together with the products as INSPIRE-compliant XML files according to the EEA Metadata Standard for Geographic Information (EEA-MSGI). EEA-MSGI has been developed by EEA to meet needs and demands for inter-operability of metadata. EEA's standard for metadata is a profile of the ISO 19115 standard for geographic metadata and contains more elements than the minimum required to comply the INSPIRE metadata regulation. Detailed conceptual specifications on EEA-MSGI and other relevant information on metadata can be found online at http://www.eionet.europa.eu/gis.

INSPIRE mapping tables show the evidence that the products delivered are compatible with the INSPIRE Data Specification on Land Cover. This evidence is provided as table document showing the associations between the source (product/deliverable) and the target data model (INSPIRE Data Specification on Land Cover). Mapping tables are provided together with the final products.

6. Thematic Accuracy

The general accuracy level of the primary 20m status layers Dominant Leaf Type and Tree Cover Density of the HRL Forest is aimed to be in the order of 90 % (both, Producers and User's Accuracy). This accuracy should be reached for the pan-European mosaic. There will be two levels of accuracy assessment:

a) internal assessment performed by the service providers and reported in the delivery report,

b) full independent validation of the full European mosaics to be performed after production.

Annex I: File Format and Delivery Details Specification

Raster products are delivered as GeoTIFF (*.tif) with world file (*.tfw), pyramids (*.ovr), attribute table (*.dbf) and statistics (*.aux.xml). Each product is accompanied with product-specific color tables (*.clr & *.txt) and INSPIRE-compliant metadata in XML format and an INSPIRE Mapping Table.

In addition, a PDF providing Coordinate Reference System (CRS) information, including details of parameters used to transform to ETRS89 LAEA projection as in the following example from Hungary will be delivered. CRS information sheets will be static and named as follows:

CRS_Information_Sheet_<country 2-letter ISO code>, e.g. CRS_Information_Sheet_BG.pdf.

Table 5: Example of a Coordinate Reference System Sheet

National		
Datum		HD72 (EOV - Egységes Országos Vetületi rendszer)
	type	geodetic
	valid area	Hungary
Prime meridian		Greenwich
	longitude	0°
Ellipsoid		IUGG GRS 1967 (International 1967)
	semi major axis	6 378 160.0 m
	inverse flattening	298.2471674
Projection		Hotine Oblique Mercator (EOV proxy)
	latitude of projection center	47°08'39.817392"
	longitude of projection center	19°02'54.858408"
	azimuth of initial line	90°00'00"
	scale factor on initial line	0.99993
	false easting	650 000 m
	false northing	200 000 m
European		
Datum		ETRS89 (European Terrestrial Reference System 1989)
	type	geodetic
	valid area	Europe / EUREF
Prime meridian		Greenwich
	longitude	0°
Ellipsoid		GRS 80 (New International)
	semi major axis	6 378 137 m
	inverse flattening	298.257222101
Projection		Geographic (Ellipsoidal Coordinate System)
Datum shift parameters used		
Operation method		Bursa-Wolf (PositionVector)
	geocentric X translation	+52.684 m
	geocentric Y translation	-71.194 m
	geocentric Z translation	-13.975 m
	rotation X-axis -	0.312"
	rotation Y-axis -	0.1063"
	rotation Z-axis -	0.3729"
	correction of scale -	1.0191 ppm

Annex II: Detailed Product Specifications

Tree Cover Density 20m	**Acronym** TCD	**Product category** Primary status layer
Reference year 2012 (+/- 1 year) / 2015 (+/- 1 year)		
Geometric resolution Pixel resolution 20m x 20m, fully conform with the EEA reference grid		
Coordinate Reference System European ETRS89 LAEA projection / national projections		
Geometric accuracy (positioning scale) Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA.		
Thematic accuracy Minimum 90% user's / producer's accuracy		
Data type 8bit unsigned raster with LZW compression		
Minimum Mapping Unit (MMU) Pixel-based (no MMU)		
Tree cover density threshold N/A		
Necessary attributes Raster value, count, class name, area (in km2), percentage (taking outside area not into account)		
Raster coding (thematic pixel values) 0: all non-tree covered areas 1-100: tree cover density values 254: unclassifiable (no satellite image available, or clouds, shadows, or snow) 255: outside area		
Metadata XML metadata files according to INSPIRE metadata standards		
Delivery format GeoTIFF		

Dominant Leaf Type 20m	Acronym DLT	Product category Primary status layer
Reference year 2012 (+/- 1 year) / 2015 (+/- 1 year)		
Geometric resolution Pixel resolution 20m x 20m, fully conform with the EEA reference grid		
Coordinate Reference System European ETRS89 LAEA projection / national projections		
Geometric accuracy (positioning scale) Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA.		
Thematic accuracy Minimum 90% user's / producer's accuracy for both, broadleaved and coniferous class		
Data type 8bit unsigned raster with LZW compression		
Minimum Mapping Unit (MMU) Pixel-based (no MMU)		
Tree cover density threshold N/A		
Necessary attributes Raster value, count, class name, area (in km2), percentage (taking outside area not into account)		
Raster coding (thematic pixel values) 0: all non-tree covered areas 1: broadleaved trees 2: coniferous trees 254: unclassifiable (no satellite image available, or clouds, shadows, or snow) 255: outside area		
Metadata XML metadata files according to INSPIRE metadata standards		
Delivery format GeoTIFF		

Forest Type 20m	Acronym	Product category
	FTY	Secondary status layer

Reference year

2012 (+/- 1 year) / 2015 (+/- 1 year)

Geometric resolution

Pixel resolution 20m x 20m, fully conform with the EEA reference grid

Coordinate Reference System

European ETRS89 LAEA projection

Geometric accuracy (positioning scale)

Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA.

Thematic accuracy

Determined by the accuracy of the source Tree Cover Density and Dominant Leaf Type in 20m spatial resolution.

Data type

8bit unsigned raster with LZW compression

Minimum Mapping Unit (MMU)

0.52 ha (13 pixels)

Tree cover density threshold

10%

Necessary attributes

Raster value, count, class name, area (in km2), percentage (taking outside area not into account)

Raster coding (thematic pixel values)

0: all non-forest areas

1: broadleaved forest

2: coniferous forest

254: unclassifiable (no satellite image available, or clouds, shadows, or snow)

255: outside area

Metadata

XML metadata files according to INSPIRE metadata standards

Delivery format

GeoTIFF

Forest Type Additional Support Layer 20m	Acronym	Product category
	FADSL	Derived layer

Reference year

2012 (+/- 1 year) / 2015 (+/- 1 year)

Geometric resolution

Pixel resolution 20m x 20m, fully conform with the EEA reference grid

Coordinate Reference System

European ETRS89 LAEA projection

Geometric accuracy (positioning scale)

Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA.

Thematic accuracy

Determined by the accuracy of the source Forest Type, Imperviousness Degree and CLC in 20m spatial resolution.

Data type

8bit unsigned raster with LZW compression

Minimum Mapping Unit (MMU)

Pixel-based (no MMU)

Tree cover density threshold

10%

Necessary attributes

Raster value, count, class name, area (in km2), percentage (taking outside area not into account)

Raster coding (thematic pixel values)

0: all non-tree areas, and tree cover without urban context or agricultural use

3: trees predominantly used for agricultural practices – broadleaved (from CLC2012)

4: trees in urban context – broadleaved and coniferous (from IMD2012 / IMD2015)

5: trees in urban context – broadleaved and coniferous (from CLC2012)

254: unclassifiable (no satellite image available, or clouds, shadows, or snow)

255: outside area

Metadata

XML metadata files according to INSPIRE metadata standards

Delivery format

GeoTIFF

Tree Cover Density 100m	Acronym TCD	Product category Aggregated status layer
Reference year 2012 (+/- 1 year) / 2015 (+/- 1 year)		
Geometric resolution Pixel resolution 100m x 100m, fully conform with the EEA reference grid		
Coordinate Reference System European ETRS89 LAEA projection		
Geometric accuracy (positioning scale) Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA.		
Thematic accuracy Determined by the accuracy of the source Tree Cover Density in 20m spatial resolution.		
Data type 8bit unsigned raster with LZW compression		
Minimum Mapping Unit (MMU) Pixel-based (no MMU)		
Tree cover density threshold N/A		
Necessary attributes Raster value, count, class name, area (in km2), percentage (taking outside area not into account)		
Raster coding (thematic pixel values) 0: all non-tree covered areas 1-100: tree cover density values 254: unclassifiable (no satellite image available, or clouds, shadows, or snow) 255: outside area		
Metadata XML metadata files according to INSPIRE metadata standards		
Delivery format GeoTIFF		

Forest Type 100m	Acronym	Product category
	FTY	Aggregated status layer

Reference year

2012 (+/- 1 year) / 2015 (+/- 1 year)

Geometric resolution

Pixel resolution 100m x 100m, fully conform with the EEA reference grid

Coordinate Reference System

European ETRS89 LAEA projection

Geometric accuracy (positioning scale)

Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA.

Thematic accuracy

Determined by the accuracy of the source Forest Type and Forest Additional Support Layer in 20m spatial resolution.

Data type

8bit unsigned raster with LZW compression

Minimum Mapping Unit (MMU)

Pixel-based (no MMU)

Tree cover density threshold

10%

Necessary attributes

Raster value, count, class name, area (in km2), percentage (taking outside area not into account)

Raster coding (thematic pixel values)

0: all non-forest areas

1: broadleaved forest

2: coniferous forest

3: mixed forest

254: unclassifiable (no satellite image available, or clouds, shadows, or snow)

255: outside area

Metadata

XML metadata files according to INSPIRE metadata standards

Delivery format

GeoTIFF

Dominant Leaf Type Change 20m	Acronym DLTC	Product category Change layer

Reference year

2012 (+/- 1 year) to 2015 (+/- 1 year)

Geometric resolution

Pixel resolution 20m x 20m, fully conform with the EEA reference grid

Coordinate Reference System

European ETRS89 LAEA projection

Geometric accuracy (positioning scale)

Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA.

Thematic accuracy

Determined by the accuracy of the source Tree Cover Density and Dominant Leaf Type 2012/2015 in 20m spatial resolution.

Data type

8bit unsigned raster with LZW compression

Minimum Mapping Unit (MMU)

1 ha (25 pixels) for detected changes; plus additional 1 ha (25 pixels) boundary filter

Tree cover density threshold

30%

Necessary attributes

Raster value, count, class name, area (in km2), percentage (taking outside area not into account)

Raster coding (thematic pixel values)

0: unchanged areas with no tree cover

1: new broadleaved cover - increased tree cover density

2: new coniferous cover - increased tree cover density

3: loss of broadleaved cover - decreased tree cover density

4: loss of coniferous cover - decreased tree cover density

10: unchanged areas with tree cover

11: increased broadleaved cover density

22: increased coniferous cover density

33: decreased broadleaved cover density

44: decreased coniferous cover density

120: broadleaved changed to coniferous

210: coniferous changed to broadleaved

254: unclassifiable in any of parent status layers

255: outside area

Metadata

XML metadata files according to INSPIRE metadata standards

Delivery format

GeoTIFF

Tree Cover Density Change 100m	Acronym TCDC	Product category Change layer
Reference year 2012 (+/- 1 year) to 2015 (+/- 1 year)		
Geometric resolution Pixel resolution 100m x 100m, fully conform with the EEA reference grid		
Coordinate Reference System European ETRS89 LAEA projection		
Geometric accuracy (positioning scale) Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA.		
Thematic accuracy Determined by the accuracy of the source Tree Cover Density 2012/2015 in 20m spatial resolution.		
Data type 16bit signed raster with LZW compression		
Minimum Mapping Unit (MMU) Pixel-based (no MMU)		
Tree cover density threshold 30%		
Necessary attributes Raster value, count, class name, area (in km2), percentage (taking outside area not into account)		
Raster coding (thematic pixel values) -100 to -30[1]: decreased tree cover density 0: unchanged areas 30-100: increased tree cover density 254: unclassifiable in any of parent status layers 255: outside area		
Metadata XML metadata files according to INSPIRE metadata standards		
Delivery format GeoTIFF		

[1] A filtering approach with a 30% density significance threshold has been applied to differentiate between "noise" and the expected real change between both time steps. Changes in the magnitude of tree cover density will be derived, if the difference between TCD 2012 and 2015 products is exceeded by the defined significance threshold of 30%. This is why only positive or negative changes >30% are represented in the raster coding.

Annex III: Colour Palettes

For each product both, the GIS file [*.clr) specifying the colour palette and a text file (*.txt) listing the RGB values for possible non-GIS products and material will be provided.

Tree Cover Density

Class Code	Class Name	Red	Green	Blue	
0	all non-tree and non-forest areas	240	240	240	
1	1% tree cover density	186	255	172	
50	50% tree cover density	85	160	89	
100	100% tree cover density	28	92	36	
254	unclassifiable (no satellite image available, or clouds, shadows, or snow)	153	153	153	
255	outside area	0	0	0	

Dominant Leaf Type

Class Code	Class Name	Red	Green	Blue	
0	all non-tree covered areas	240	240	240	
1	broadleaved trees	70	158	74	
2	coniferous trees	28	92	36	
254	unclassifiable (no satellite image available, or clouds, shadows, or snow)	153	153	153	
255	outside area	0	0	0	

Forest Type

Class Code	Class Name	Red	Green	Blue	
0	all non-tree and non-forest areas	240	240	240	
1	broadleaved forest	70	158	74	
2	coniferous forest	28	92	36	
3	mixed forest (only for aggregated 100m layer)	76	133	67	
254	unclassifiable (no satellite image available, or clouds, shadows, or snow)	153	153	153	
255	outside area	0	0	0	

Forest Additional Support Layer

Class Code	Class Name	Red	Green	Blue	
0	all non-tree and non-forest areas	240	240	240	
3	trees predominantly used for agricultural practices – broadleaved (from CLC2012)	204	173	71	
4	trees in urban context – broadleaved and coniferous (from IMD 2012 / IMD 2015)	255	85	0	
5	trees in urban context – broadleaved and coniferous (from CLC2012)	168	56	0	
254	unclassifiable (no satellite image available, or clouds, shadows, or snow)	153	153	153	
255	outside area	0	0	0	

Dominant Leaf Type Change

Class Code	Class Name	Red	Green	Blue	
0	unchanged areas with no tree cover	255	255	255	
1	new broadleaved cover - increased tree cover density	20	255	20	
2	new coniferous cover - increased tree cover density	0	150	0	
3	loss of broadleaved cover - decreased tree cover density	255	0	0	
4	loss of coniferous cover - decreased tree cover density	255	128	0	
10	unchanged areas with tree cover	191	191	191	
11	increased broadleaved cover density	191	255	191	
22	increased coniferous cover density	80	150	80	
33	decreased broadleaved cover density	255	128	128	
44	decreased coniferous cover density	255	191	128	
120	broadleaved changed to coniferous	28	72	201	
210	coniferous changed to broadleaved	70	163	235	
254	unclassifiable in any of parent status layers	153	153	153	
255	outside area	0	0	0	

Tree Cover Density Change

Class Code	Class Name	Red	Green	Blue	
-100	decreased tree cover density	240	118	5	
-50	decreased tree cover density	255	200	145	
-30	decreased tree cover density	255	237	207	
0	unchanged areas	240	240	240	
30	increased tree cover density	206	255	207	
50	increased tree cover density	158	242	150	
100	increased tree cover density	14	204	14	
254	unclassifiable in any of parent status layers	153	153	153	
255	outside area	0	0	0	

Annex IV: Derivation of the 20m Forest Type Layer

The following workflow is applied to derive the 20m Forest Type product from the two 20m primary status layers Dominant Leaf Type and Tree Cover Density:

1) All pixel values ≥ 10% and ≤ 100% TCD from the Tree Cover Density product are initially considered for the Forest Type product and are used to extract the associated leaf type information (broadleaved or coniferous) from the 20m Dominant Leaf Type product.
2) Application of a 4-pixel-connectivity MMU filter to all extracted “tree covered” areas < 0.52 ha (13 pixels). All “tree cover” patches < 0.52 ha are reclassified to “all non-tree areas”. “Forest/tree cover” patches < 0.52 ha adjacent to (buffered) country borders can remain as they are.
3) Application of a 4-pixel-connectivity MMU filter to “all non-tree areas” < 0.52 ha (13 pixels) within forest stands. All “non-tree area” patches < 0.52 ha are reclassified to “forest (broadleaved or coniferous)”. “All non-tree area” patches < 0.52 ha adjacent to (buffered) country borders can remain as they are.
4) To keep consistency with the 20m Dominant Leaf Type product, the leaf type information of existent pixels within filtered “all non-tree area” patches will be explicitly kept, if available.

Annex V: FADSL Products 2012/2015

The Forest Additional Support Layer (FADSL) provides information on trees under agricultural or urban use by utilization of CORINE Land Cover (CLC) 2012 information and HRL Imperviousness products 2012/2015. The layer has the following main specifications:

- 20m spatial resolution
- Tree Cover Density range of ≥ 10-100%
- No Minimum Mapping Unit (MMU); pixel-based
- Minimum Mapping Width (MMW) of 20m
- Providing information:
  - trees predominantly used for agricultural practices – broadleaved (from CLC)
  - trees in urban context – broadleaved and coniferous (from CLC)
  - trees in urban context – broadleaved and coniferous (from HRL Imperviousness)

Considering different options for separating real “forest” areas as far as possible compliant with the FAO definition from non-forest tree-covered areas (i.e. trees predominantly used for agricultural practices, trees in an urban context) for the 20m Forest Type product, the following procedure is applied:

In order to avoid misinterpretation of the 20m Forest Type product by potential users, specifically with respect to the contents / accuracies / information origins of the additional information on "trees predominantly used for agricultural practices - broadleaved" (as derived from CLC classes 2.2.2 and 2.2.3) and "trees in urban context – broadleaved and coniferous" (as derived from a filtering approach applied to HRL Imperviousness and from CLC class 1.4.1 Green Urban Areas), this additional information is made available through a labelling approach. In technical terms, this requires that in addition to the 20m Forest Type product’s basic raster data set with the nomenclature of [0: all non-forest areas, 1: broadleaved forest, 2: coniferous forest] an additional support raster data set is provided with information on the occurrence of "trees predominantly used for agricultural practices - broadleaved" and "trees in urban context – broadleaved and coniferous" – both only within the confines of broadleaved and coniferous tree areas of the basic product (not beyond!) – in the sense of additional, and not contradicting/conflicting information (as would be the case e.g. if CLC orchards would be identified in non-forest areas).

Such approach will allow providing to users the required real “forest” information, which will then actually be contained in the combination of the 2 raster data sets described above. This will allow:

i. to have a clear, traceable and explainable separation of the different sources of information, i.e. the 20m highly-accurate Forest Type classification vs. the 25 / 5 ha CLC-based overlay information, without already giving to users a “hard” intersection (with all associated problems of misinterpretation);
ii. users nevertheless to simply derive the real "Forest" areas (close to the FAO definition) by simple GIS (Geographic Information System) operations between these 2 raster data sets, i.e. by doing an intersection;

iii. to preserve the mapped dominant leaf type information on pixel-level for various later applications, also e.g. in the climate change domain– without irreversibly casting away all non-Forest tree-based information.

In practical terms, the FADSL can be derived by GIS operations using the HRL Imperviousness Degree (IMD), CLC 2012 data and FTY products respectively, considering the following processing steps:

1) Reclassification of the Imperviousness Degree layer (pixel range 0-100%) in 20m spatial resolution to a binary mask of impervious with *0 = all non-impervious areas* and *1 = all impervious areas*. Clouds are explicitly not considered

2) Filtering of all contiguous *all non-impervious* patches < 25 ha which are fully surrounded by *impervious areas* in a 4-pixel connectivity mode and subsequently reclassification to *1 = all impervious areas*;

3) Hierarchical intersection of HRL Forest Type, CLC (full vector resolution) and the gap-filled Imperviousness dataset and subsequent reclassification according to the product specifications, resulting in the following thematic classes:

Table 6: FADSL: Hierarchical intersection of input layers and resulting thematic classes

Order	FTY Class	CLC Class	IMD Class	FADSL Class	Class Description
1.)	1 or 2	any	1	4	trees in urban context – broadleaved and coniferous (from HRL Imperviousness context)
2.)	1 or 2	141	0	5	trees in urban context – broadleaved and coniferous (from CLC class 1.4.1)
3.)	1	222 or 223	any	3	trees predominantly used for agricultural practices – broadleaved (from CLC classes 2.2.2 and 2.2.3)
	254	any	any	254	unclassifiable (no satellite image available, or clouds, shadows, or snow)
	255	any	any	255	outside area
	any other remaining combination			0	all non-tree areas, and tree cover without urban context or agricultural use

Annex VI: Aggregation Rules to 100m Products

In the following, the aggregation rules to derive the aggregated status layers Tree Cover Density and Forest Type in 100m spatial resolution and European projection will be described. This supports users in the understanding of the products.

Tree Cover Density (100m, European Projection)

1) The spatially consistent EEA 100m grid is overlaid to the 20m Tree Cover Density product in European projection.
2) If the number of valid pixels (i.e. without "outside area" and "unclassifiable" values) is <50% (i.e. <13 pixels), the 100m grid cell is assigned "outside area" (255) or "unclassifiable"(254) depending on the relative majority of 255 or 254 underlying 20m pixels, or "unclassifiable" (254) in case of equal number of such 254 and 255 pixels.
3) Within those 100m grid cells with a number of valid pixels (all pixels with TCD value of 0-100) >50% (i.e. ≥ 13 pixels), the arithmetic mean density of all valid underlying 20m pixels (with density values from 0-100) is calculated (excluding "outside area" and "unclassifiable"). The thereof resulting mean values from the aggregation (floating point data type) are rounded and finally converted to integer values (e.g. raw values in the range from 33.5 to 34.4 are converted to a density value of 34).

Forest Type (100m, European Projection)

1) The spatially consistent EEA 100m grid is overlaid to the 20m Forest Type product and the associated Forest Additional Support Layer with information on trees in agricultural use and urban context.
2) If the number of valid pixels (i.e. without "outside area" and "unclassifiable" values) is <50% (i.e. <13 pixels), the 100m grid cell is assigned "outside area" (255) or "unclassifiable"(254) depending on the relative majority of 255 or 254 underlying 20m pixels, or "unclassifiable" (254) in case of equal number of such 254 and 255 pixels.
3) Within those 100m grid cells with a number of valid pixels >50% (i.e. ≥ 13 pixels), the numbers of underlying 20m coniferous forest pixels and broadleaved forest pixels, as well as broadleaf agriculture pixels (from FADSL), and broadleaf/coniferous urban pixels (from FADSL) are separately counted [resulting in frequency values for these classes between 0 and 25]. Pixels coded as "outside area" and "unclassifiable" are not counted.
4) The 100m grid cell is classified according to the majority rule first. That means that a 100m grid cell is assigned "forest", if a majority (>50%) of valid pixels (as defined in step 2) in the grid cell which do not in parallel have FADSL code 3, 4 or 5 belongs to broadleaf and/or coniferous (in this case continue with step 5). It is assigned "all non-forest areas", if a majority (>50%) of valid pixels in the grid cell belongs to non-tree area and/or broadleaf agriculture

trees and/or broadleaf/coniferous urban trees (in this case, processing is finished). If all the counts (from step 3) are 0 (but the number of valid pixels is >0), the 100m grid cell is also assigned “all non-forest areas” (in this case, processing is finished). If the number of valid pixels is >0, some counts (from step 3) are >0, but no majority of valid pixels exists for either “forest” or “all non-forest areas” in the grid cell (i.e. both have the same number of valid pixels), the 100m grid cell is considered “unclassifiable” (254) (in this case, processing is finished).

5) In this step, the CORINE Land Cover definition for coniferous, broadleaved and mixed forest is applied for grid cells having a “forest” majority: 100m grid cells with “coniferous” constituents with ≥75% of the forest pixels are assigned the thematic class “coniferous forest”, 100m grid cells with “broadleaved” constituents with ≥75% of the forest pixels are assigned the thematic class “broadleaved forest”, and 100m grid cells in which neither “coniferous” nor “broadleaved” constituents account for ≥75% of the forest pixels are devised as the thematic class “mixed forest”.

6) The resulting thematic classes of the 100m x 100m product are coded with the following values:
    - all non-forest areas = 0
    - broadleaved forest = 1
    - coniferous forest = 2
    - mixed forest = 3

As a consequence of this aggregation, small patches in the 100m x 100m grid will be generalised (i.e. exaggerated or deleted) according to the above aggregation rules.

Annex VII: Derivation of Change Products

This annex describes the processing steps to derive the newly introduced change layers Dominant Leaf Type Change and the Tree Cover Density Change.

Tree Cover Density Change (100m, European Projection)

The generation of the Tree Cover Density Change product requires the aggregated 100m status layers TCD 2012 and TCD 2015 and is calculated in two steps:

1) The pixels of the aggregated 100m status layer TCD 2012 are subtracted from the aggregated status layer TCD 2015. The resulting raster provides information on the difference between both time steps ranging from -100% to +100% at a 100m pixel level.
2) Application of the 30% significance difference threshold. All pixel in the range of -29% to -1% and +1% to +29% are recoded to *0 = unchanged areas*.

Dominant Leaf Type Change (20m, European Projection)

A more complex workflow has been designed for derivation of the 20m Dominant Leaf Type Change product, which relies on the primary status layers DLT and TCD of each time step. The complexity of the change product calculation requires the arrangement in working units. For this purpose, the EEA 100km reference grid with a 500m buffer applied has been chosen.

Calculation of the Dominant Leaf Type Change is then based on a combination of DLT and TCD layers:

1) Calculation of the difference between the TCD status layers of the 2012 and 2015 reference year (*ΔTCD = TCD_2015 – TCD_2012*). Subsequently, the DLT difference is calculated for both reference years (*ΔDLT = DLT_2015 – DLT_2012*).
2) Application of the 30% significance difference threshold. The DLTC is then derived based on the following conditions using a python script:

Combined TCD – DLT	DLTC Code*	Class Description
(TCD_2012==0)&(TCD_2015==0)	0	unchanged areas with no tree cover
(TCD_2012==0)&(DLT_2015==1)	1	new broadleaved cover
(TCD_2012==0)&(DLT_2015==2)	2	new coniferous cover
(DLT_2012==1)&(DLT_2015==0)	3	loss of broadleaved cover
(DLT_2012==2)&(DLT_2015==0)	4	loss of coniferous cover
(ΔDLT==0)&(TCD_2015>0)&(abs(ΔTCD) <= TCD_30%)	10	unchanged areas with tree cover
(ΔDLT==0)&(DLT_2012==1)&(ΔTCD > TCD_30%)	11	increased broadleaf density
(ΔDLT==0)&(DLT_2012==2)&(ΔTCD > TCD_30%)	22	increased coniferous density
(ΔDLT==0)&(DLT_2012==1)&(ΔTCD < -TCD_30%)	33	decreased broadleaved density
(ΔDLT==0)&(DLT_2012==2)&(ΔTCD < -TCD_30%)	44	decreased coniferous density
(DLT_2012==1)&(DLT_2015==2)&(TCD_2015>0)&(TCD_2012>0)	120	broadleaved changed to coniferous
(DLT_2012==2)&(DLT_2015==1)&(TCD_2015>0)&(TCD_2012>0)	210	coniferous changed to broadleaved

(TCD_2012==254)|(TCD_2015==254)	254	unclassifiable
(TCD_2012==255)|(TCD_2015==255)	255	outside area

* Class codes 1 to 4 and 11 to 210 represent change classes.

3) Application of a 1 ha boundary filter to the unfiltered (raw) DLTC product in order to address geometric differences between the products 2012/2015, inherited by the initially different EO data basis of 2012 and 2015. If certain conditions are met, the filtering is applied to the change classes 1 to 4 (change of tree cover extent) in a multi-stage approach:
    a. Calculation of the area size by performing a region group in a 4-pixel-connectivity mode for all pixels different than *0 = unchanged areas with no tree cover* and without class distinction.
    b. Identification of border pixels within region groups (as derived in step a.) > 1 ha MMU using a 2-pixel erosion filter (40m).
    c. Calculation of the area size for all change objects in the identified borders by performing a region group in a 4-pixel-connectivity mode.
    d. Recoding of change objects < 1 ha MMU according to the following rules: change objects with the original pixel code 1 or 2 will be recoded to *10 = unchanged areas with tree cover*; pixel codes with class codes 3 or 4 will be recoded to *0 = unchanged areas with no tree cover.*
4) Application of a 4-pixel-connectivity MMU filter to the full-extent raster:
    a. Calculation of the area size for all change objects by performing a region group in a 4-pixel-connectivity mode.
    b. Recoding of change objects < 1 ha MMU (25 pixels) and with class codes 3 or 4 to *0 = unchanged areas with no tree cover.*
    c. Recoding of all remaining change objects < 1 ha MMU (25 pixels) to *10 = unchanged areas with tree cover.*
5) Mosaicking of the filtered results without a 500m buffer applied to a European-wide mosaic.