

# Copernicus Land Monitoring Service

High Resolution land cover characteristics

Small Woody Features 2018 and Small Woody Features Changes 2015-2018



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Consortium Composition of the Copernicus HRL Lot 5 2018			
No.	Organisation name	Organisation short name	Country
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Document version 1.2

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## ACRONYMS AND ABBREVIATIONS

AA	Agricultural Area
AD	Applicable Document
AP	Attribute Profiles
AWF	Additional Woody Features
CAP	Common Agricultural Policy
CCMs	Copernicus Contributing Missions
CIR	Coloured Infra-Red
CL	Confidence Layer
CLC	CORINE Land Cover
CLMS	Copernicus Land Monitoring Service
CLS	Collecte Localisation Satellites
CPU	Central Processing Unit
CRS	Coordinate Reference System
CSCDA	Copernicus Space Component Data Access
DAP	Differentiated Attribute Profiles
DG AGRI	Directorate-General for Agriculture and Rural Development
DG	Directorate-General
DOMs	French Overseas Departments
DWH	Data Warehouse
ECoLaSS	Evolution of Copernicus Land Service based on Sentinel data
EEA	European Environment Agency
EO	Earth Observation
EPSG	European Petroleum Survey Group
ESA	European Space Agency
ETRS	European Terrestrial Reference System
ETRS89	European Terrestrial Reference System 1989
FAO	Food and Agriculture Organisation
GEOBIA	Geographic Object-Based Image Analysis
GIS	Geographic Information System
GLE	Green Linear Element
GRA	Grassland
H2020	Horizon 2020 European Program
HR	High Resolution
HRL	High Resolution Layer
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standard Organisation
ITT	Invitation to Tender
JRC	Joint Research Centre
LAEA	Lambert Azimuthal Equal Area
LC	Land Cover
LF	Landscape Feature

LUCAS	Land Use/Cover Area frame Statistical survey
LULUCF	Land Use, Land Use Change and Forestry
MML	Minimum Mapping Length
MMU	Minimum Mapping Unit
MMW	Minimum Mapping Width
MSGI	Metadata Standard for Geographic Information
NDVI	Normalised Difference Vegetation Index
NGOs	Non-Governmental Organisations
NIR	Near Infra-Red
NUTS	Nomenclature of territorial units for statistics
OA	Overall Accuracy
OSM	Open Street Map
PA	Producer's Accuracy
PP	Post-Processing
PSIL	Parent Scene Identification Layer
PSU	Primary Sample Unit
PU	Production Unit
QA	Quality Assurance
QC	Quality Control
RGB	Red Green Blue
SDI	Spatial Data Infrastructure
SLF	Small Landscape Feature
SWF	Small Woody Features
SWFC	Small Woody Feature Change
TCCM	Tree Cover Change Mask
TCD	Tree Cover Density
UA	User's Accuracy
UAA	Utilised Agricultural Area
UK	United Kingdom
UN SDGs	United Nations Sustainable Development Goals
UTM	Universal Transverse Mercator
VHR	Very High Resolution
WMS/WCS	Warehouse Management System / Warehouse Control System
WVM	Woody Vegetation Mask
XML	eXtensible Markup Language

## I. Executive Summary

Copernicus is the European Union's Earth Observation Programme. It offers information services based on satellite earth observation and in situ (non-space) data. These information services are **freely** and **openly** accessible to users through six thematic Copernicus Services (atmosphere monitoring, marine environment monitoring, land monitoring, climate change, emergency management and security).

The Copernicus Land Monitoring Service (CLMS) provides geographical information on land cover and its changes, land use, vegetation status, water cycle and earth surface energy variables to a broad range of users in Europe and across the world in the field of environmental terrestrial applications.

CLMS is jointly implemented by the European Environment Agency and the European Commission DG Joint Research Centre (JRC).

This document captures detailed definitions and product specifications for the High Resolution Layer (HRL) Small Woody Features (SWF) for the 2018 reference year. It provides an update of the previous Small Woody Feature product for the 2015 reference year, following a 3-year monitoring cycle. It aims to deliver homogeneous information on Small Woody Features across EEA38 countries + United Kingdom (UK), including linear structures such as hedgerows, tree alignments or scrubs/bushes along fields margins, roads, riparian woody vegetation as well as scattered and isolated patches of trees or scrubs. The HRL Small Woody Features for the reference year 2018 has been fully produced in the European Terrestrial Reference System 1989 (ETRS89) and in Lambert Azimuthal Equal Area (LAEA) projection by a consortium of well-established European service providers.

The HRL SWF 2018 status layers comprise 3 main products: SWF 2018 vector, SWF 2018 raster at 5 m spatial resolution and a Woody Vegetation Mask at 5 m spatial resolution in LAEA and national projections. These products are derived from Very High Resolution (VHR) satellite imagery from Copernicus Contributing Missions (CCMs) made available through the ESA Data Warehouse (DWH) for the reference year 2018 (+/-1 year). HRL SWF 2018 product portfolio also includes (i) a new Small Woody Feature Change layer over the period 2015-2018 at 100 m spatial resolution in LAEA projection, (ii) an aggregated SWF Density raster product at 100 m spatial resolution in LAEA and national projections, (iii) additional Expert Products, namely a Confidence Layer for the Woody Vegetation Mask 2018 at 5 m spatial resolution and a Parent Scene Identification Layer (PSIL) in LAEA projection, as well as (iv) a Forest Mask 2018 derived from HRL Forest Tree Cover Density (TCD) 2018 and CORINE Land Cover (CLC) 2018 (see section V Product Description below).

The HRLs are designed for use by a broad user community as basis for environmental and regional analyses and for supporting political decision-making. Specifically, they are supporting (amongst others) the reporting on Land Use, Land Use Change and Forestry (LULUCF).

## II. Background of the Document

### Scope of the Document

The Product User Manual is the primary document that users are recommended to read before using the product. It provides an overview of the product characteristics, product methodology and workflows, user requirements and example/potential use cases, information about the quality assessment checks and their results as well as a product technical support.

### Content and Structure

The document is structured as follows:

- Chapter III recalls the user requirements
- Chapter IV presents potential application areas and/or example use cases
- Chapter V presents product description (product file naming convention and format(s), product content and characteristics)
- Chapter VI provides a description of the product methodology and workflows
- Chapter VII summarises the quality assessment and/or validation procedure and the results
- Chapter VIII provides information about product access and use conditions as well as the technical product support
- Chapter IX lists references to the cited literature
- Chapter X provides annexes

### Applicable Documents

The following applicable documents (AD) serve as further background information to the users. All documents are freely accessible and available for download.

Ref.	Document Name
AD01	H2020 ECoLaSS User Requirement Analysis: <a href="#">Deliverable D3.2 – Service Evolution Requirements Report Vol. 2</a>
AD02	Nextspace User Study: <a href="#">Nextspace database for user requirements</a>
AD03	Tender Specifications EN-EEA.DIS.R0.20.006_Annex 7

## III. Review of User Requirements

In the frame of the Horizon 2020 (H2020) project EcoLaSS, a survey (AD01) of key stakeholders has been performed in order to evaluate the user requirements towards the evolution of existing and future Copernicus products. This survey also made use of the results from the Nextspace User Study (AD02) and revealed that HRL users (such as European institutions, service industry, research and academia, national agencies, regional administrations, NGOs or private users) would in general appreciate:

- High accuracy of the products
- No data gaps - due to enhanced cloud gap mitigation
- Extensive coverage of the product
- Sufficient spatial and timely resolution concerning both, status layer and change layer
- Short update cycles
- Change monitoring
- Free and open access
- High technical quality
- High thematic quality/meaningful and application-oriented product definitions
- Standardised and comparable nomenclature
- Transparent and scientific workflows and state-of-the-art methodology
- Detailed documentation of these workflow and the respective methodology
- Consistency of the pan-european products enabling synergistic use of all products
- Streamlining the pan-european product with global ones
- Availability of historic data and compatibility of time series
- Open access to the original Copernicus Sentinel data
- Sophisticated product presentation and visualisation possibilities in an online viewer on the Copernicus platform
- IPCC conformity

It is the strength of the HRL products that many of the mentioned requirements are already satisfied or at least considered in current or upcoming implementations.

Frequently updated reliable data about forests and woodlands in general, and specifically linear and patchy woody elements in Europe is crucial to many key Copernicus users and stakeholders. A wall-to-wall accurate mapping of small woody features across EEA38 + UK already serves several purposes, such as a meaningful spatial location of a pan-European green corridor ecological network connecting natural and semi-natural habitats, reservoir of biodiversity, and preserving protected areas. It also reflects the regional variety and identity of old Europe's rural and agricultural landscapes and its modern transformation, along with the increase of urbanisation and artificial surfaces. Even though SWF usually represents stable landscape markers across time, the small woody feature change product 2015-2018 at 100m spatial resolution - novelty of the 2018 production - is an indicator of the European territory's profound mutation in recent years. However, key Copernicus users and stakeholders would appreciate a more precise delineation of these changes which are currently difficult to capture mainly due, to difference of technical specification between SWF 2015 and SWF 2018 (see Table 2 in the technical details section) and to EO data current limitations (e.g., still insufficient VHR spatial resolution > 2 m, geographical misregistration between 2 monitoring cycles, etc.). Ultimately, the interlocking between SWF and HRL Lot 2 Forest Tree Cover Density (TCD) product, and in general with other HRL products, still needs improvement, as SWF somehow fills the gaps of the TCD while the coarser spatial 10 m resolution of the latter can mask out significant SWF.

## IV. Product Application Areas and Examples of Use Cases

Compared to the other HRLs, the SWF 2015 product is a relatively new product. Additionally as it was only publicly released about 2 years ago (in the second semester 2019), there have not been many use cases brought to the attention of EEA.

### Use case: Carbon storage assessment in agroforestry systems

In 2021, a multi-disciplinary team working in fields (such as landscape ecology and planning, agricultural landscape research, agronomy, organic farming and environmental science), led an interesting piece of research work on the role of small woody landscape features and agroforestry systems for national carbon budgeting in Germany (Golicz & al. 2021). This showed that the intensification of food production systems has resulted in landscape simplification, with trees and hedges disappearing from agricultural land, principally in industrialised countries. In recent years, the potential of agroforestry systems and small woody landscape features to sequester carbon was highlighted as one of the strategies to combat global climate change. The Federal Republic of Germany was one of the first countries to develop a long-term action plan for a low carbon economy and is considered a pioneer in this transition. Limited information exists on the carbon storage potential of emerging land use system such as agroforestry. The SWF 2015 dataset was used in conjunction with CLC 2012 in order to define several agricultural system types. Overall, this study showed that the implementation of agroforestry is promising for reducing agricultural Green House Gas emissions.

### Use case: CAP Indicator for preservation of biodiversity and farmed landscape features

The Common Agricultural Policy (CAP) comprises 9 key objectives for the period 2021-2027, among which the preservation of biodiversity and farmed landscapes as explained in brief<sup>6</sup>. The disappearing of landscape features and semi-natural vegetation in agricultural land over the past decades, being a pressure on biodiversity and the environment has become a concern. Landscape features play an important role as a support to biodiversity and ecosystem services (e.g., habitat provision, mitigation of soil erosion, improvement of soil fertility), and also have aesthetic and cultural values attached. Thus, the importance to develop a stable and consistent indicator based on a sustainable and reproducible data source for monitoring changes and to track changes of landscape features in European agricultural landscapes. The CAP Indicator I.21 aims to assess the area covered by landscape features in the agricultural land. The Copernicus Small Woody Features products are proposed as one of the information sources for the creation of the CAP I.21 indicator on landscape features (Figure 1). The agricultural area is derived with the help of Corine Land Cover (CLC) data which is spatially refined with Copernicus High Resolution Layers (HRL).

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<sup>6</sup> [https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key\\_policies/documents/cap-specific-objectives-brief-6-biodiversity\\_en.pdf](https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/cap-specific-objectives-brief-6-biodiversity_en.pdf)

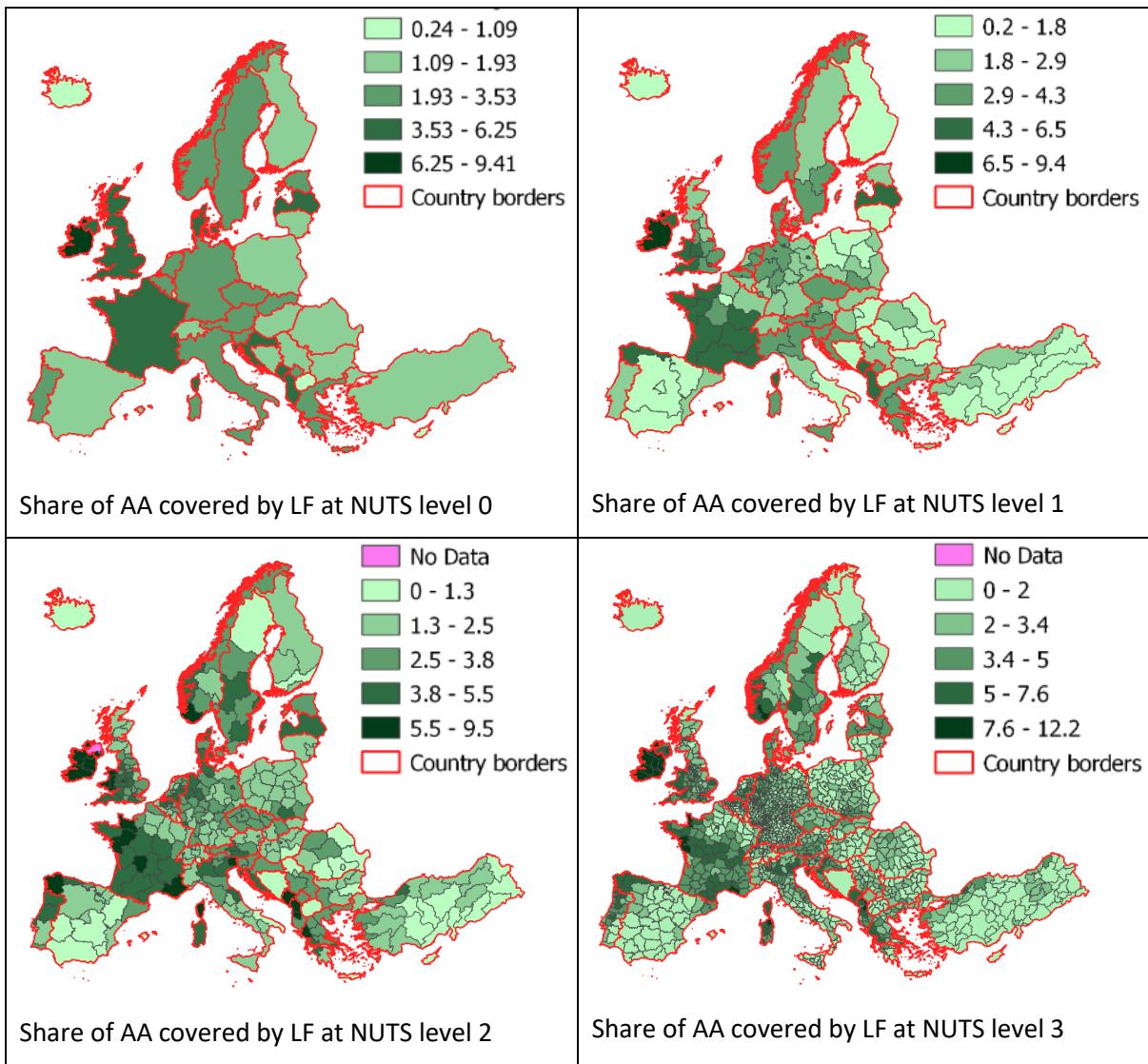


Figure 1: Share of agricultural area covered with woody landscape features at different NUTS levels based on SWF 2015 (Kleeschulte, 2020)

## V. Product Description

### Overview of the Product Portfolio

The HRL Small Woody Features 2018 portfolio (Figure 2) comprises three main primary status layers, provided both in pan-European LAEA projection and in national projections:

- Woody Vegetation Mask at 5 m spatial resolution
- SWF vector
- SWF raster at 5 m spatial resolution

From those products, aggregated and change products (combination with SWF 2015 status layer) were created:

- SWF Density raster at 100 m spatial resolution (in pan-European LAEA and national projections)
- Mosaic of Small Woody Feature Change for the 2015-2018 period at 100 m spatial resolution (in pan-European LAEA projection only)

Furthermore, other ancillary data and three additional expert products are provided (both in pan-European LAEA projection only):

- Mosaic of Confidence Layer for WVM at 5 m spatial resolution
- Parent Scene Identification Layer (PSIL) in vector format
- Forest Mask 2018 at 5m spatial resolution

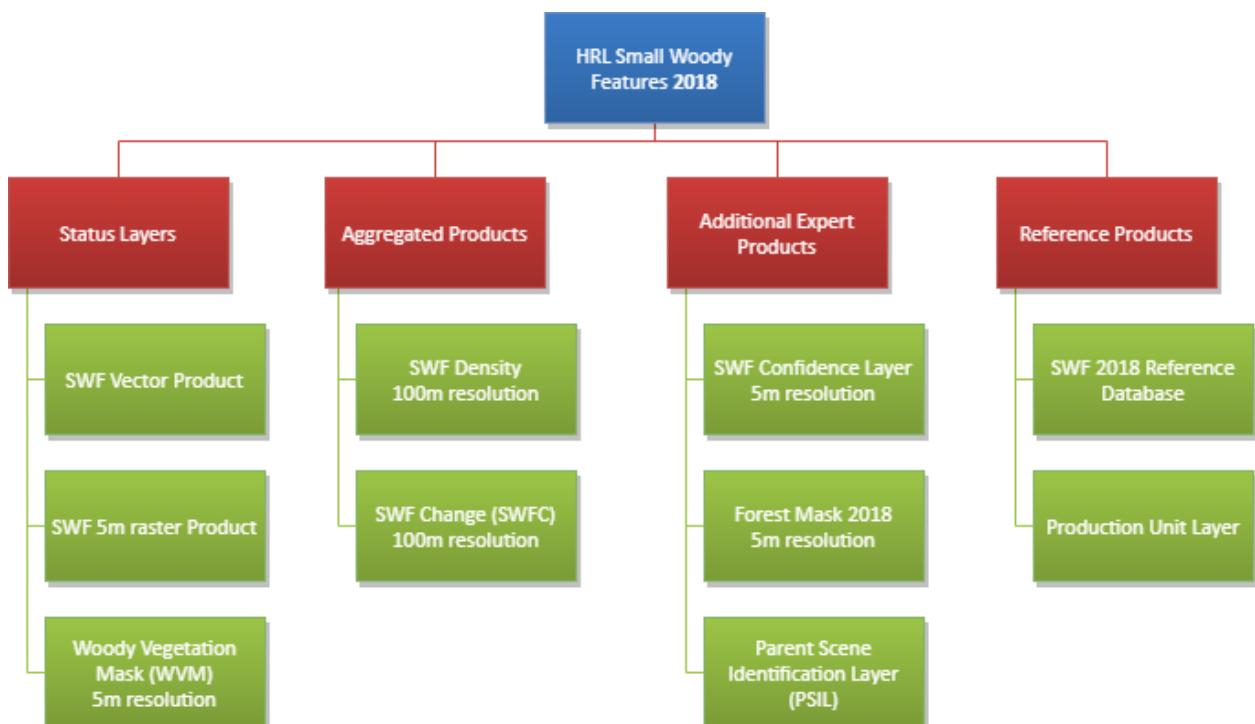


Figure 2: HRL Small Woody Features 2018 Product Portfolio

## Definitions and Thematic Characteristics of the HRL Small Woody Features 2018

Small woody landscape features are important vectors of biodiversity and provide information on the fragmentation and connectivity of habitats, especially considering the importance of Green Infrastructure and hazard protection. Moreover, the HRL Small Woody Features contributes to monitor and evaluate the United Nations (UN) Sustainable Development Goals (SDGs). It can specifically support the Ecosystem assessment and land accounting in the context of SDG 15 “Life on Land”.

Small Woody Features can be defined by two types of linear or patchy structures of woody/scrubby/bushy vegetation:

- Linear structures include:
  - Hedgerows
  - Tree alignments or scrubs along field margins
  - Tree alignments or scrubs along roads
  - Riparian woody vegetation along waterways and streams
- Patchy structures include:
  - Scattered group of trees/scrubs
  - Isolated trees/scrubs

No height differentiation (trees vs. scrubs/bushes) is applied.

Elements to be included or excluded in Small Woody Features 2018 are summarised in Table 1.

*Table 1: Thematic definition of SWF 2018*

Elements included in small woody features	Elements excluded from small woody features
<ul style="list-style-type: none"><li>● linear hedgerows and scrubs</li><li>● tree rows (along field boundaries)</li><li>● isolated/scattered patches of trees areas, storm damages, insect-infested damages, etc.)</li></ul>	<ul style="list-style-type: none"><li>● stone walls</li><li>● drainage ditches</li><li>● grass margins</li><li>● field boundaries without hedgerows or trees</li><li>● any kind of “grey” infrastructure such as roads</li><li>● artificial tree rows like olive tree plantations, vineyards, and orchards</li></ul>

## Technical Details of the HRL Small Woody Features 2018

### Status Layers

#### *SWF vector*

In the SWF 2015 production, in addition to linear and patchy structures, a third class of Additional Woody Features (AWF) was included to ensure connectivity between linear and patchy features which were disconnected due to the geometric rules applied. However, after the production AWF were considered too confusing by the users and have therefore been removed from the SWF 2018 product. The geometric rules are now adapted to the revised SWF 2018 technical specifications, as presented in Table 2.

To ensure connectivity between mapped linear and patchy elements, features that are outside of the geometric specification can be included in the product if:

- Connected to a valid (e.g., geometrically compliant) linear or patch, with no min/max criterion
- Isolated and with an area comprised between 0.15 and 5 ha.

*Table 2: Geometric specifications of SWF 2018*

	Linear Structures	Patchy Structures
<b>Width</b>	$\leq 30 \text{ m}$	n/a
<b>Length</b>	$\geq 30 \text{ m}$ (was 50m for 2015)	n/a
<b>Area</b>	n/a	$200 \text{ m}^2 \leq \text{area} \leq 5000 \text{ m}^2$
<b>Compactness</b>	$\leq 0.785$ (was 0.75 for 2015)	$> 0.785$ (was 0.75 for 2015)

The discrimination between linear, patchy or out of specification features included in the product is not visible in the final 2018 product as all the elements are dissolved in the end in one unique class "Small Woody Feature".

In the same way that each country tends to have its own forest definition, there may also be a need for users to adapt the list of parameters above to fit the specificities of certain landscapes. Therefore, the Woody Vegetation Mask (WVM), for which no geometry rules have been applied, is made available as a separate deliverable.

Furthermore, SWF 2018 includes a forest masking, preventing any mapping of SWF in forested areas. These forested areas are aligned with canopy cover criteria of the FAO forest definition<sup>2</sup> and are derived from HRL TCD 2018 and CLC 2018 products. The workflow allowing to obtain this Forest Mask 2018 is described in section VI. Table 3 summarises the technical specifications for the SWF 2018 vector layer.

<sup>2</sup> In Forest Resources Assessment 2020 terms and definitions, the forest is described as "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use." <https://www.fao.org/3/l8661EN/i8661en.pdf>

Table 3: Technical specifications for the SWF 2018 vector

<b>Product</b>
Small woody features (SWF) 2018 vector layer "SWF_2018_vec"
<b>Geometric resolution /Scale</b>
Equivalent 1: 5,000
<b>Coordinate Reference System</b>
Production in European ETRS89 LAEA projection (EPSG 3035) / national projections to be provided after production
<b>Geometric accuracy (positioning scale)</b>
According to ortho-rectified satellite image base delivered by ESA
<b>Thematic accuracy (in %)</b>
N/A
<b>Data type</b>
GIS compatible vector format; too complex polygons shall be split into GI-technical manageable units
<b>Minimum Mapping Unit (MMU)</b>
No MMU for the linear elements. MMU for Patchy structures of trees and scrub: 200 m <sup>2</sup> (size limit of 5000 m <sup>2</sup> )
<b>Minimum Mapping Length (MML)</b>
Linear structures/elements: >= 30 m length. No MML for Patchy structures
<b>Minimum Mapping Width (MMW)</b>
Linear structures/elements: <= 30 m
<b>Necessary attributes</b>
Area, class names and code
<b>Thematic coding</b>
1: Small structures of trees, hedges, bushes and scrub
<b>Metadata</b>
XML metadata files are to be produced according to INSPIRE metadata standards. INSPIRE compliant meta data profile. Specifications available online at <a href="http://taskman.eionet.europa.eu/projects/sdi/wiki/Cataloguemetadata_guidelines">http://taskman.eionet.europa.eu/projects/sdi/wiki/Cataloguemetadata_guidelines</a> . Always refer to the online version as these guidelines are periodically updated.
<b>Delivery format</b>
Geospatial data shall be provided either in geopackage or file geodatabase for the vector files; Opendoc shall be used for the documentation and XML for the metadata.

## *SWF 5 m raster*

SWF 2018 5 m raster product is derived from SWF 2018 vector product, using a conversion to the raster format compliant with EEA grid (see section VI). Therefore, thematic and technical specifications of the SWF 2018 vector product also apply to SWF 2018 5 m raster product (see Table 4).

A thematic accuracy assessment of the SWF 2018 5 m raster product was performed and its detail can be found in section VII.

*Table 4: Technical specifications for the SWF 2018 5 m raster*

<b>Product</b>
Small woody features (SWF) 2018 5 m "SWF_2018_005m"
<b>Geometric resolution /Scale</b>
Pixel resolution 5 m x 5 m
<b>Coordinate Reference System</b>
Production in European ETRS89 LAEA projection (EPSG 3035) / national projections to be provided after production
<b>Geometric accuracy (positioning scale)</b>
According to ortho-rectified satellite image base delivered by ESA.
<b>Thematic accuracy (in %)</b>
> 80% user's / producer's accuracy taking into account the relative occurrence of the thematic classes to be identified
<b>Data type</b>
8bit unsigned raster with LZW compression
<b>Minimum mapping Unit (MMU)</b>
No MMU (The MMU > 200 m <sup>2</sup> for the patchy structures is applied on the vector product)
<b>Minimum Mapping Length (MML)</b>
No MML (The MML >= 30 m for the linear structures is applied on the vector product)
<b>Minimum Mapping Width (MMW)</b>
No MML (The MMW <= 30 m for the linear structures is applied on the vector product)
<b>Thematic coding</b>
0: Non SWF area 1: SWF area (Linear or patchy structures of trees, hedges, bushes and scrub) 254: Unclassifiable (no satellite image available, or clouds, shadows) 255: Outside area
<b>Metadata</b>
XML metadata files are to be produced according to INSPIRE metadata standards
<b>Delivery format</b>
GeoTIFF

## Woody Vegetation Mask 5 m

Woody Vegetation Mask is a product depicting woody vegetation without height, size, or shape differentiation. It allows the user to flexibly apply their own rules to derive any type of features they specifically require for their topic of interest. To separate the product vis-à-vis forested areas, the same masking as for the main SWF product (using Forest mask 2018) is applied. Table 5 summarises the technical specifications for the Woody Vegetation Mask.

*Table 5: Technical specifications for the WVM 2018 5 m raster*

<b>Product</b>
Woody Vegetation Mask (WVM) 2018 5 m raster layer "WVM_2018_005m"
<b>Geometric resolution /Scale</b>
Pixel resolution 5 m x 5 m
<b>Coordinate Reference System</b>
Production in European ETRS89 LAEA projection (EPSG 3035) / national projections to be provided after production
<b>Geometric accuracy (positioning scale)</b>
According to ortho-rectified satellite image base delivered by ESA
<b>Thematic accuracy (in %)</b>
N/A
<b>Data type</b>
8bit unsigned raster with LZW compression
<b>Minimum mapping Unit (MMU)</b>
100 m <sup>2</sup>
<b>Minimum Mapping Length (MML)</b>
No MML
<b>Minimum Mapping Width (MMW)</b>
No MMW
<b>Thematic coding</b>
0: Non woody area
1: Woody area
254: Unclassifiable (no satellite image available, or clouds, shadows)
255: Outside area
<b>Metadata</b>
XML metadata files are to be produced according to INSPIRE metadata standards
<b>Delivery format</b>
GeoTIFF

## *Forest Mask 2018*

In order to limit overlaps of SWF with large and densely tree covered areas, the production workflow included a masking approach using the HRL 2018 TCD layer. The forest masking derived from HRL 2018 TCD follows as much as possible the FAO forest definition while considering landscape specifications to exclude from the forest mask valid SWFs. Following discussions between EEA and SWF 2018 consortium, an agreement was reached regarding the technical specifications of the Forest Mask 2018 which are specified in the following section VI and summarised in Table 6.

*Table 6: Technical specifications for the Forest Mask 2018*

<b>Product</b>
Forest mask 2018 5 m raster layer "FM_2018_005m"
<b>Geometric resolution /Scale</b>
Pixel resolution 5 m x 5 m
<b>Coordinate Reference System</b>
Production in European ETRS89 LAEA projection (EPSG 3035) / national projections to be provided after production
<b>Geometric accuracy (positioning scale)</b>
According to HRL2018 TCD
<b>Thematic accuracy (in %)</b>
N/A
<b>Data type</b>
8bit unsigned raster with LZW compression
<b>Minimum mapping Unit (MMU)</b>
5 ha
<b>Minimum Mapping Length (MML)</b>
N/A
<b>Minimum Mapping Width (MMW)</b>
60 m
<b>Thematic coding</b>
0: non forested area 1: Forested area
<b>Metadata</b>
XML metadata files are to be produced according to INSPIRE metadata standards
<b>Delivery format</b>
GeoTIFF

## Aggregated Products

Small Woody Features Density 100 m raster is an aggregated version of the SWF 5 m raster product and is consistent with the EEA 100m grid. It can be used as a landscape descriptor of SWF density for large areas.

Within the 100 m grid cells, if the number of 5 m valid pixels is above 50%, the arithmetic mean density of all valid SWF 5 m pixels is calculated, excluding the “outside areas” and “unclassifiable” pixels. (See Table 7 for technical specifications.)

*Table 7: Technical specifications of the Small Woody Feature 100m Product*

<b>Product</b>
Small Woody Feature 100 m Product
<b>Geometric resolution /Scale</b>
Pixel resolution 100 m x 100 m
<b>Coordinate Reference System</b>
Production in European ETRS89 LAEA projection (EPSG 3035)
<b>Geometric accuracy (positioning scale)</b>
According to HRL2018 SWF
<b>Thematic accuracy (in %)</b>
N/A
<b>Data type</b>
8bit unsigned raster with LZW compression
<b>Minimum mapping Unit (MMU)</b>
N/A
<b>Minimum Mapping Length (MML)</b>
N/A
<b>Minimum Mapping Width (MMW)</b>
N/A
<b>Thematic coding</b>
0: Absence of SWF 1-100: Density of SWF (%) 255: Outside Area
<b>Metadata</b>
XML metadata files are to be produced according to INSPIRE metadata standards
<b>Delivery format</b>
GeoTIFF

## Small Woody Features Change 2015-2018 100 m raster

Small Woody Features Change 2015-2018 product aims to map, at 100 m only, SWF increase, decrease or stable levels. It is based on SWF 2015 and SWF 2018 with additional filtering, but without any re-analysis of the 2015 reference year (see Table 8).

Table 8: Technical specifications of the Small Woody Feature 100 m Change Product

<b>Product</b>
Small Woody Feature Change Product
<b>Geometric resolution /Scale</b>
Pixel resolution 100 m x 100 m
<b>Coordinate Reference System</b>
Production in European ETRS89 LAEA projection (EPSG 3035)
<b>Geometric accuracy (positioning scale)</b>
According to HRL2018 SWF
<b>Thematic accuracy (in %)</b>
N/A.
<b>Data type</b>
8bit unsigned raster with LZW compression
<b>Minimum mapping Unit (MMU)</b>
N/A
<b>Minimum Mapping Length (MML)</b>
N/A
<b>Minimum Mapping Width (MMW)</b>
N/A
<b>Thematic coding</b>
0: stable area 1: Increase in SWF Density 2: Decrease in SWF Density 201: Area covered by Forest Mask in 2015 202: Area covered by Forest Mask in 2018 203: Area covered by Forest Mask in 2015 & 2018 254: Missing data in 2015 255: Outside Area
<b>Metadata</b>
XML metadata files are to be produced according to INSPIRE metadata standards
<b>Delivery format</b>
GeoTIFF

## VI. Product Methodology and Workflow

### a. Production Workflow

This section describes in detail the methodology used to generate all products. From the raw data to the final delivery products, the different steps comprise: (i) input data and pre-processing, (ii) reference database for calibration and validation, (iii) segmentation and pre-classification, (iv) manual enhancement, (v) post-processing and vectorisation (vi) SWF 2018 5 m raster (vii) derived products (viii) change layer 2015-2018. These steps are illustrated as a workflow diagram in Figure 3.

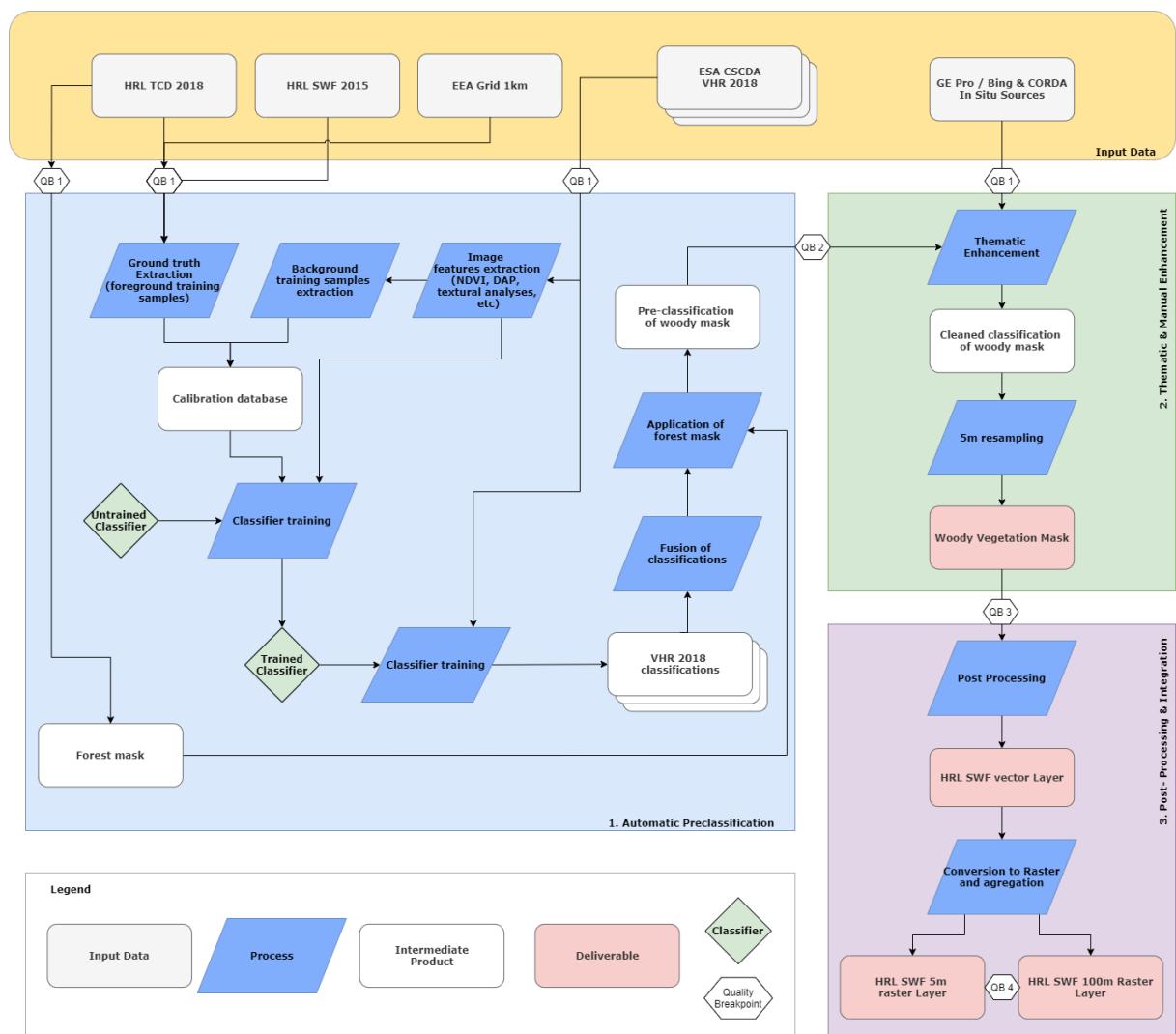


Figure 3: Workflow for the HRL SWF 2018 Status Layers

## (i) Input data and pre-processing

The main source of data for the HRL SWF 2018 production is the European Space Agency (ESA) Copernicus Space Component Data Access (CSCDA) providing the VHR\_IMAGE\_2018 dataset<sup>3</sup> with a complete, cloud-free coverage of EEA38 + UK, including French Overseas Departments (DOMs), and complemented by the VHR\_IMAGE\_2018\_ENHANCED.

The data was captured within predefined acquisition windows corresponding to the vegetation season. Each VHR was delivered in two processing levels: level 1 and level 3 (ortho-rectified) provided in European projection (ETRS89-LAEA, EPSG code 3035), except for the DOMs (Local UTM projections) at 2-4 m spatial resolution for four spectral bands (blue, green, red, and NIR). The VHR\_IMAGE\_2018 dataset was acquired from the selected satellite missions listed below:

- Primary satellite missions:
  - Pléiades 1A & 1B: 47%
  - PlanetScope: 15%
  - SuperView-1: 7%
  - Kompsat-3/3A: 10%
- Backup Satellite missions:
  - SPOT6/7: 20%
  - TripleSat: less than 1%

Compared to the VHR\_IMAGE\_2015 used for HRL SWF 2015 production, the new VHR\_IMAGE\_2018 has the advantage of improved geometric correction (good juxtaposition of the multiple sensor scenes), a cloud mask and gap filling. However, the reduced spatial resolution from 1 m to 2-4 m spatial resolution as well as the missing panchromatic band, influences the product. The resolution of the image data is included and integrated as an attribute in the PSIL layer.

The image data was processed on a cloud platform and was stored in a way that facilitates bulk automated image processing.

Each image of the VHR\_IMAGE\_2018 was quality-assured with respect to the presence of clouds and absence of snow and haze. The geometric quality of the data was checked against available reference data. As much as possible, the choice of data favoured consistent seasonal imagery in order to minimize the seasonal impact on the radiometry.

As the VHR\_IMAGE\_2018 dataset does not include panchromatic images, no pan-sharpening operation could be achieved, limiting the storage and analysis to the multispectral scenes included in the dataset.

Along with the online storage mandatory for the bulk automated image processing, a WMS/WCS flux VHR\_IMAGE\_2018 dataset was generated to facilitate the work of interpreters involved in thematic and manual enhancement and internal validation.

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<sup>3</sup> <https://spacedata.copernicus.eu/web/cscda/dataset-details?articleId=56342>

## (ii) Reference Database for Calibration and Validation

For supervised land cover classification from VHR optical satellite imagery, it is essential to have a reference dataset of samples for calibration and training data (hereafter referred to as reference dataset), and validation which is representative for the LC of interest and covers the whole EEA38 + UK territory.

In order to maximise the applicability of this reference dataset and foster economies of scale for its generation, the selection of samples was performed automatically. Each sample consisted of a labelled data example, which was analysed from an active learning algorithm.

For a reference dataset over the whole EEA38 + UK territory, the spectrally heterogeneous coverage of SWF throughout the biogeographical zones needed to be considered. Therefore, a sufficiently high number of reference samples per production unit (6 samples/km<sup>2</sup> when possible) was used to extract representative reference statistics in order to successfully train the supervised learning algorithm.

In contrast to the 2015 production, for which only reference data Green Linear Element (GLE) and TCD were available, the existing HRL SWF 2015 layer was used as main data source for sample selection. Its availability drastically improved the application of more complex classification approaches and made Machine Learning more realistic, as such an approach requires a large amount of reference data. In any case, using the SWF 2015 layer significantly improved product quality and reduced the need for manual enhancement. One main advantage was the already classified distinction between linear and patchy structures and between the additional woody features to consider the full range of SWF characteristics and to meet the required geometrical specifications. For areas where the density of SWF 2015 was too scarce, other data sources were used such as the HRL TCD 2018 dataset.

Due to the very nature of the SWF, other existing datasets at pan-European level cannot be directly sampled to obtain pure and adequate non-SWF reference samples. Spectral and textural analyses of the VHR, coupled with land cover data from CLC 2018 and HRL TCD 2018 were performed to obtain satisfying non-SWF reference across the whole EEA38 + UK.

The use of the SWF 2015, TCD 2018 and other sources of input data required some automated processing to be suitable as a reference dataset. In order to match the target specifications, an automated cleaning of the reference samples was applied to remove structures that did not fit the geometric specifications. Further procedures ensured that the samples matched the spectral range of the product. The first step was based on NDVI-images derived from the VHR\_IMAGE\_2018 data by dynamically calculating statistics (mean and standard deviation) for each region from the reference samples.

The application of these multiple dataset (SWF 2015, HRL TCD 2018 and non-SWF references) ensured a set-up of a high-quality reference dataset with a minimum of manual interaction, which also saved efforts and time.

For the Validation step, VHR EO data of similar or higher spatial resolution and quality than the production data was used. Two types of datasets against which the interpretation was performed can be distinguished: guiding data and reference data. The guiding data were those used as basis of the production of the Small Woody Features layer. Hence, the available guiding data were:

- VHR\_IMAGE\_2018 & VHR\_IMAGE\_2018\_ENHANCED described in sub-section (i).

The reference data are complementary independent data used to provide more spatial detail and strong landscape context to the assessment. The available reference data were:

- Bing maps image / cartography layer
- Open Street Map (OSM) data
- Google Earth image / cartography data
- Further in-situ data, e.g., national and regional VHR (airborne) orthophoto Web Map Services (RGB and/or CIR imagery, with varying spatial resolution) or ancillary data

### (iii) Segmentation and pre-classification

This step aims at providing a binary mask discriminating woody vegetation from non-woody vegetation. The input datasets were the VHR\_IMAGE\_2018 dataset, as well as the reference databases for calibration and validation described in the previous sub-sections (i) and (ii), respectively. Prior to any classification, the latter was split into two independent subsets respectively used for:

- 1) Training the classifier and
- 2) Deriving the binary output from the probability map (see below).

The methodology of classification and segmentation is based on Geographic Object-Based Image Analysis (GEOBIA) (Merciol & al, 2019). It relies on two main components which are feature extraction derived from attribute profiles, and a semi-supervised classification using a random forest algorithm. The first step consists in computing predefined indices such as the Normalised Difference Vegetation Index (NDVI), as well as texture characterisation such as Sobel gradient and Haar-like features based on integral image (Viola & Jones 2001) representations (Faucqueur & al. 2019). The texture information is extracted from each spectral band of the original VHR multispectral image, as well as from the NDVI. This textural information has a significant role in allowing the discrimination between woody vegetation and cropland or grassy vegetation, as their spectral response can be close, considering the limited spectral resolution of VHR imagery (Near Infra-Red, Red, Green and Blue). Multi-scale features called Attribute Profiles (AP) and Differential Attribute Profiles (DAP) were derived through a model of morphological tree, which can be seen as a hierarchical segmentation: these trees allow to identify, depending on the way they are pruned, morphological objects from the VHR scenes (Figure 4).

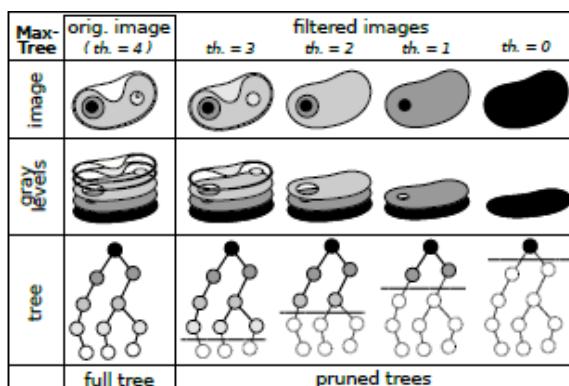
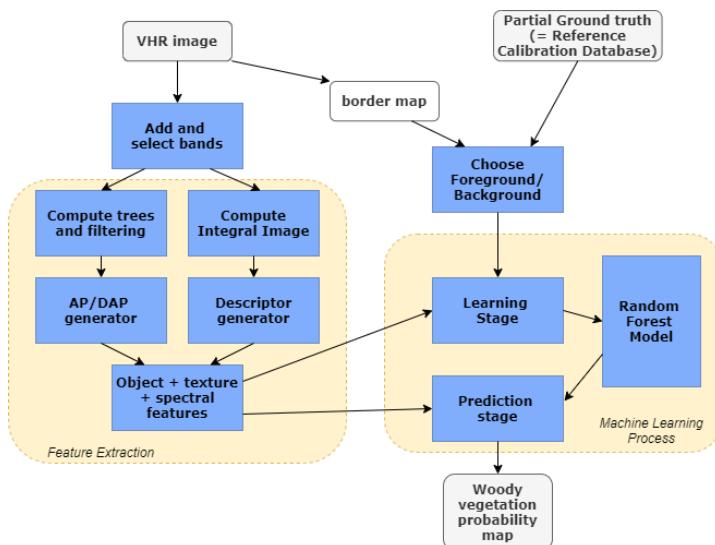


Figure 4: Principle of morphological trees derived from Attributes Profiles (example of Max-tree) to identify objects from the imagery

The second step was the use of the random forest classifier in a semi-supervised framework (Figure 5). The reference calibration database ensured the quality of the training set by providing foreground (woody) and background (non woody) samples, needed to comply with the large and heterogeneous landscape from Iceland to Turkey. The output of this classification was a probability map where each pixel is given a probability to depict woody vegetation.



*Figure 5: Flowchart of the classification approach*

Each VHR scene from the VHR\_IMAGE\_2018 was processed independently to consider its specifications (spatial resolution, band order, acquisition time, etc.), then all probability maps were combined according to the mean of observations to obtain a global probability map at the production-unit scale (i.e., a grid cell of 200\*200km). A threshold was then applied to derive a binary woody/non-woody vegetation layer.

Automated processes were performed at the end of this step, to clean the classification output (a 100 m<sup>2</sup> MMU is applied), include specific mapping rules (all detected elements closer than 5 m from each other were merged into one unique element) and apply the production unit boundaries.

A first thematic enhancement was applied at this stage, with the application of the forest mask 2018.

To ensure a good compliance between HRL SWF 2018 and HRL TCD 2018, and to avoid a large overlap between those two products, the large and densely forested areas - in which the presence of valid SWF is unlikely - were removed from the classification result. To achieve this, a mask was derived from the HRL TCD 2018 layer and CLC 2018 according to the following steps:

- A 10% canopy cover threshold is applied to HRL TCD 2018, to meet the FAO forest definition.
- A morphological filter is applied to remove linear elements that could represent valid SWF from the forest mask (ex: large hedgerow connected to a forest which would be included in the forest mask after the first step of thresholding). Thus, only dense and compact forested areas are kept in the forest mask.
- A minimal mapping unit (MMU) of 5 ha is applied, to remove small forest areas from the mask. The application of this MMU filter is necessary because of the different spatial resolution of the input

imagery that was used to produce HRL TCD 2018 and the HRL SWF 2018 product, which makes the presence of features below 5 ha likely.

- A 10 m external buffer is applied to prevent wrongly detected SWF at forest boundaries due to the different spatial resolution between the HRL TCD 2018 and HRL SWF 2018 product (and respective input data).
- Within CLC 2018 agricultural classes (classes 21, 22, 23 & 24), dense linear forested elements (>40 m wide, > 50 % TCD) are excluded from the forest mask. It allows to avoid the masking of riparian trees or parcel-delimiting hedgerows within the large agricultural areas.

#### (iv) Manual Enhancement

Following the classification / segmentation process, a manual thematic enhancement step was included in order to meet the SWF thematic specifications. This step was the removal of the artefacts appearing and woody vegetation in the product classification that is not included in the SWF definition. Indeed, artificial tree rows such as olive trees plantation, orchards, tree plantations or vineyards present the same spectral and textural response (i.e., land cover) as a hedgerow or a patch of trees on a VHR image but cannot be considered as valid SWF due to their artificial aspects.

Open forest includes vegetation types in which SWF candidates are likely to be detected by the automatic classification but are not SWF according to the definition. A cluster of trees in these landscapes may fit the geometrical specifications of SWF (if the trees are closer than 5 m from each other) but would not fit the thematic SWF definition from an ecological point of view. Although these landcovers (open forests and tree plantations) are already partially masked out by the application of the forest mask, these landscapes are known to be difficult to map using EO data. Indeed, correctly mapping an area with a low-density tree cover require satellite imagery compliant with the identification of individual trees. The forest mask, being based on HRL TCD 2018, is derived from the analysis of Sentinel-2 data at 10m spatial resolution, where the mapping of individual (and potentially small) trees is challenging. Therefore, some very low tree cover density areas can be considered as forest (following FAO forest definition) or tree plantations but might not be covered by the forest mask. This is especially true in Mediterranean and Scandinavian landscapes, where low density open forest is frequent. The thematic and manual enhancement steps will address and correct these commission errors of the classification results.

In mountainous area, the relief and the process of ortho-rectification of satellite imagery can lead to artefacts that will impact the quality of the product classification. The manual enhancement step also includes the correction of major artefacts in those areas.

The output of this thematic enhancement step is a binary layer of woody vegetation which is thematically compatible with the SWF definition. A conversion to a 5 m spatial resolution raster layer will provide the 5 m Woody Vegetation Mask deliverable, which is submitted in LAEA projection and national projections.

## (v) Post-Processing & vectorisation

The post-processing procedure ensures that all small woody features are represented in the final product according to their specified geometric properties by selecting small woody features with sub-routines and applying the geometric specifications (such as length, width, and area). Figure 6 shows the difference between the WVM and the final SWF product, in the latter blue features are removed due to their non-compliant geometric specification. The decision tree of the post-processing can be found in Figure 7.

As requested in AD03, the final SWF product no longer differentiates between linear and patchy features.

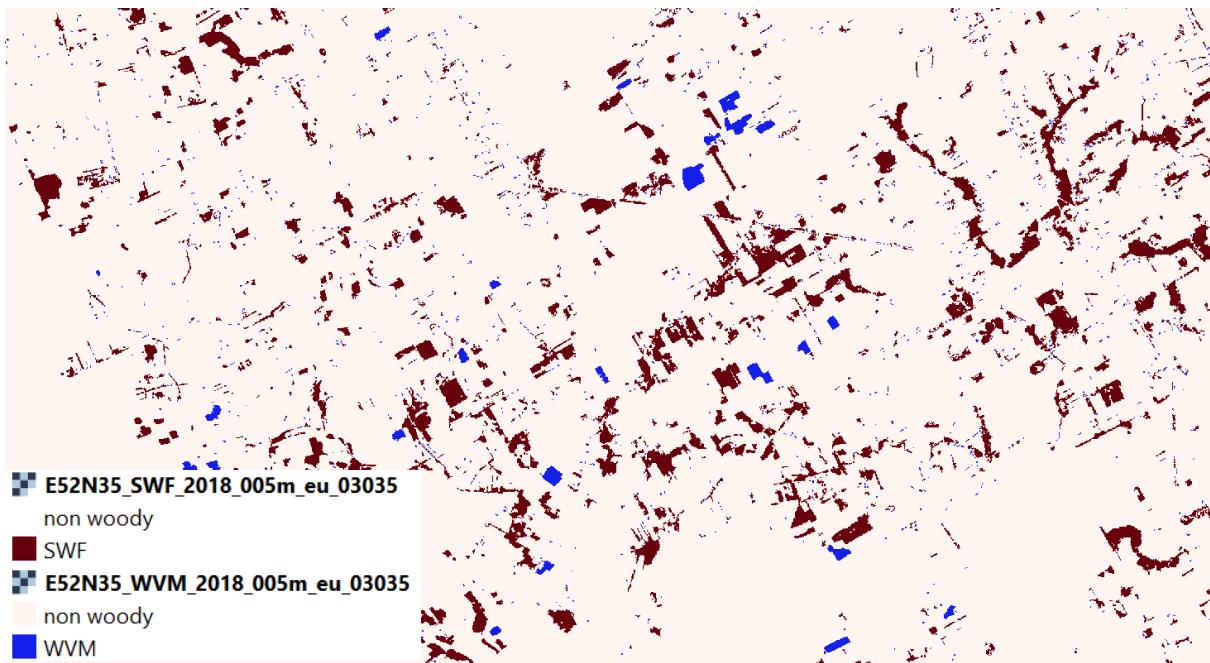


Figure 6: Final SWF product in red compared to the “raw” WVM in blue. Due to non-matching specifications, the blue features are removed during the post-processing. Poland, near Sokolany.

The first step is a separation of features in linear and patchy elements. The compactness parameter according to Bogaert & al. (2000) is calculated to separate the small woody features of the pre-classification into linear and patchy structures. The compactness is calculated with the following formula:

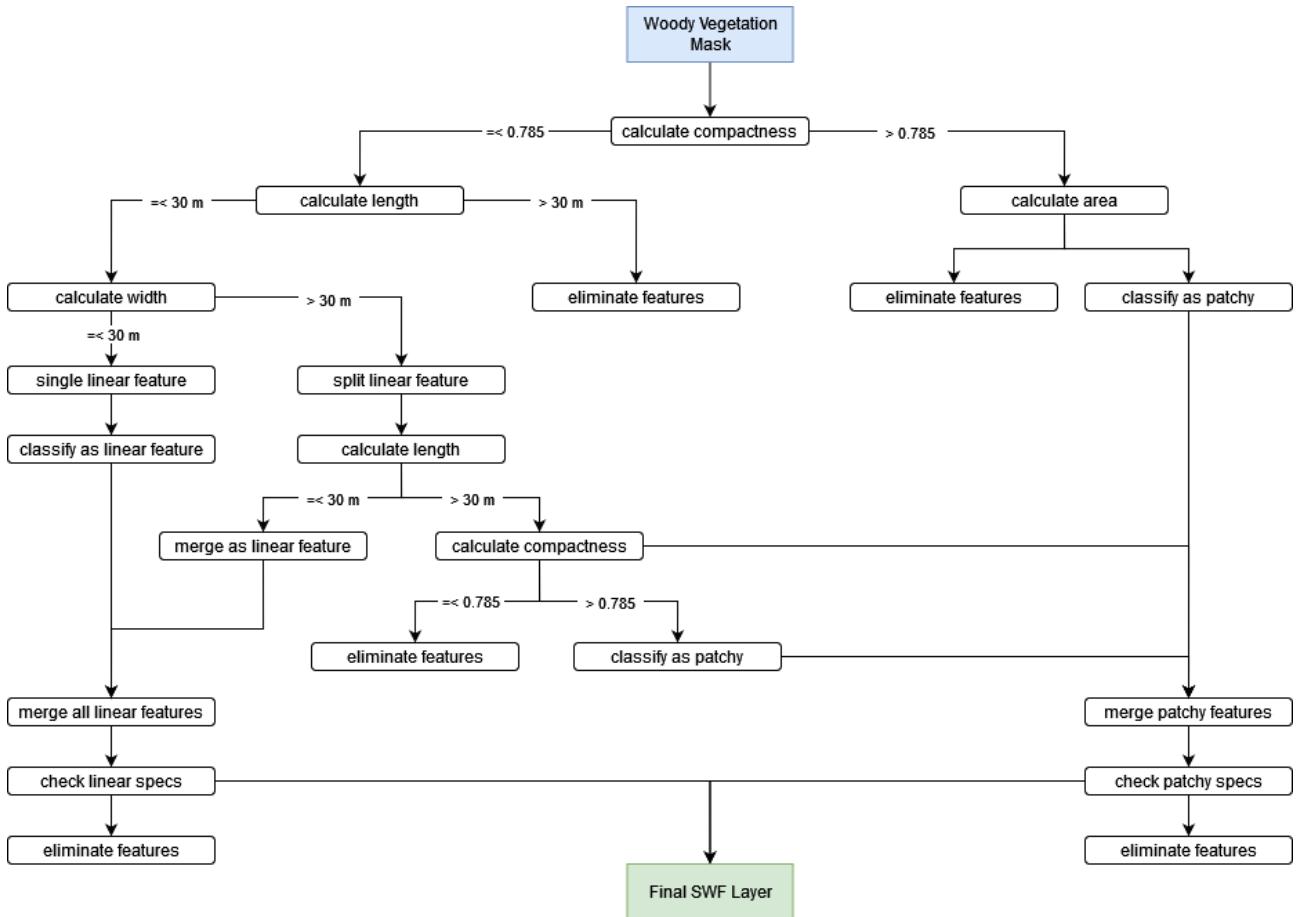
$$C = \frac{4 * \pi * \text{area}}{\text{perimeter}^2}$$

Compared to 2015 reference year, adjusting the length from 50 m to 30 m has also changed the compactness from 0.75 to 0.785 (Table 2). According to the product specifications, small woody features with a compactness  $\leq 0.785$  are assigned to linear structures, whereas small woody features with a compactness  $> 0.785$  are assigned to patchy structures. After that, the actual length of a polygon is calculated to eliminate all linear structures with a length of  $< 30\text{m}$ . The width of the remaining linear features is determined using the Euclidean distance and wider parts are identified using Voronoi polygons. In an iterative process, all geometric rules are checked and all non-fitting features removed (Figure 7). As a new rule in the 2018 product (in contrast to the 2015 product), isolated patches above 5 ha are removed.

In addition to the previous mentioned steps, elements which did not match the specifications are re-integrated into the classification. This applies to isolated areas comprised between 1500 and 5000  $\text{m}^2$ , and

to areas connected to already valid linear or patchy structures, without any area limitation. These elements were formerly known as Additional Woody Features (AWF).

The selected linear and patchy structures are dissolved, and attributes are set. Furthermore, the topological relation between the eliminated and the potential woody features are checked to keep primarily connected features and improve the look and feel of the final result. This is done by examining compactness, area and length of those eliminated features in the previous steps with the proximity of SWF. Finally, smoothing and simplification procedures clean artefacts derived from the automatic post-processing. Geometry and topology checks ensure the correctness of the final polygons.



*Figure 7: Decision tree of the differentiation into linear and patchy small woody features. For the final product, all features are dissolved into a single SWF class.*

The post-processing framework is developed in a modular and independent way and can be easily configured from outside. It is possible to adapt the above-mentioned post-processing chain to any geometric definitions and specifications. Thus, the post-processing procedure is independent of the actual geometric specifications.

**Input:** Woody Vegetation Mask (WVM) 2018 5 m

**Output:** SWF 2018 vector product

**Production steps:**

1. Selection of linear and patchy elements and applying the geometry rules
  - a. Sub-setting the smoothed and simplified vector file by using a grid approach to enable parallel processing
  - b. Geometry and topology checks
  - c. Creation of the final geometric representation of the small woody features
  - d. Separation of features in linear and patchy elements by calculating the area and the compactness factor according to Bogaert & al. (2000)
  - e. Polygon skeletisation - calculating the actual length of a polygon and eliminate all linear structures with a length of < 30 m
  - f. Calculation of the Euclidean distance to determine the width of the remaining linear features. Wider parts are identified by using Voronoi polygons.
  - g. Subsequently, the same rules are applied over and over again to divide the features into patchy or linear features and elimination of feature that do not meet the specifications.
  - h. Merging of the corrected linear and patchy structures, dissolve features and set the final attributes
  - i. Final smoothing and simplification procedures as well as quality, geometry and topology checks
2. Creation of the final, cleaned, correct vector product as an ArcGIS geodatabase

#### (vi) SWF 2018 5 m raster

The status SWF raster layer for the reference year 2018 provides information on the presence or absence of Small Woody Features at 5 m spatial resolution derived from the SWF 2018 vector layer. It is the main status product of the SWF 2018 and it describes the SWF landscape according to the very high resolution of the input data, but without considering the possible small geometric inaccuracies of the vector product (due to VHR geometric imprecision, smoothing of the vector products outlines, etc.). The geometric resolution is consistent with the EEA reference grid. The coding of the raster is as follows:

- 0: all non-SWF area
- 1: SWF area
- 254: unclassifiable (missing data, clouds)
- 255: outside area

**Input:** SWF 2018 vector

**Output:** SWF 2018 5 m raster

**Production steps:**

1. Conversion from vector to raster layer (value of 1 is assigned to pixels covering more than 50% of the SWF found in the vector layer)
2. Add attribute table
3. Add boundary

## (vii) Derived Products

### *SWF 2018 Density 100 m raster*

The SWF 2018 100 m raster layer, consistent with the EEA 100 m grid, is a 100 m-aggregated version of the SWF 2018 5 m raster layer. It represents the SWF density from 0 to 100 % in a 100x100 m cell.

To derive this layer from the SWF 2018 5 m raster layer, the 100 m grid cell value is the arithmetic mean density of valid SWF 5 m pixels, excluding all “outside area” and “unclassifiable” pixels (= invalid pixels). This is done considering that the 5 m valid pixels represent more than 50 % of a corresponding 100 m grid cell. If the number of valid 5 m pixels represent less than 50 % of a corresponding 100 m grid cell, this cell is assigned the value “outside area” (255) or “unclassifiable” (254) depending on the relative majority of underlying 254 or 255 5 m pixels (Table 9). The coding of the raster is as follows:

- 0: all non-SWF area
- 1: SWF area
- 254: unclassifiable (missing data, clouds)
- 255: outside area

**Input:** SWF 2018 5 m raster

**Output:** SWF 2018 100 m raster

#### **Production steps:**

1. Aggregation of 5 m raster product (arithmetic mean density of valid SWF 5 m pixels, excluding all “outside area” and “unclassifiable” pixels)
2. Add attribute table
3. Add boundary

*Table 9: Aggregation rules for the 100 m SWF status product.*

Aggregation rules for status layers	
Valid pixels (inside AOI)	If the majority of 5 m pixels within a 100 m cell has a valid value (other than 255) the following rules apply:  If one or more underlying pixels are unclassifiable (pixel value 254) within the valid pixel mask, then unclassifiable (254) is assigned.  If no pixel is unclassifiable (pixel value 254): <ul style="list-style-type: none"><li>• The average value of the 100 m cell is calculated, taking only the valid pixels into account.</li></ul>
Invalid pixels (outside area)	If the majority of 5 m pixels within a 100 m cell is outside area (pixel value 255).

### *Confidence Layer for the Woody Vegetation Mask 5 m raster*

A Confidence Layer for the Woody Vegetation Mask 5m raster layer is provided to indicate the quality of the information and the reliance of the mapped features. The production of this confidence layer was an

integrated part of the production workflow. This layer provides useful supplemental information about the product's quality. It allows users to take into account the different reliability of the SWF product, e.g., caused by input data quality, and e.g., exclude information with high uncertainty from further analysis.

The uncertainty associated with thematic classification is generally due to:

1. the uncertainties from the input data,
2. the propagation of these uncertainties through the pre-processing chain, and
3. the uncertainties introduced within the classification module.

The confidence of the classification is calculated based on different measures derived during the production process:

- The amount and quality of input EO data (amount and dispersion of valid observations)
- The confidence of the classification by accounting for uncertainties within the woody vegetation classification procedure

Depending on the used classification algorithm, the above-mentioned properties can be derived during the classification procedure. The quality of the input data is directly affecting the classification accuracy. Since the classification is performed using a random forest classifier, the probability of the binary mask is a direct output of the algorithm and a strong indicator for both, the data quality and the classification accuracy. Therefore, the classification confidence is derived as the numeric proximity to the class probability threshold.

#### *[Parent Scene Identification Layer](#)*

The Parent Scene Identification Layer (PSIL) of the SWF product is an additional layer in form of a Geodatabase. The layer comprises information on the VHR EO image data used in the production of the HRL. For each SWF 2018 production unit, the layer gives information about the intersecting VHR footprints ID's and all filtered VHR\_IMAGE\_2018 and VHR\_IMAGE\_2018\_ENHANCED scenes that were used for the production. The PSIL product is meant to increase transparency of the layer production, to provide a valuable aid in the validation process and quality control of the SWF layers, and to provide a basis for further analyses and investigations.

#### *(viii) Small Woody Feature Change Layer 2015-2018*

The Small Woody Feature Change (SWFC) Layer 2015-2018 is produced by comparison of 2015 data with the new 2018 status layer. The steps of the change workflow are illustrated in Figure 8.

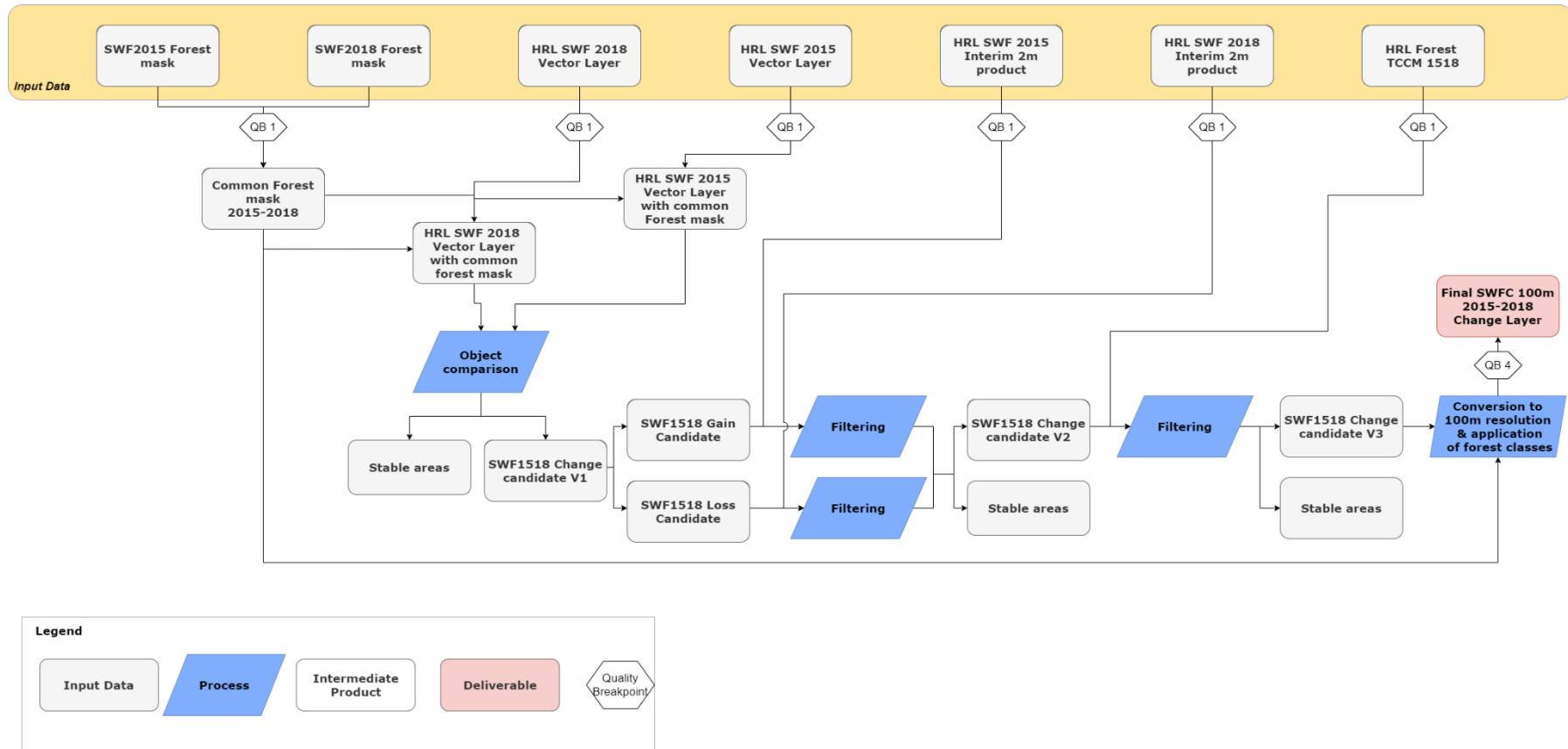


Figure 8: Workflow for the HRL SWFC 2015-2018 100 m raster layer

The workflow relies on four main steps:

1. Comparison between SWF 2015 and SWF 2018 products was performed at the object level on the vector product. Using complex geometric testing, objects that present similar outlines were excluded from the change candidates. This allowed for the removal of the artefacts around edges of stable elements. This is illustrated in Figure 9. On the left side, the direct comparison of status layer in raster format produced noise around central stable elements. On the right side, the comparison of objects allowed to avoid the slight outline differences to be considered as changes, and therefore only significant differences between the two reference years were considered as potential change.

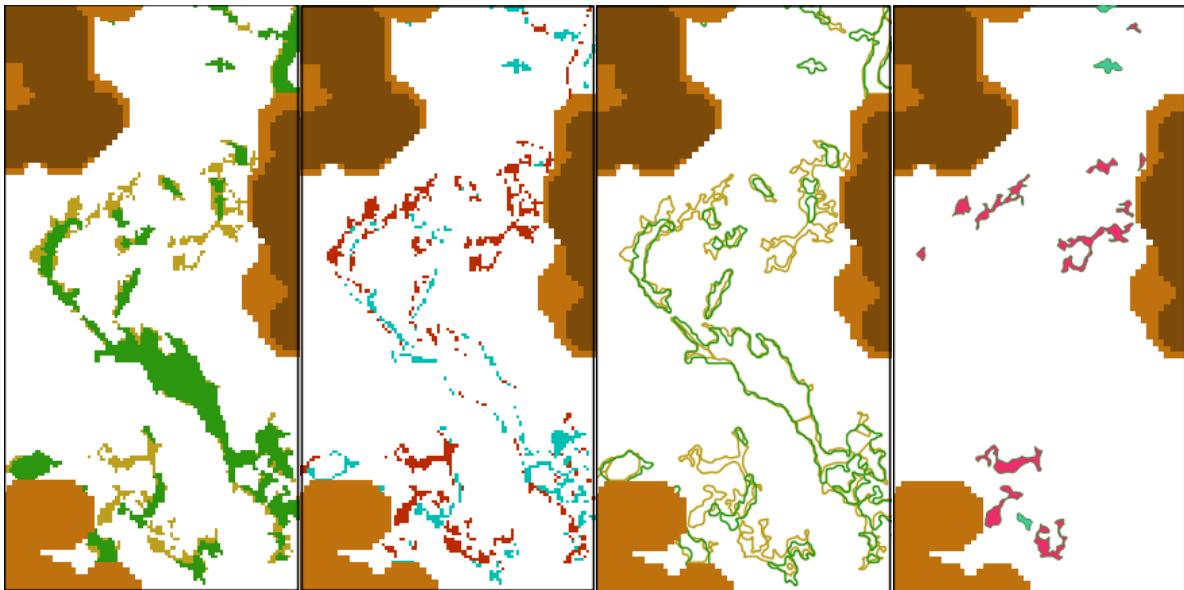


Figure 9: Comparison between SWF 2015 and SWF 2018 (left: raster comparison; right: vector comparison. Yellow: SW F2015; green: SWF 2018; blue: gain candidate; red: loss candidate; light brown: forest mask 2015; dark brown: forest mask 2018) Italy, near Turin

2. Removal of false changes: During SWF 2015 and SWF 2018 production, an interim 2 m resolution woody/non woody product was generated. The change candidates from step 1 were compared to those interim 2 m products. If a similarity was detected between the change candidate and the interim product, this candidate was considered as false change and classified as a stable area. In Figure 10, the black polygon is a loss candidate (present in SWF 2015 status layer, but not in SWF 2018 status layer). Being a tree plantation, it is present in the interim 2018 layer but has been removed from the final layer (it is therefore a commission error in the SWF 2015 product). As a similarity existed between the 2018 interim layer and the polygon outline, it was not considered as a valid change. On the opposite, the red polygon was also a loss candidate that did not appear in the 2018 interim product and thus was kept as a valid change candidate.

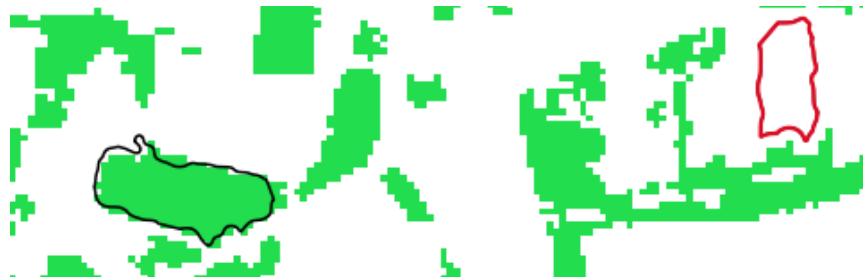


Figure 10: Filtering using 2 m interim product, example of loss candidate (Green: 2018 interim product; Black: loss candidate excluded; Red: loss candidate selected) Italy, near Turin

3. Consistency check with HRL Tree Cover Change Mask (TCCM) 2018: To ensure consistency with HRL 2018 Forest products, any large change candidate ( $> 1 \text{ ha}$ ) was compared to HRL TCCM 2018. A large change candidate was considered valid if detected in both products.

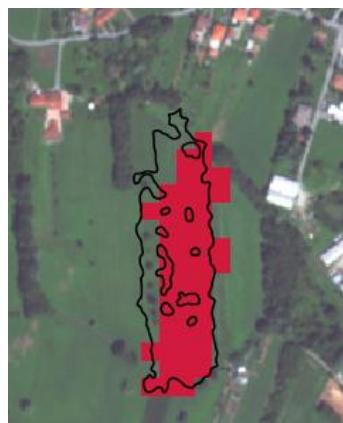


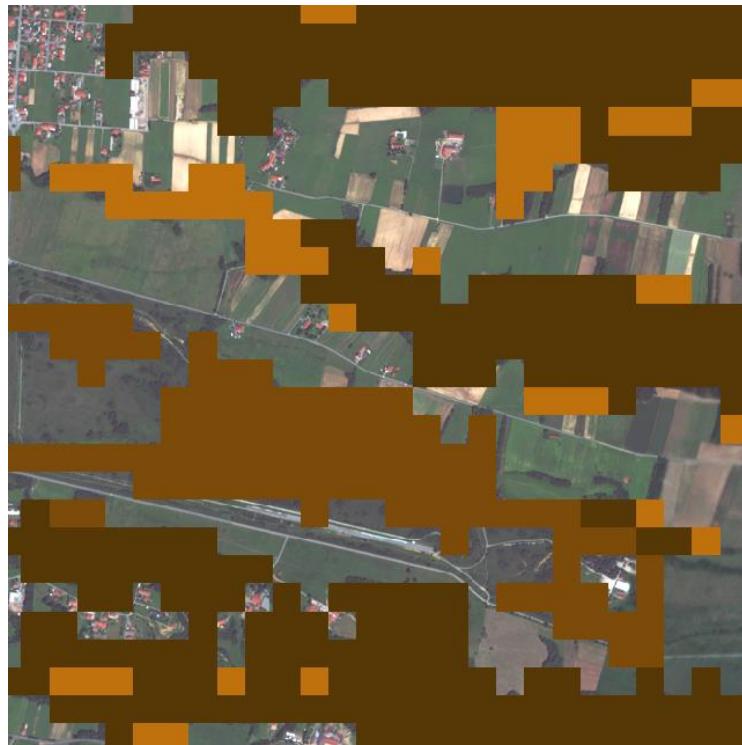
Figure 11: Large loss candidate (black outline) confirmed by HRL TCCM 2018 (red pixels) Italy, near Turin



Figure 12: Gain candidate (black outline) not confirmed by HRL TCCM 2018. Young tree plantation can be easily identified in 2015 (thus removed from the product). Using 2018 VHR, artificial nature of this area is not obvious, and the woody feature has been kept in 2018. Italy, near Turin

4. Application of forest masks 2015 & 2018: The forest masks 2015 and 2018 were applied to the SWFC product to clearly identify which areas were masked in one or both reference years. Indeed,

areas masked by one or both forest mask cannot contain change information as SWF data is missing for at least one reference year.



*Figure 13: Identification of Forest masks in SWFC product (from light brown to dark brown: covered by Forest Mask 2015, covered by Forest Mask 2018, covered by both Forest Masks) Italy, near Turin*

## b. Limitations

### EO Data Availability and Quality

EO dataset used to produce HRL SWF 2018 products are detailed in previous sub-section (i).

As the HRL 2018 SWF products relies on a mono-temporal EO dataset, the quality of the VHR scenes is primordial to allow the correct detection of landscape elements, especially for small elements such as SWF. While the 2018 EO dataset shows an overall improvement compared to the 2015 EO dataset used for the production of SWF2015, some specifications of the 2018 EO datasets can lower locally the quality of the SWF 2018 products:

- The 2018 EO dataset consists of VHR scenes between 2 m and 4 m spatial resolution. With no access to panchromatic data, the detection of small elements can be complex when processing 4 m spatial resolution data. This situation worsens if the area covered by 4 m data is subject to relief or high acquisition angle with long shadows.
- There is no co-registration within VHR scenes for an EO dataset, and no co-registration between VHR scenes from different datasets (2018 and 2015).
- For a given area, 2015 and 2018 coverage may present differences in terms of acquisition time, acquisition angle and sensor (i.e., spatial resolution). Due to these differences, a stable element can

be depicted differently on VHR 2015 and VHR 2018 and therefore in SWF 2015 and SWF 2018 products. This has an impact on the change detection.

## Change Detection

While the SWFC workflow allows the ability to deal with a significant part of challenges faced during the production - mostly due to definition changes between SWF 2015 and SWF 2018 (SWF classes, Forest mask extent) or EO input data limitations (cf. above section) - the change detection, and therefore the SWFC product suffers some limitations as a consequence. These are:

- The workflow used cannot deal with significant shifts ( $> 10$  m) that could exist between VHR\_IMAGE\_2015 and VHR\_IMAGE\_2018 datasets.
- Complex landscapes (e.g., open forest in Mediterranean areas) can be significantly impacted by the evolution of the status layer production. For SWF 2015, the Forest Mask (based on HRL Tree Cover Density (TCD) 2015 30%) was quite inaccurate over those areas. It implied a tremendous amount of manual effort to clean woody features detected within these landscapes as they were not totally covered by the forest mask. For SWF 2018, the definition of the forest mask and the improved spatial/thematic accuracy of TCD 2018 allowed to better cover these landscapes. However, applying the same manual effort in cleaning the not covered open forest would have had an impact on the Woody Vegetation Mask product (i.e. woody vegetation not covered by the forest mask, without any application of geometric rules). Therefore, it is likely that open forest not covered by the respective forest masks can be reflected differently in SWF 2015 and SWF 2018, leading to potential confusions within the SWFC.
- Additionally, the SWFC workflow does not aim at correcting existing errors within 2015 and 2018 status products and leans toward a conservative approach to avoid removing real changes from the product. Errors from SWF 2015 and SWF 2018 products are the origins of the remaining commissions errors (false changes) or omission errors (false stable area) within the SWFC product. Correcting those errors would need a dedicated workflow aiming at harmonising the reference status layers 2015 and 2018 (independent from SWFC production but linked to its thematic quality).

## c. Differences with the previous version 2015

A short overview of the major changes in the methodology compared to the previous version 2015 is given below:

- Input data VHR 2018 at 2-4 m spatial resolution, with no pan sharpening
- SWF 2018 Product geometrical specifications (see section V)
- Forest masking based on HRL TCD 2018 with new definitions (see section V)
- Updated reference and calibration dataset

## VII. Quality Assessment

### Internal Validation

Each HRL product is subject to an internal validation. This section provides guidance on how the products are validated by defining suitable indicators or metrics. Although the validation is consortium-internal, independency is sought as far as possible. The accuracy requirements to be achieved according to AD03 are 90 % for producer's accuracy (commission) and 90 % for user's accuracy (omission).

Classification correctness is evaluated using misclassification rate and/or misclassification matrix. Contrary to logical consistency or completeness, thematic accuracy cannot be subjected to an exhaustive check. Thus, thematic accuracy assessment has three components: (i) the sampling design, (ii) the response design and (iii) the estimation and analysis procedures.

The stratification and the sampling design consist primarily in selecting an appropriate sampling frame and sampling unit. It is based on the LUCAS (Land Use/Cover Area frame statistical Survey) sampling approach. LUCAS corresponds to a grid of approximately 1,100,000 points throughout the European Union where land cover or land use type is observed. Using LUCAS points ensures traceability and coherence between the different layers. Primary Samples Units (PSU) of 100 x 100 m were drawn based on this LUCAS grid.

The response design is the photo-interpretation of each sample unit and is based on the independent assessment at the unit level. The reference data are the images used in the production, the VHR\_IMAGE\_2018 dataset complemented by other ancillary data and on-line EO platforms (see section VI. (ii)). The last step, the analysis procedure, consists in analysing the samples in order to draw conclusions for the thematic accuracy of the product. Thematic accuracy is presented in the form of an error matrix resulting from samples interpretation. The different accuracies (Overall thematic, Producer's and User's Accuracy) are provided as well as 95 % confidence intervals and documented in the relevant delivery reports and metadata.

### Thematic Accuracy

SWF 2018 5m raster product has been validated during the course of the production, with results available through a confusion matrix. The confusion matrix below (Table 10) illustrates the weighted accuracies figures at PSU level for the EEA38 + UK area including DOMs, which corresponds to 282 Production Units of the final 100% delivery.

Table 10: Weighted accuracy figures for the SWF2018 5m product at PSU level for EEA39 areas including DOMs

	Reference data		Row Total	User's Accuracy	Commission Error	95% Confidence Interval
SWF2018 product	SWF	Non SWF				
SWF	<b>3223.91</b>	322.25	3546.16	90.91%	9.90%	0.52
Non SWF	432.69	<b>8803.18</b>	9235.87	95.32%	4.68%	0.32
Column Total	3656.60	9125.43	<b>12782.03</b>			
Producer's Accuracy	88.17%	96.47%				
Omission Error	11.83%	3.53%				
95% Confidence Interval	0.59	0.20				
<b>Overall Accuracy</b>	<b>94.09%</b>					
<b>95% Confidence Interval</b>	0.22					
<b>Kappa coefficient</b>	0.85					

Table 10 shows the highly improved quality of the SWF product for the reference year 2018 as compared to 2015 (see HRL2015 SWF product specification document<sup>4</sup>). Overall thematic Accuracy (OA) as well as User's (UA) and Producer's Accuracies (PA) exceed the required minimum of 80 % at 95 % confidence level. As expected, the weighted figures confirm the very good results at PSU level. Commission errors for SWF is 9.09 % and UA of 90.91 %, for Non-SWF the commission error is 4.68 % with a UA of 95.32 %. The omission error for the Non-SWF is 3.53 % with a PA of 96.47 % and the omission error of the SWF class is slightly higher at 11.83 % with a PA of 88.17 %. This reveals that presence and absence of SWF and Non-SWF within a PSU could be detected with high precision, however, a certain degree of SWF land cover was not detected. The OA of the weighted results is 94.09 % with a confidence interval of +/-0.22 at 95 % confidence level.

The slightly lower figures for PA of the SWF class at PSU level might derive from the complex differentiation between woody vegetation and the different types of forest (types of trees, density, height, coverage), which in some cases is not obvious and straightforward. Since spectral characteristics are similar, a semi-automated production workflow might have its limitations in correctly capturing the differences. Nevertheless, the overall accuracy results are more than satisfying and confirm that the SWF 2018 is a highly meaningful and reliable product.

<sup>4</sup> [https://land.copernicus.eu/user-corner/technical-library/hrl\\_lot5\\_d5-1\\_product-specification-document\\_i3-4\\_public-1.pdf](https://land.copernicus.eu/user-corner/technical-library/hrl_lot5_d5-1_product-specification-document_i3-4_public-1.pdf)

## QA/QC Procedures

Checking the quality of the products is a key component of the project. Technical Quality Assurance (QA) and Quality Control (QC) procedures were implemented on all production sites (Partners and sub-contractors). All procedures of technical Quality Assurance (QA) and Quality Control (QC) have been implemented consistently and under the coordination and supervision of the project's Quality Manager. Within the overall QA/QC scheme dedicated technical QA/QC were performed throughout the entire HRL production chain, including:

- Continuous monitoring and maintenance of the processing infrastructure
- Quality Assurance within the production process, applying planned and systematic checks at various stages between data collection and the final product, as well as
- Final Quality Control after the main production of the HRLs (but still before making final data aggregation and re-projection), where the accuracy and precision of the products is being assessed.

The introduction of a centralised cloud processing environment was a key improvement compared to previous implementations and permitted a more systematic and objective QA/QC mechanism.

Quality assurance followed the ISO9001 standards for Quality Management<sup>5</sup> and the INSPIRE data quality elements. It comprised dedicated procedures of quality checks (QA breakpoints) during implementation of the production chain, in order to (i) keep persistent control over the various stages of production, (ii) assure fitness-for-purpose of the end-products and (iii) assure that all quality requirements are fulfilled, including:

- Thematic accuracy & consistency
- Geometric accuracy & consistency
- Logical / topologic consistency
- Thematic coding / attributes
- Metadata completeness and compliance to INSPIRE.

Priority was given to the target thematic accuracies to be achieved by each product, as well as to the issues of product consistency (spatial and temporal) and homogeneity.

QC breakpoints (QB) were located at the end of each main production steps (see Figure 3 and Figure 8):

- **QB1 – Verification of incoming EO and ancillary data**
- **QB2 – Quality Check of pre-classified Woody Vegetation Mask**
- **QB3 – Quality of the Woody Vegetation Mask**
- **QB4 – Quality check of final vector and raster layer**
- **QB5 - Quality check of final raster change layer**

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<sup>5</sup> ISO 9001:2015

## VIII. Terms of Use and Product Technical Support

### Terms of Use

The product(s) described in this document is/are created in the frame of the Copernicus programme of the European Union by the European Environment Agency (product custodian) and is/are owned by the European Union. The product(s) can be used according to the Copernicus full free and open data policy, which allows the use of the product(s) also for any commercial purpose. Derived products created by end users from the product(s) described in this document are owned by the end users, who have all intellectual rights to the derived products.

### Citation

In cases of re-dissemination of the product(s) described in this document or when the product(s) is/are used to create a derived product it is required to provide a reference to the source. A template is provided below:

"© European Union, Copernicus Land Monitoring Service <year>, European Environment Agency (EEA)"

### Product Technical Support

Product technical support is provided by the product custodian through Copernicus Land Monitoring Service helpdesk at [copernicus@eea.europa.eu](mailto:copernicus@eea.europa.eu). Product technical support doesn't include software specific user support or general GIS or remote sensing support.

## IX. References

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THE COUNCIL OF THE EUROPEAN COMMUNITIES (1992): COUNCIL DIRECTIVE 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive). OJ L 206 of 22.7.1992

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## X. Annexes

### Annex 1: Naming Convention of HRL 2018 Products

The following 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
- 4 letter abbreviation for change products
- 5 letter abbreviation for additional and expert products

#### REFERENCE YEAR

- 2018, 2015, etc. in four digits
- Change products in four digits (e.g., 1518)

#### RESOLUTION

- Four-digit (e.g., 010m and 100m)

#### EXTENT

- 2-digit country code for country deliveries in national projection
- “eu” for all deliveries in European Projection

#### 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

## Annex 2: File Naming Nomenclature of HRL Small Woody Features 2018 Products

Legend:

Status product	Change product	Expert product
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Descriptor	To be written as	Meaning	Comments
THEME	SWF	Small Woody Feature	Abbreviation to be used for main products
	VVM	Woody Vegetation Mask	
	SWF_FM	Small Woody Feature Forest mask	
	SWFC	Small Woody Feature Change	Abbreviation to be used for change product
	SWFCL	Confidence Layer	Additional products
	SWFPSIL	Parent Scene Identification Layer	
REFERENCE YEAR	2015	Reference year 2015 (+/- 1 year)	
	2018	Reference year 2018 (+/- 1 year)	
	1518	Change 2015-2018	
RESOLUTION	05m	5m spatial (pixel) resolution	
	100m	100m spatial (pixel) resolution	
EXTENT	al	Albania	2-letter abbreviation for the country (in national projections), "eu" for deliveries in European projection and additional EEA cell grid code for tile based delivery (e.g., eu_E02N65)
	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	European Projection mosaic deliver	
	ExxNxx	European Projection tile based delivery	
	fi	Finland	
	fr	France	
	gb	United Kingdom	
	gf	French Guiana	
	gp	Guadeloupe	
	gr	Greece	
	hr	Croatia	
	hu	Hungary	
	ie	Ireland	
	im	Isle of Man	
	is	Iceland	
	it	Italy	
	li	Liechtenstein	
	lt	Lithuania	
	lu	Luxembourg	

<b>Descriptor</b>	<b>To be written as</b>	<b>Meaning</b>	<b>Comments</b>
	lv	Latvia	
	me	Montenegro	
	mk	Macedonia, FYR of	
	mq	Martinique	
	mt	Malta	
	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	LAEA (European Projection)	5-digit EPSG code (see <a href="http://www.epsg-registry.org/">http://www.epsg-registry.org/</a> )
VERSION	V1_0	First full final version	4-digit qualifier of the version number, starting with "V1_0" for a first full final version, and allowing to capture re-processing/calculation of small changes as ("V1_1", "V1_2" etc.). In case of major changes, a second version should be used ("V2_0").
	V1_1	Re-delivery of first full final version with small changes	
	V2_0	Second full final version	
	etc.	etc.	

## Annex 3: Download Content

All HRL products can be downloaded from the CLMS website under <https://land.copernicus.eu/pan-european/high-resolution-layers>. Please note, that an account needs to be created in order to login and download the products. Products can be downloaded as full pan-European mosaic or as tiles with a side length of 1000 km x 1000 km.

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 colour tables (\*.clr & \*.txt) and INSPIRE-compliant metadata in XML format and an INSPIRE Mapping Table.

In addition, a Coordinate Reference Sheet (CRS) is provided in PDF format, listing the characteristics of the European Terrestrial Reference System 1989.

Vector products are provided in shapefile (\*.shp) format or as ESRI File Geodatabase.

## Annex 4: Coordinate Reference System Sheet

National products are accompanied with a PDF providing Coordinate Reference System (CRS) information, including details of parameters used to transform to ETRS89 LAEA projection. CRS information sheets will be static and named as follows:

CRS\_Information\_Sheet\_<country 2-letter ISO code>, e.g., CRS\_Information\_Sheet\_HU.pdf.

*Table 1: Example of a Coordinate Reference System Sheet for Hungary*

National		
Datum		HD72 (EOV - Egységes Országos Vétületi 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 (Position vector)
	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 5: Colour Palettes and Attribute Fields

All HRL products are delivered with an embedded raster colormap including the following attribute fields in the \*.tif.dbf file: ["value", "count", "area\_km2", "area\_perc", "class\_name"].

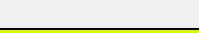
For each product, both the GIS files specifying the colour palettes, and a table listing the RGB values for possible non-GIS products and material are provided.

Formats:

- \*.clr for GIS colour palettes
- \*.txt for other purpose

The colour palettes are as follow:

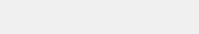
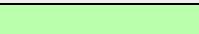
### SWF 5 m raster product

Class code	Class name	Red	Green	Blue	Render
0	Non SWF area	240	240	240	
1	SWF area	215	245	0	
254	Unclassified	153	153	153	
255	Outside Area	0	0	0	

### WVM 5 m raster product

Class code	Class name	Red	Green	Blue	Render
0	Non Woody area	240	240	240	
1	Woody vegetation	117	221	0	
254	Unclassified	153	153	153	
255	Outside Area	0	0	0	

### SWF 100 m raster product (SWF density)

Class code	Class name	Red	Green	Blue	Render
0	Non SWF area	240	240	240	
1	1% SWF density	186	255	172	
50	50% SWF density	85	160	89	
100	100% SWF density	28	92	36	
254	Unclassified	153	153	153	
255	Outside Area	0	0	0	

### **SWFC 1518 100 m Change product**

<b>Class code</b>	<b>Class name</b>	<b>Red</b>	<b>Green</b>	<b>Blue</b>	<b>Render</b>
0	Stable Area	240	240	240	
1	Increase in SWF density	20	255	0	Green
2	Decrease in SWF density	255	0	0	Red
201	Forest mask 2015	188	130	67	Brown
202	Forest mask 2018	121	83	43	Brown
203	Forest mask 2015 & 2018	88	61	31	Brown
254	Unclassified (missing data 2015)	153	153	153	Grey
255	Outside Area	0	0	0	