

User Manual

Copernicus Land Monitoring Service

High Resolution land cover characteristics

Grassland 2018 and Grassland change 2015-2018



European Environment Agency



Consortium Partners:

Consortium Composition of the Copernicus HRL Lot 3 2018			
No.	Organisation name	Organisation short name	Country
Consortium Partners			
1	GAF AG (Lead)	GAF	Germany
2	e-geos	e-geos	Italy
3	GeoVille GmbH	GeoVille	Austria

Contact:

Copernicus Land Monitoring Service (CLMS)
European Environment Agency (EEA)
Kongens Nytorv 6 – 1050 Copenhagen K. – Denmark
<https://land.copernicus.eu/>

Lead service provider for production: GAF AG
Arnulfstr. 199 – 80634 Munich - Germany
E-mail: info@gaf.de – Internet: <https://www.gaf.de/>

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ABBREVIATIONS

AD	Applicable Document
BfN	Bundesamt für Naturschutz (German Federal Agency for Nature Conservation)
BoA	Bottom of Atmosphere
CLMS	Copernicus Land Monitoring Service
DIAS	Data and Information Access Services
DDL	Data Density Layer
DDL	Data Score Layer
CLMS	Copernicus Land Monitoring Service

CORINE	Coordination of Information on the Environment
DIAS	Data and Information Access Services
DOM	Départements d'outre-mer
DVVVH	Difference of polarizations VV and VH
ECoLass	Evolution of Copernicus Land Services based on Sentinel data
EEA	European Environment Agency
EO	Earth Observation
ETRS89	European Terrestrial Reference System 1989
GRA	Grassland
GRAC	Grassland Change Layer
GRACL	Grassland Confidence Layer
GRAVPI	Grassland Vegetation Probability Index
IMD	Imperviousness Degree
INSPIRE	INfrastructure for SPatial InfoRmation in Europe
IPCC	Intergovernmental Panel on Climate Change
IRECI	Inverted Red-Edge Chlorophyll Index
JRC	European Commission DG Joint Research Centre
HRL	High Resolution Layers
S-1	Sentinel-1, space mission carried out by ESA within Copernicus Programme, C-band SAR satellites (S-1A + S-1B)
S-2	Sentinel-2, space mission carried out by ESA within Copernicus Programme, EO satellites (S-2A + S-2BL1C)
LAEA	Lambert Azimuthal Equal Area projection
LPIS	Land Parcel Identification Service
LC	Land Cover
LU	Land Use
LUCAS	Land Use/Cover Area Frame Statistical Survey
MMU	Minimum Mapping Unit
MUNDI	Satellite Date platform
NBR	Normalized Difference BIR/SWIR
NDVI	Normalized Difference Vegetation Index (NIR-R)/(NIR+R)
NDVVVH	Normalized Difference of VV and VH polarisation (S-1 Index)
NDWI	Normalized Difference Water Index (NIR-SWIR)/(NIR+SWIR)
NIR	Near Infrared
OA	Overall Accuracy
OSM	open Street Map
OTC	Open Telecom Cloud

PA	Producer's Accuracy
PLOUGH	Layer indicating ploughing events on grassland patches
PU	Production unit
QA	Quality Assurance
R&D	Research & Development
RF	Random Forest (Classifier)
RVV VH	Ratio of VV and VH polarisation
SCL	Scene Classification Layer
SAR	Synthetic Aperture Radar
SWIR	Short-wave Infrared
TF	Time feature
UA	User's Accuracy
WFS	Web Feature Service
WMS	Web Map Service
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 information on land cover and its changes, land use, vegetation state, 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.

The 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) Grassland for the 2018 reference year. One previous Grassland product exists for the 2015 reference year, following a 3-years update cycle. The HRL Grassland with reference year 2018 has been fully produced in the European Terrestrial Reference System 1989 (ETRS89) and Lambert Azimuthal Equal Area (LAEA) projections by a consortium of well-established European service providers.

As its predecessor, the HRL Grassland 2018 (HRL 2018 GRA) product aims at providing a synoptic view on the distribution, extent and dynamics of the pan-European grasslands, comprising natural, semi-natural and managed grasslands and displaying the diversity of grassland types and various typical grassland landscapes.

The pan-European HRL 2018 GRA consists of two main products: the HRL 2018 Grassland status layer at 10m spatial resolution with reference year 2018 and the HRL 2018 Grassland Change 2015-2018 (GRAC 1518) at 20m spatial resolution.

The GRA status layer is a binary product differentiating between grassland and non-grassland areas with a MMU of 3 pixels (300 m^2). It has been produced with an integrated approach, combining optical Sentinel-2 (S-2) data and Sentinel-1 (S-1) radar data, in order to enhance the overall quality and avoid data gaps caused by clouds, cloud shadows and haze. The resolution of 10m allows detailed grassland mapping, with a highly homogeneous look and feel. Following the HRL GRA 2015, it is the second layer continuing the proven grassland definition but enhanced in several technical aspects (see following chapters).

The HRL GRA Change product is the first of its kind illustrating the change between the reference years 2015 and 2018. It displays newly developed grassland areas and loss of grassland vegetation cover, as well as unchanged areas with and without grass cover. Since grassland shows only little dynamics over time in general, real changes are moderate.

Additional products are the Grassland Vegetation Probability Index (GRAVPI 2018), providing details on the soundness of the grassland class assignment and on the EO data situation and the PLOUGH 2018, providing thematic information on ploughing events derived from historic data (PLOUGH 2018). Further expert products such as the Grassland Confidence Layer (GRACL 2018), indicating the reliability of the classification, complement the HRL Grassland product portfolio. Besides the pan-European

version in LAEA projection, all primary products – the GRA status maps in 10m and 100m resolution and the GRA Change Layer as well as PLOUGH and GRAVPI - have been produced as national datasets in the respective national projections.

All HRL GRA layers aim at addressing information and data needs for the support of European policy making, but also for national and regional users from science, industry and private users.

II. Background of the document

Scope of the document

The Product User Manual is the primary document that users are recommended to consult 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 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 summarizes 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

Ref.	Document Name
AD01	Tender specifications: EEA/IDM/R0/18/009
AD02	H2020 EcoLasSS User Requirement Analysis: Deliverable D3.2 - Service Evolution Requirements Report Vol. 2
AD03	Nexspace User Study: Nexspace database for user requirements

III. Review of user requirements

Grasslands cover significant parts of the European agricultural area, but are very diverse with regards to their distribution, intensity and type of use, species composition, productivity, and management systems. Grasslands have multiple functions and values, they provide grazing for domestic and wild animals, protect the soil from erosion, support biodiversity and some extensive grassland types have very high nature value. In addition, they fulfil a variety of cultural and recreational functions.

Generally speaking, grasslands, in particular high nature value extensive grasslands, are under threat from both agricultural intensification, and land abandonment.

The distribution and dynamics of grassland (and ultimately also grassland condition and use intensity) is therefore important for a number of European Policies, but also for national and regional applications. The CLMS grassland product can be one relevant dataset to help monitor grassland distribution, extent, and change.

More generically: In the frame of the Horizon 2020 (H2020) project ECoLaSS, a survey (AD03) of key stakeholders has been performed, in order to evaluate the user requirements towards the evolution of existing and future Copernicus products. This survey made also use of the results from the Nextspace User Study (AD04) and revealed that HRL users like European institutions, service industry, research and academia, national agencies, regional administrations, NGS 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
- Standardized and comparable nomenclature
- Transparent and scientific workflows and state-of-the-art methodology
- Detailed documentation of these workflows and the respective methodologies
- 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 taken into account in current or upcoming implementations. However, key Copernicus users and stakeholders would appreciate even more thematic information such as Grassland use intensity (or the dynamic of intensification/extensification), or mowing frequency in grassland areas, additional

seasonal and phenological information or even differentiation between different grassland types (AD02). While other projects have proven that mowing frequency and phenological information are realistic to include in future HRL Grassland implementations, the differentiation between intensification/extensification as well as the differentiation between grassland types are still difficult to implement due to the high intra-seasonal dynamics of this type of vegetation. Shorter update cycles are questionable since it would require ancillary and In-situ data of shorter update cycles as well. Further consolidation and harmonisation with a future CLMS crop monitoring product is currently under discussion.

IV. Product application areas and examples of use cases

As the largest biome of the planet, grassland - comprising both soil and plants – plays an important role, both in an ecological and political perspective. Grassland houses a variety of ecosystems, counters soil erosion, stimulates remineralisation and accumulation of humus, protects groundwater and has, similar to forest, high potential for long-term storage of CO₂ (CIAIS et al. 2010). The wide geographic spread of grasslands across different climatic, topographic and geological conditions within the European countries reflects their adaptive capacity and resilience. However, grasslands as well as other environmental resources are under pressure due to conflicting land-use demands, competing with economic activity, increased mobility, urbanization and pollution to name a few. Thus, human impact and climate change already has, and will continue to have, significant implications on the distribution of grasslands, their biological diversity and their biomass production potential in the future (CHANG et al. 2017). Objective knowledge about status, transformation and potential threats is essential for implementing effective and sound policy measures for protecting these environmental resources (EEA 2014).

Providing a synoptic overview of the distribution, extent and change of grassland, the HRL GRA products are of high interest for all users on European, national as well as regional level who deal with the preservation of natural resources and of biodiversity or work at the interface between nature, society and economy. In this respect, both, the HRL GRA status layers as well as the change layer allow for retrieving information on vegetation status for a certain reference year as well as for monitoring the dynamics of land use and land cover. They can complement more locally oriented products like Natura2000 and Riparian Zones but could also support precision and relevance of other Pan-European or even global products like CORINE, LUCAS or the Farm Structure Survey data.

In addition, HRL products can contribute to the development or enhancement of different other products. Some examples, collected in the already mentioned survey within the frame of ECoLaSS:

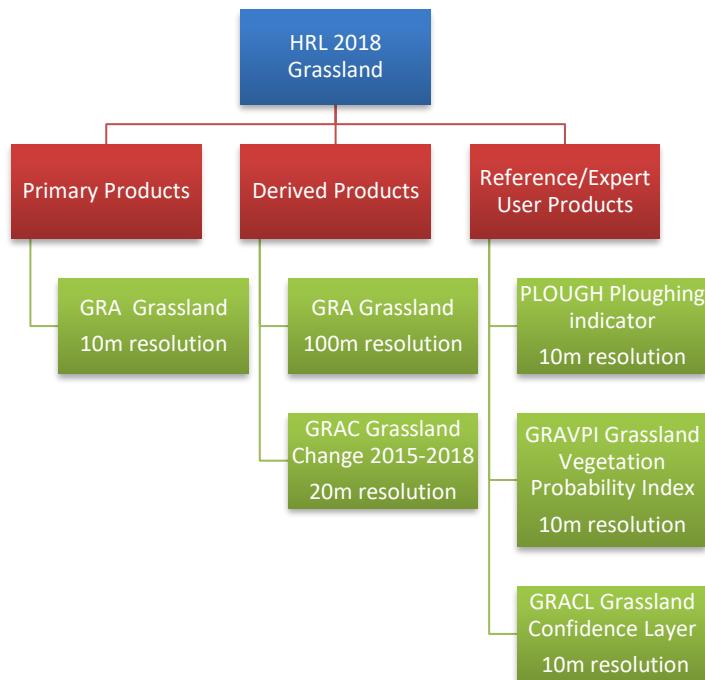
- For the member states of the EC, the HRL GRA status layer is already a source of information by meeting the need for reporting to the Habitats Directive (Article 17).

- The JRC already uses information of HRL products for the Global Atlas of Desertification and for several products of its Food Security and Forestry Unit (land grabbing, hot spot monitoring and other topics)
- BfN uses the HRL GRA as a complementary source for identifying bush encroachment in the alpine region.

All HRL products show high consistency; in combination, this comprehensive data source shows the status and dynamic of pan-European land cover and land use patterns.

V. Product description

Overview of the product portfolio



The product portfolio of the HRL GRA 2018 consists of three primary products, the Grassland Status Layer in 10m and in an aggregated 100m resolution and a Grassland Change Layer indicating gain and loss of grassland vegetation between 2015 and 2018. Two further products, PLOUGH and GRAVPI provide additional information in thematic and technical perspective, indicating ploughing events on grassland in previous years (PLOUGH) and the soundness of the grassland classification taking into account both, the confidence of the classifier and the availability of EO data (GRAVPI). A further reference product, GRACL, addresses the interest of expert users by providing information on the reliability of each grassland pixel to be classified as grassland. Examples of the HRL GRA portfolio below:



Figure 1: Part of Amsterdam in Google Earth with HRL 2018 GRA Status layer 2018, 10m



Figure 2: HRL GRA Status Layer 2018, 10m

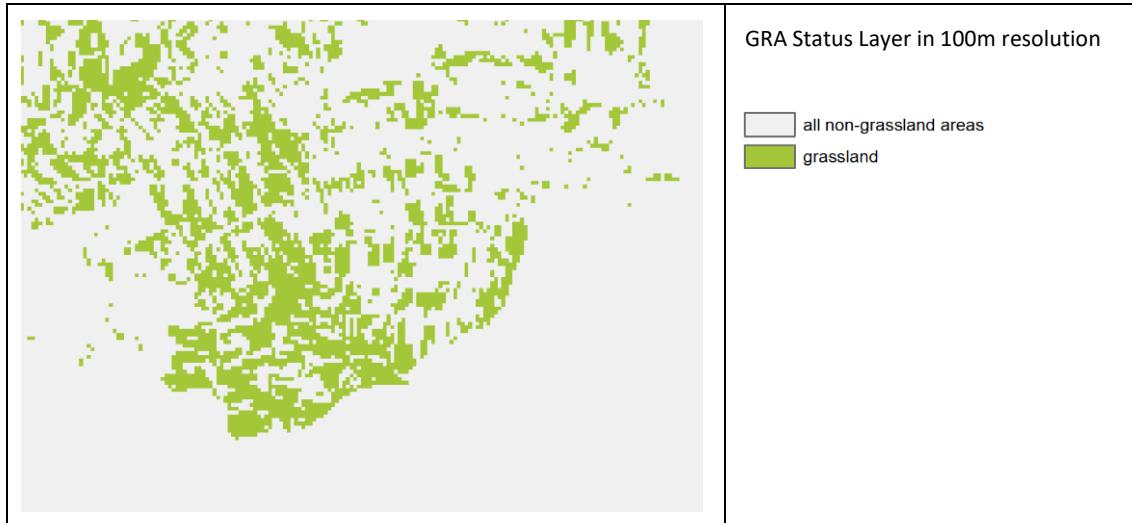


Figure 3: HRL 2018 GRA Status Layer 2018, 100m

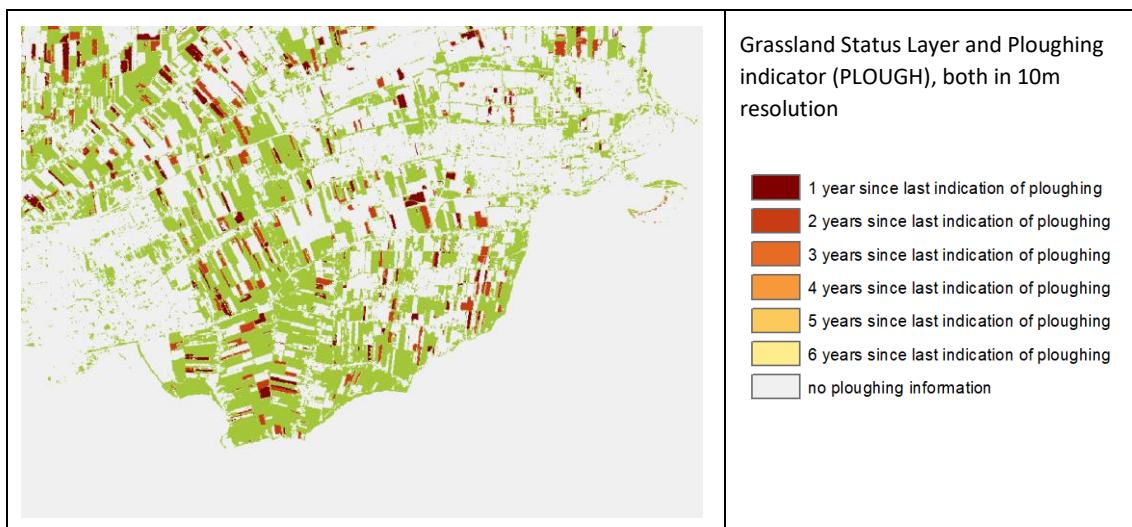


Figure 4: HRL GRA Status Layer 2018 + PLOUGH 2018, 10m

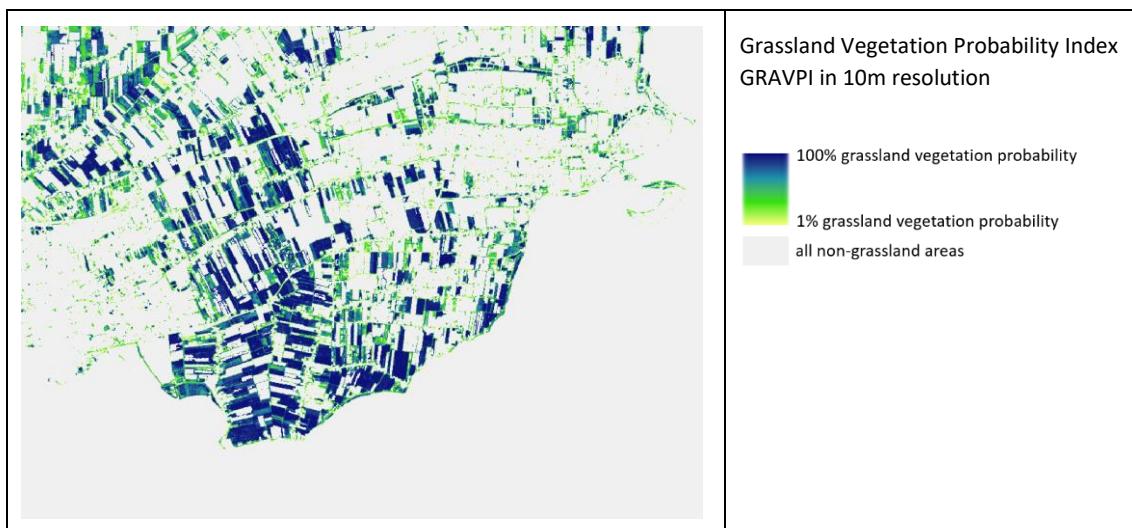


Figure 5: HRL GRAVPI 2018, 10m

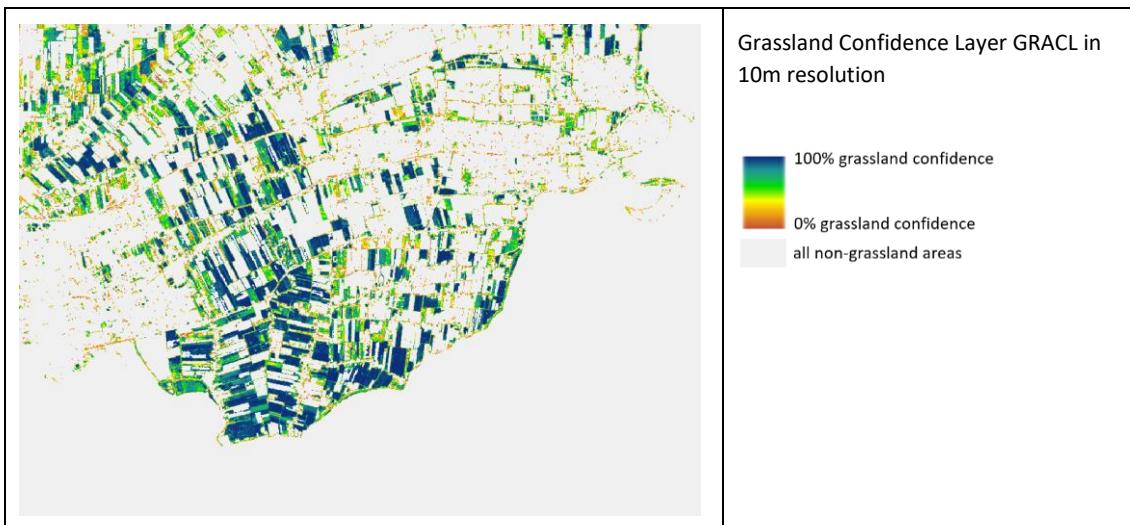


Figure 6: HRL GRACL 2018, 10m

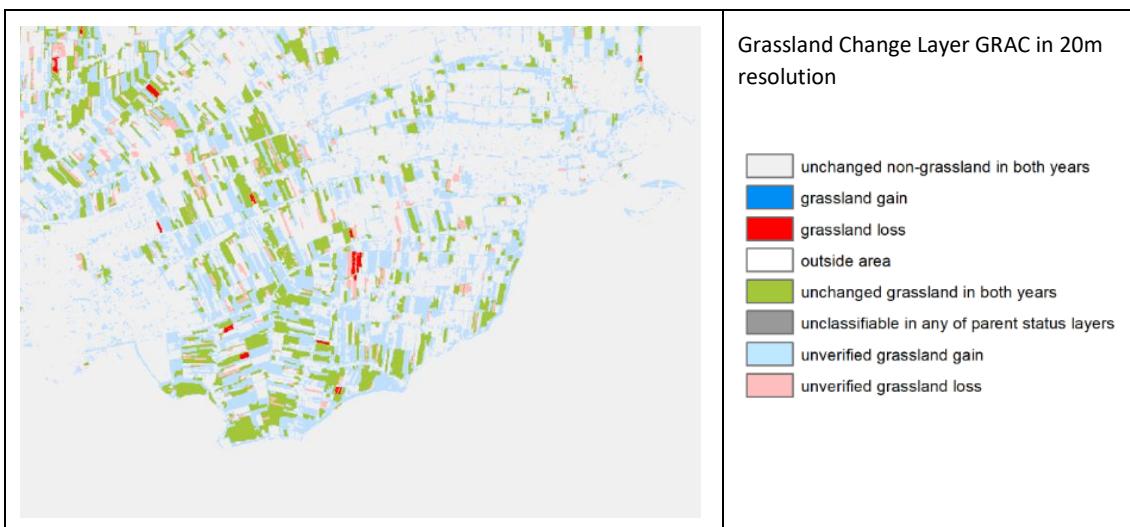


Figure 7: HRL GRAC 2018, 20m

Thematic characteristics of the HRL Grassland 2018

In terms of thematic definition, the HRL Grassland 2018 corresponds to the HRL Grassland 2015 in order to provide consistency and comparability.

The product includes natural, semi-natural and managed grasslands (according to their origin and utilization) as well as all types of grassland (permanent or seasonal) under highly heterogeneous biogeographic conditions (wet or dry climate, fertile or poor soil). Grass cover within the context of the product is understood as herbaceous vegetation with at least 30% ground cover and with at least 30% graminoid species such as Poaceae, Cyperaceae and Juncaceae. Additional non woody plants such as lichens, mosses and ferns can be tolerated.

Table 1: Definition of the HRL Grassland 2018

ELEMENTS INCLUDED IN THE HRL GRASSLAND 2018	ELEMENTS EXCLUDED FROM THE HRL GRASSLAND 2018
<ul style="list-style-type: none"> ▪ Natural, semi-natural, agricultural / managed grass-covered surfaces ▪ Grasslands with scattered trees and shrubs covering a maximum 10% ▪ Heathland with high grass cover, maximum of 10% non-grass cover ▪ Coastal grasslands, such as grey dunes and salt meadows located in intertidal flat areas with at least 30% graminoid species of vegetation cover ▪ Sparsely vegetated grasslands (>30% vegetation cover - cf. comment below) ▪ Grasslands in urban areas: parks, urban green spaces in residential and industrial areas ▪ Semi-arid steppes with scattered <i>Artemisia</i> scrub ▪ Meadows: grasslands which are not regularly grazed by domestic livestock, but rather allowed to grow unchecked in order to produce hay ▪ Grasslands in urban areas: sport fields, golf courses ▪ Grasslands on land without use ▪ Natural grasslands on military sites 	<ul style="list-style-type: none"> ▪ Peat forming ecosystems dominated by sedges ▪ Reed beds and helophytes dominated systems ▪ Tall forbs, fern, shrub dominated vegetation ▪ Grasslands that have been observed as tilled (in the reference year or a certain period before, in that case they are considered as arable fields) ▪ Rice fields ▪ Vineyards, orchards, olive groves, (if more than 10% shrubs or trees) ▪ Tundra dominated by shrubs and lichens ▪ Grasslands on fresh (and older) clear-cuts in the woods

Table 1 indicates what is included in the grassland product and what is excluded. The rate of 30% ground cover density shall be understood as a benchmark implicating that grasslands with $\geq 30\%$ ground cover can usually be distinguished very clearly from bare ground on EO data with the resolution of 10m. According to this reference, the classification of grasslands focusses on “dense grasslands” that can be identified with high accuracy and with minimal confusion or misclassification with bare soil or sparsely vegetated grasslands below 30% ground cover.

This definition applies to all main products and is represented in the additional products accordingly.

Technical details of the HRL Grassland 2018

The HRL GRA 2018 portfolio covers primary products providing information on grassland vegetation coverage, plus additional and reference products, meant to complement the primary products in providing further thematic or technical information for expert users. All products are provided in pan-European coverage, primary and additional products are also available in national projections.

Primary Products

Primary products display information on grassland and non-grassland vegetation for the reference year 2018 in the resolution of 10m and 100m (GRA Status Layer 2018 in 10m + 100m), plus the information on gain and loss of grassland, as well as unchanged areas, between the reference years of HRL 2015 and HRL 2018 in 20m resolution (GRA Change Layer2015/2018 in 20m).

HRL GRA Status Layer 2018, 10m resolution

The Grassland Status Layer 10m is a binary raster displaying grassland and non-grassland areas in 2018 in 10m spatial resolution.

HRL GRA 2018	Grassland Status Layer	Primary product
File name	GRA_2018_010m_eu_03035_V1_0	
Reference year	2018 (March to October)	
Geometric resolution	Pixel resolution 10m x 10m, 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 85% Overall Accuracy per biogeographic region	
Data type	8bit unsigned raster with LZW compression	
Minimum Mapping Unit (MMU)	Pixel-based, MMU of 3 pixel (0.03ha)	
Necessary attributes	Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)	
Raster coding (thematic pixel values)		
	0: all non-grassland areas	
	1: grassland	

	254: unclassifiable (no satellite image available, clouds, shadows or snow) ¹
	255: outside area
Metadata	
XML metadata files according to INSPIRE metadata standards	
Delivery format	
GeoTIFF	

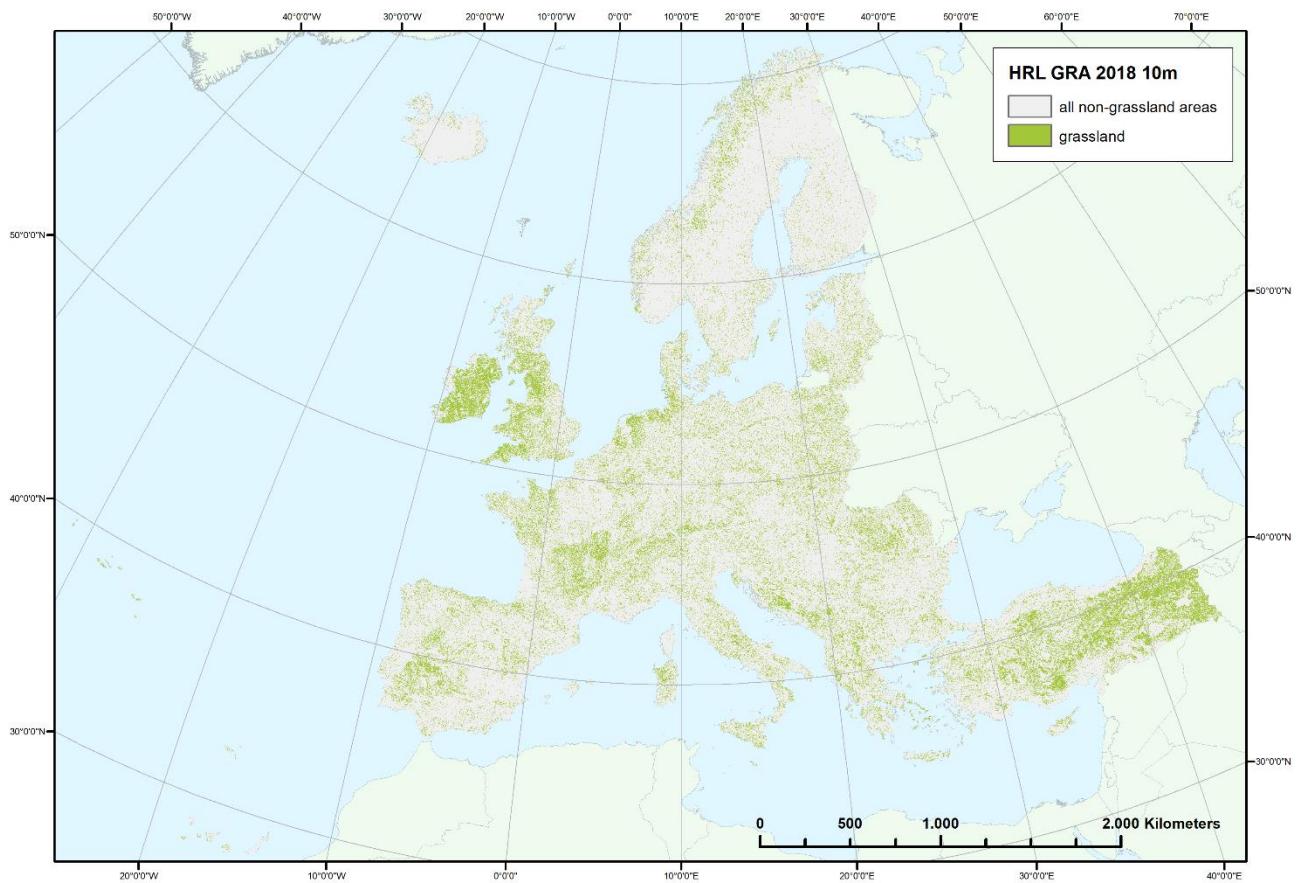


Figure 8: Grassland Status Layer, reference year 2018, 10m resolution

¹ The value of 254 is listed for reasons of completeness, however it does not appear in this Pan-European product which could be produced as cloud free product thanks to sufficient data availability in 2018.

HRL GRA Status Layer 2018, 100m resolution

The Grassland Status Layer 100m is a binary raster displaying grassland and non-grassland areas in 2018 in an aggregated version of the 10m product at 100m spatial resolution.

HRL GRA 2018	Grassland Status Layer	Primary product
File name		
GRA_2018_100m_eu_03035_V1_0		
Reference year		
2018 (March to October)		
Geometric resolution		
Pixel resolution 100m x 100m, 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 85% Overall Accuracy per biogeographic region (assessment on primary 10m product)		
Data type		
8bit unsigned raster with LZW compression		
Minimum Mapping Unit (MMU)		
N/A		
Necessary attributes		
Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)		
Raster coding (thematic pixel values)		
 0: all non-grassland areas		
 1: grassland		
 254: unclassifiable (no satellite image available, clouds, shadows or snow) ²		
 255: outside area		
Metadata		
XML metadata files according to INSPIRE metadata standards		

² The value of 254 is listed for reasons of completeness, however it does not appear in this Pan-European product which could be produced as cloud free product thanks to sufficient data availability in 2018.

Delivery format

GeoTIFF

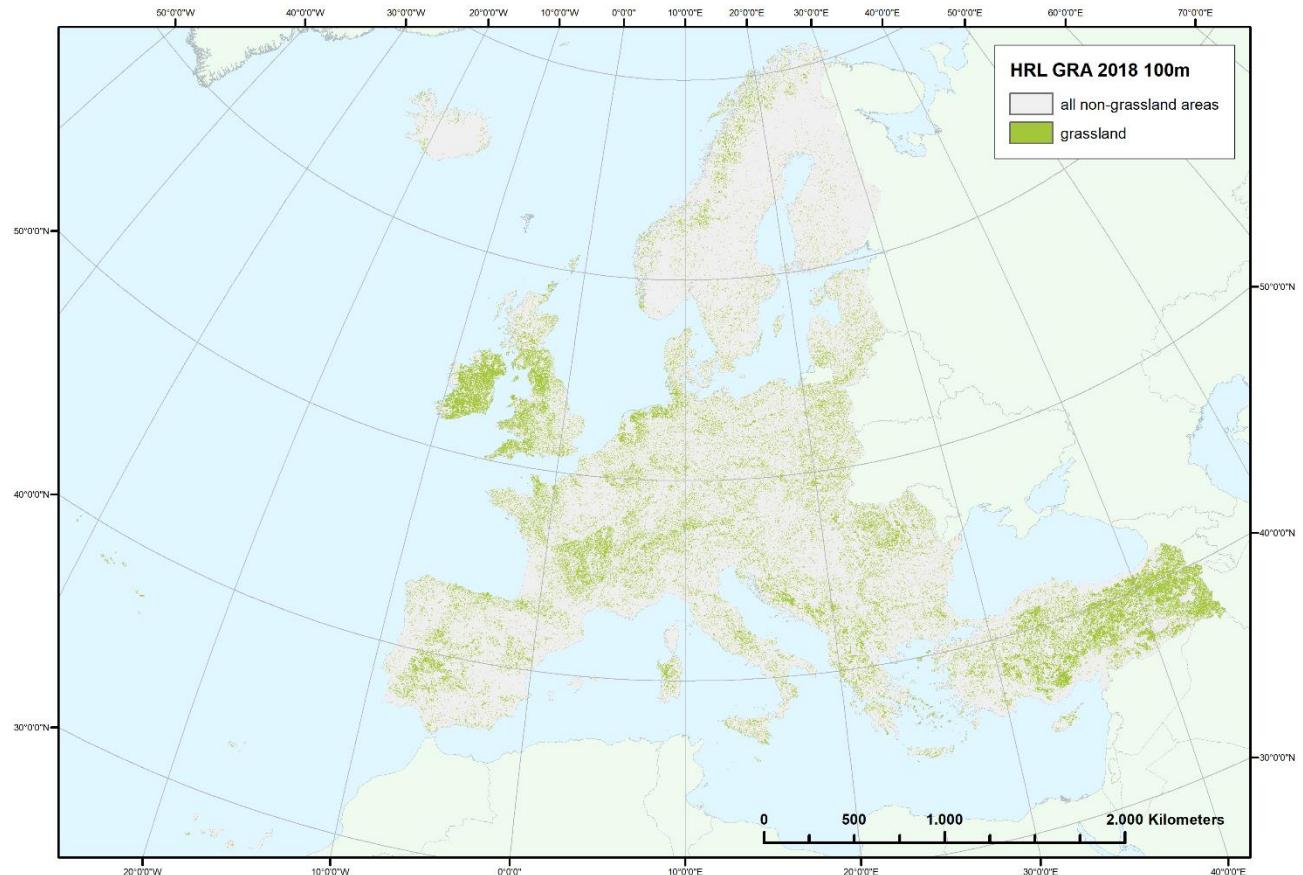


Figure 9: Aggregated Grassland Status Layer, reference year 2018, 100m resolution

The aggregation of the Grassland Layer to 100m resolution leads to rougher grassland patterns with loss of detail but giving a more synoptic information on grassland occurrence in the pan-European context. Figure 3 illustrates the impact of the spatial aggregation on pixel level.

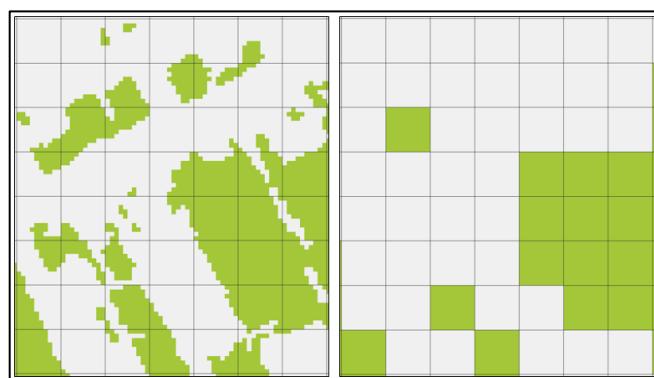


Figure 10: Example for the impact of spatial aggregation in the 100m grassland product

HRL GRA Change Layer 2015-2018

The grassland change layer 2015-2018 is a raster product showing changes in the grassland vegetation cover between the reference years 2015 and 2018 and all unchanged areas with and without grass cover. Due to the change in the spatial resolution (from 20m in 2015 to 10m in 2018), the change of the MMU (from 1ha in 2015 to 0.03ha in 2018) and differing production workflows, HRL GRA 2015 and HRL GRA 2018 can differ significantly in many areas. To sort out the changes that are mainly coming from these technical differences and display the real change in the grassland vegetation cover, a simple map to map change detection is not enough. Therefore further change indicators, derived from vegetation indices of both reference years (for grassland loss) and the historic information from PLOUGH 2015 (for grassland gain), have been implemented to verify if a change between the two layers is a real change (i.e. loss of grassland or gain of grassland vegetation cover). The changes that have not been verified as real changes by this workflow are displayed in separate classes, namely “unverified grassland gain” and “unverified grassland loss”. There are two reasons for changes to be assigned to the “unverified” classes:

- 1) The difference between the two HRLs has not been confirmed as real change by the derived change indicators
- 2) The detected change patch is smaller than the MMU of 1ha, that had been applied to the 2015 grassland layer

HRL GRAC 1518	Grassland Change Layer 2015-2018	Primary product
File name	GRAC_1518_020m_eu_03035_V1_1 ³	
Reference year	2015 + 2018	
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 80% Overall Accuracy	
Data type	8bit unsigned raster with LZW compression	

³ In Version 1.1 of the GRAC class 0 was renamed from “all non-grassland areas” to “unchanged non-grassland in both years”. For the national products the naming for class 0 remains unchanged.

Minimum Mapping Unit (MMU)	
MMU of 1ha for classes 1 & 2 only; no MMU for all other classes	
Necessary attributes	
Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)	
Raster coding (thematic pixel values)	
	0: unchanged non-grassland areas in both years ⁴
	1: grassland gain
	2: grassland loss
	10: unchanged grassland in both years
	11: unverified grassland gain
	22: unverified grassland loss
	254: unclassifiable in any of parent status layers
	255: outside area
Metadata	
XML metadata files according to INSPIRE metadata standards	
Delivery format	
GeoTIFF	

⁴ Class naming for the pan-European GRAC layer. Naming of class 0 for national products differs slightly ("all non-grassland areas")

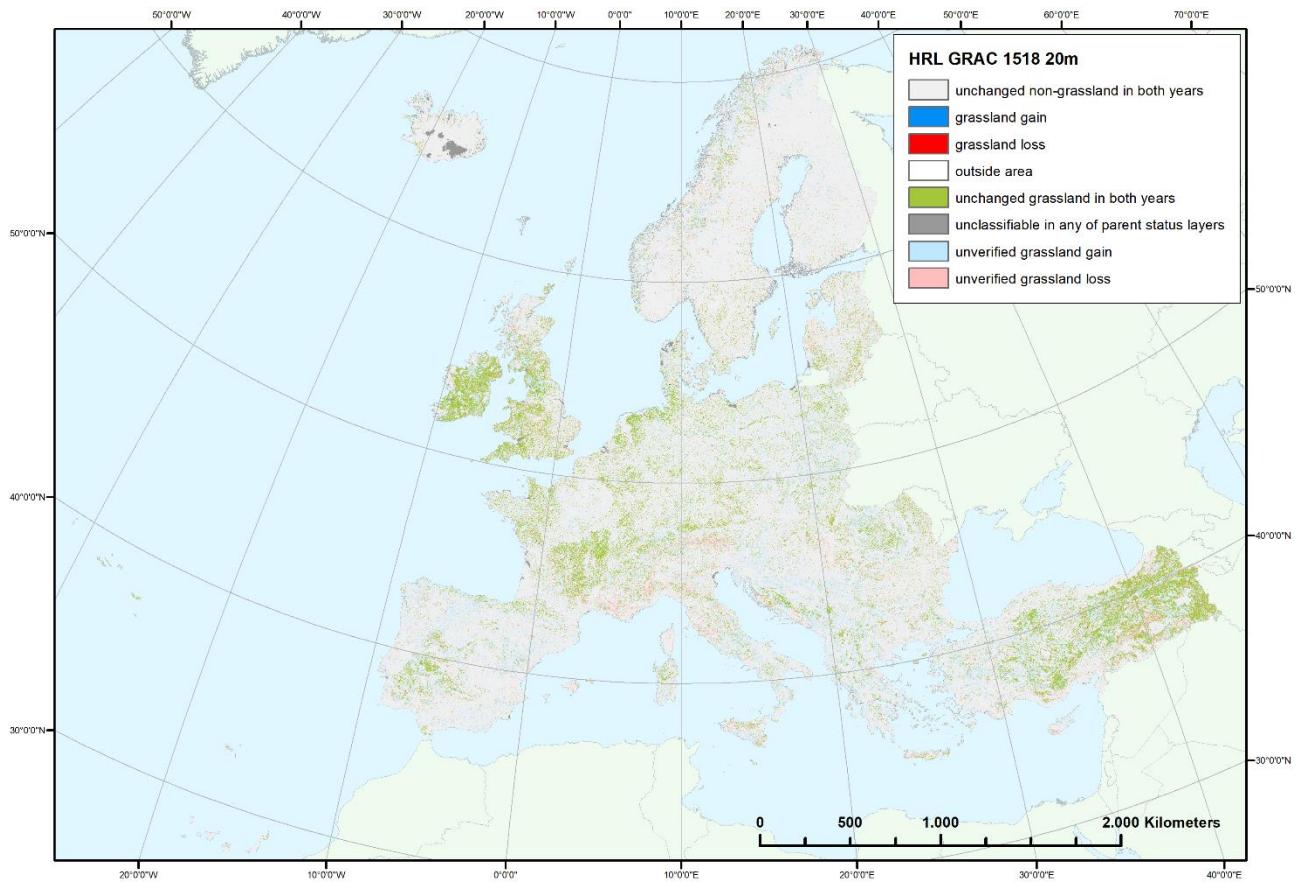


Figure 11: Grassland Change Layer 2015-2018, 20m resolution

Additional products

Plough 2018

The PLOUGH Layer indicates the number of years (1-6) since the last observed ploughing event on a grassland patch, referring to the reference years 2017 back to 2012. Grassland ploughed in 2018 is already excluded from the HRL Grassland Status Layer within the classification process. The PLOUGH was used to clip out patches of grassland that have been observed as ploughed in the past years in order to fully comply with the Grassland definition. Whereas all areas included in the PLOUGH (values 1-6) had been removed from the grassland layer in the 2015 production, only classes 1 and 2 (ploughing in 2017 or 2016) were removed from the HRL GRA 2018. This is due to the fact that the patches with values 3-6, originating from PLOUGH 2015, have originally 20m spatial resolution and even though resampled to 10m they still have the 20m pixel shapes. Clipping the 10m grassland product with these patches would significantly reduce the look and feel by introducing these 20m edges to the final grassland layer. Nevertheless the ploughing information for the historic years 2012 to 2015 is still displayed in the PLOUGH 2018 and can be utilized for specific applications.

PLOUGH 2018	Ploughing indicator	Additional product
File name	PLOUGH_2018_010m_eu_03035_V1_0	
Reference year	2012-2017	
Geometric resolution	Pixel resolution 10m x 10m, 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	N/A	
Data type	8bit unsigned raster with LZW compression	
Minimum Mapping Unit (MMU)	MMU of 3 pixel (0.03ha)	
Necessary attributes	Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)	
Raster coding (thematic pixel values)		
	0: no ploughing information	
	1: 1 year since last indication of ploughing	
	2: 2 years since last indication of ploughing	
	3: 3 years since last indication of ploughing	
	4: 4 years since last indication of ploughing	
	5: 5 years since last indication of ploughing	
	6: 6 years since last indication of ploughing	
	254: unclassifiable (no satellite image available, clouds, shadows or snow)	
	255: outside area	
Metadata	XML metadata files according to INSPIRE metadata standards	

Delivery format

GeoTIFF

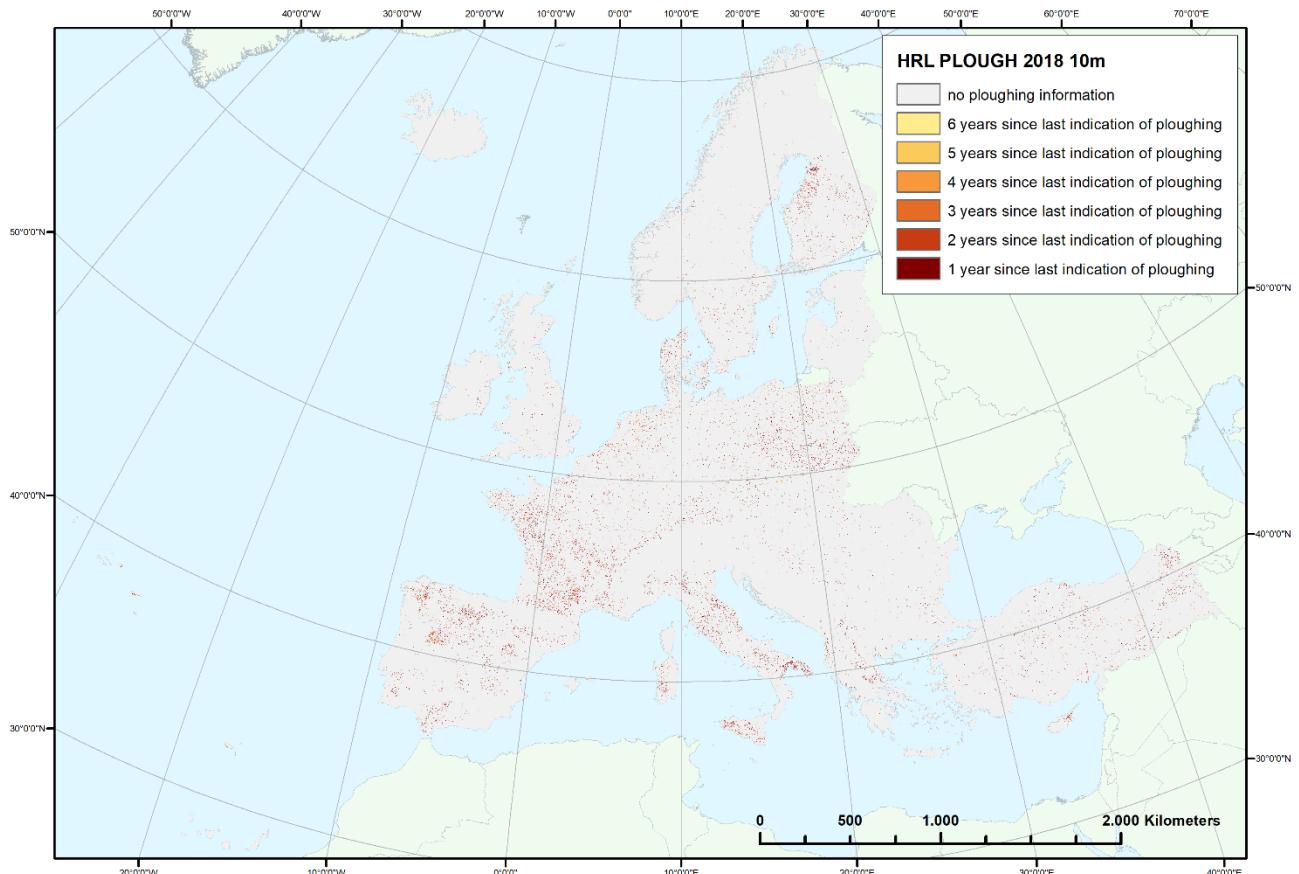


Figure 12: PLOUGH for the reference year 2018, 10m resolution

GRAVPI 2018

The Grassland Vegetation Probability Index measures the soundness of the grassland class assignment by combining the confidence of the classifier for a pixel to be grassland with the EO data situation for this pixel (taking into account the number of cloud free observations within the production time window).

GRAVPI 2018	GRA Vegetation Probability Index	Additional product
File name GRAVPI_2018_010m_eu_03035_V1_0		
Reference year 2018		

Geometric resolution	Pixel resolution 10m x 10m, 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	N/A
Data type	8bit unsigned raster with LZW compression
Minimum Mapping Unit (MMU)	N/A
Necessary attributes	Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)
Raster coding (thematic pixel values)	
	0: all non-grassland areas
	1: 1% grassland vegetation probability index
colour shades in between	2-49: 2-49% grassland vegetation probability index
	50: 50% grassland vegetation probability index
colour shades in between	51-99: 51-99% grassland vegetation probability index
	100: 100% grassland vegetation probability index
	254: unclassifiable (no satellite image available, clouds, shadows or snow)
	255: outside area

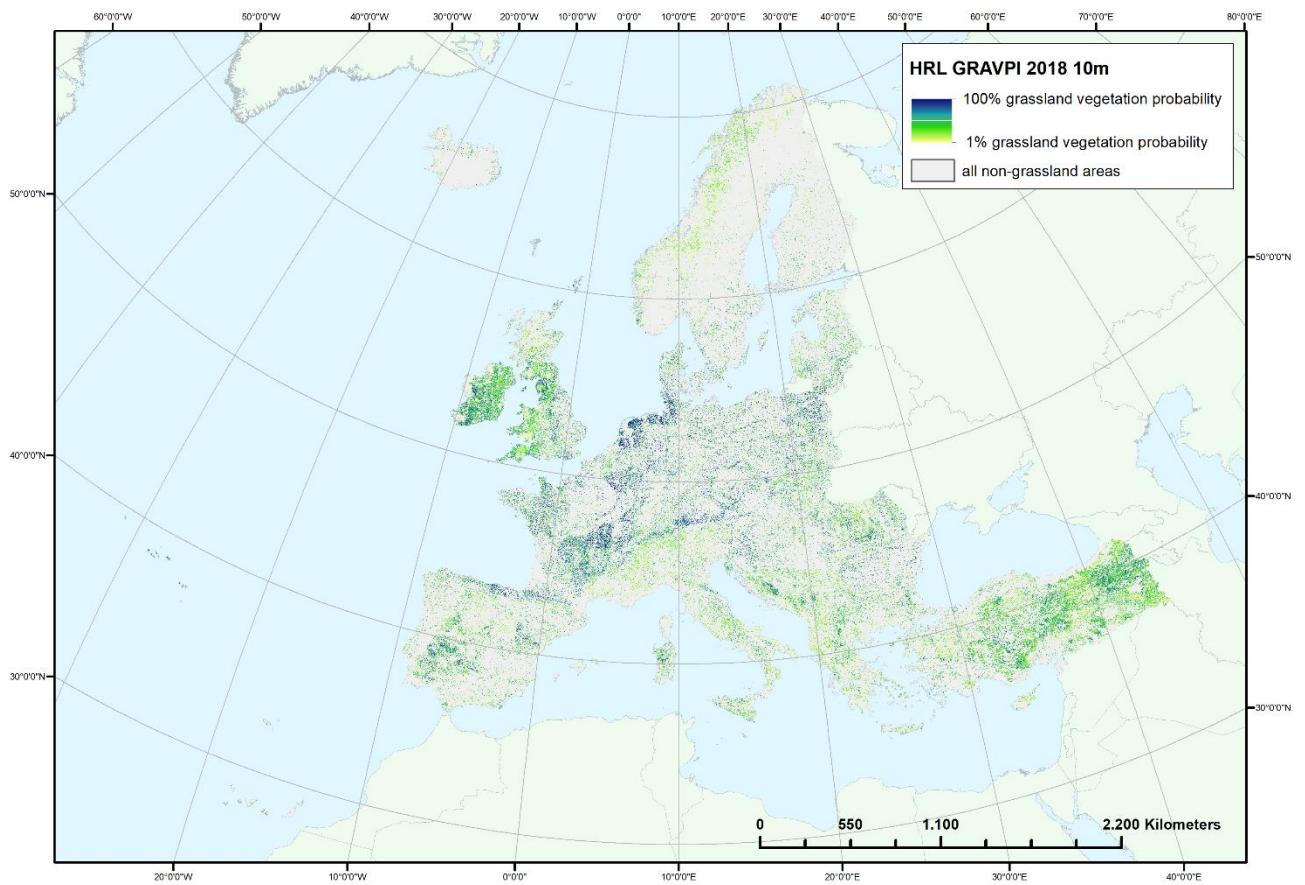


Figure 13: Grassland Vegetation Probability Index of the reference year 2018, 10m resolution

Reference/Expert user products

GRACL 2018

As a product addressing the scientific interest of an expert user, the Grassland Confidence Layer provides additional information on the separability of each grassland pixel from other land cover. It shows the confidence of the classifier for each pixel in the grassland mask to really be grassland. The values range from 0-100, referring to 0-100% confidence for a pixel to be grassland.

GRACL 2018	GRA Confidence Layer	Reference/expert product
File name GRACL_2018_010m_eu_03035_V1_0		
Reference year 2018		
Geometric resolution Pixel resolution 10m x 10m, 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
N/A
Data type
8bit unsigned raster with LZW compression
Minimum Mapping Unit (MMU)
N/A
Necessary attributes
Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)
Raster coding (thematic pixel values)
 0: 0% grassland confidence
colour shades in between 1-49: 1-49% grassland confidence
 50: 50% grassland confidence
colour shades in between 51-99% grassland confidence
 100% grassland confidence
 253: all non-grassland
 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

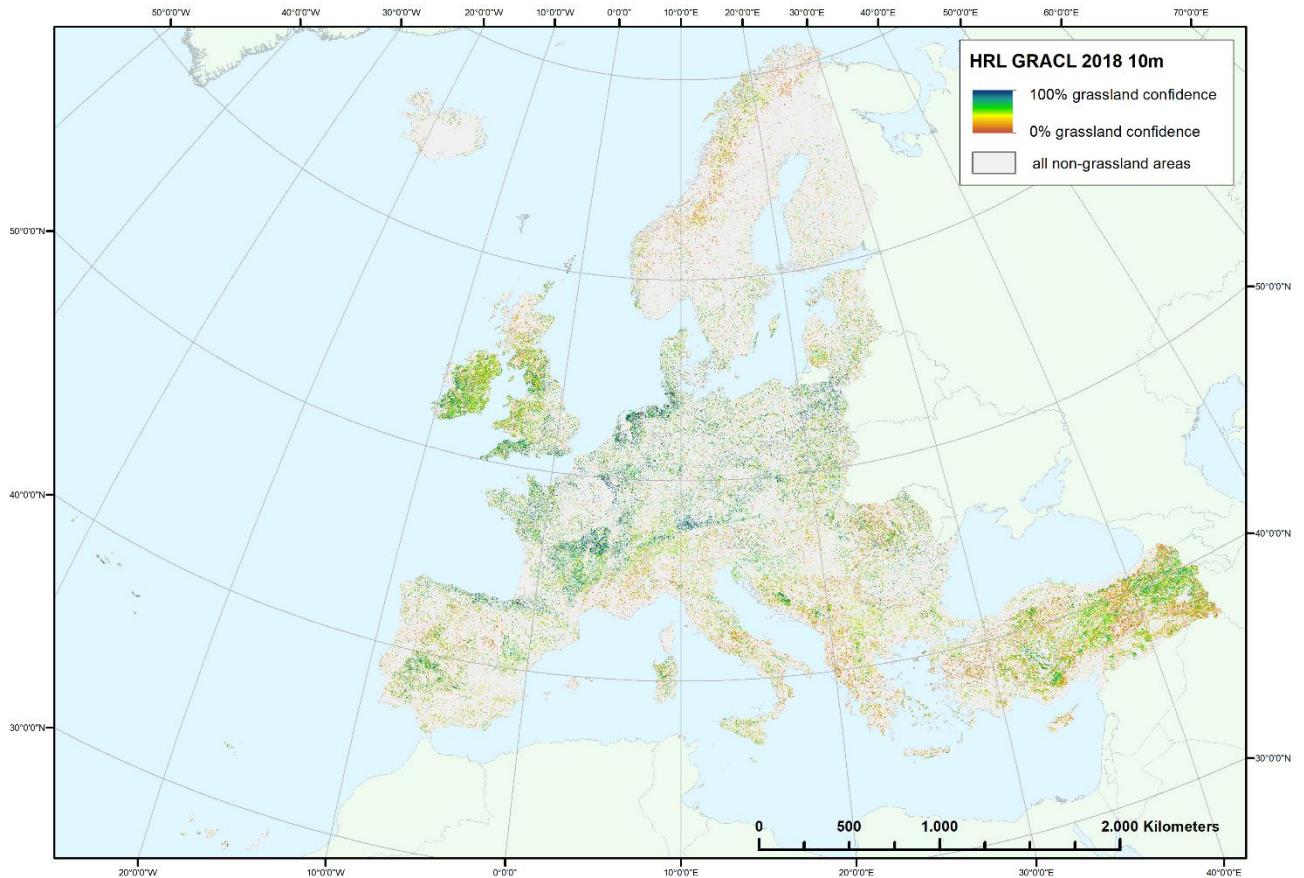


Figure 14: Grassland Confidence Layer for the reference year 2018, 10m resolution

VI. Product methodology and workflow

Methodology

Thematic and technical basis for all steps of the production workflow is a stratification of the production area according to biogeographic regions - a conceptual approach which allows for regional adaption of the technical workflow in order to guarantee accurate classification results.

Highly varying conditions not only of grassland types but also of soil, temperature, water and nutrient supply across Europe fostered a new approach concerning the stratification of the production area. Whereas in HRL 2015 all classifications were based on the fixed S-2 tiling grid, the HRL 2018 production took the differing biogeographic conditions into account and started the classification workflow on production unit (PU) level that has been derived from the classification idea of environmental zones developed by Metzger et al. (see Figure 15). Environmental zones are areas of similar nature in terms of biogeographic parameters such as precipitation and temperature, soil, nutrient supply, growing periods, seasonal and/or yearly climate dynamic, topography and altitude and thus harbour similar vegetation types. Working on a sub-stratification level of biogeographic regions has proven to guarantee higher accuracy and a better detection of specific regional vegetation types (Inglada et al).

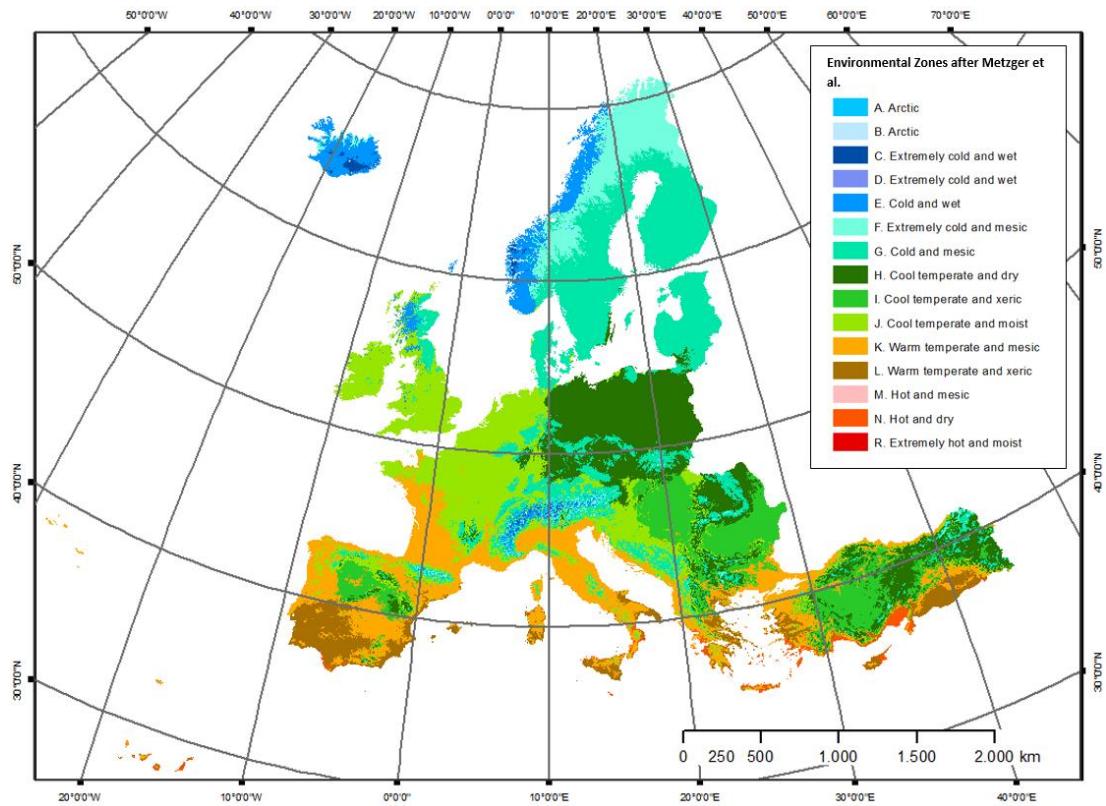


Figure 15: Environmental Zones according to Metzger et al. 2012 for the EEA 39 area

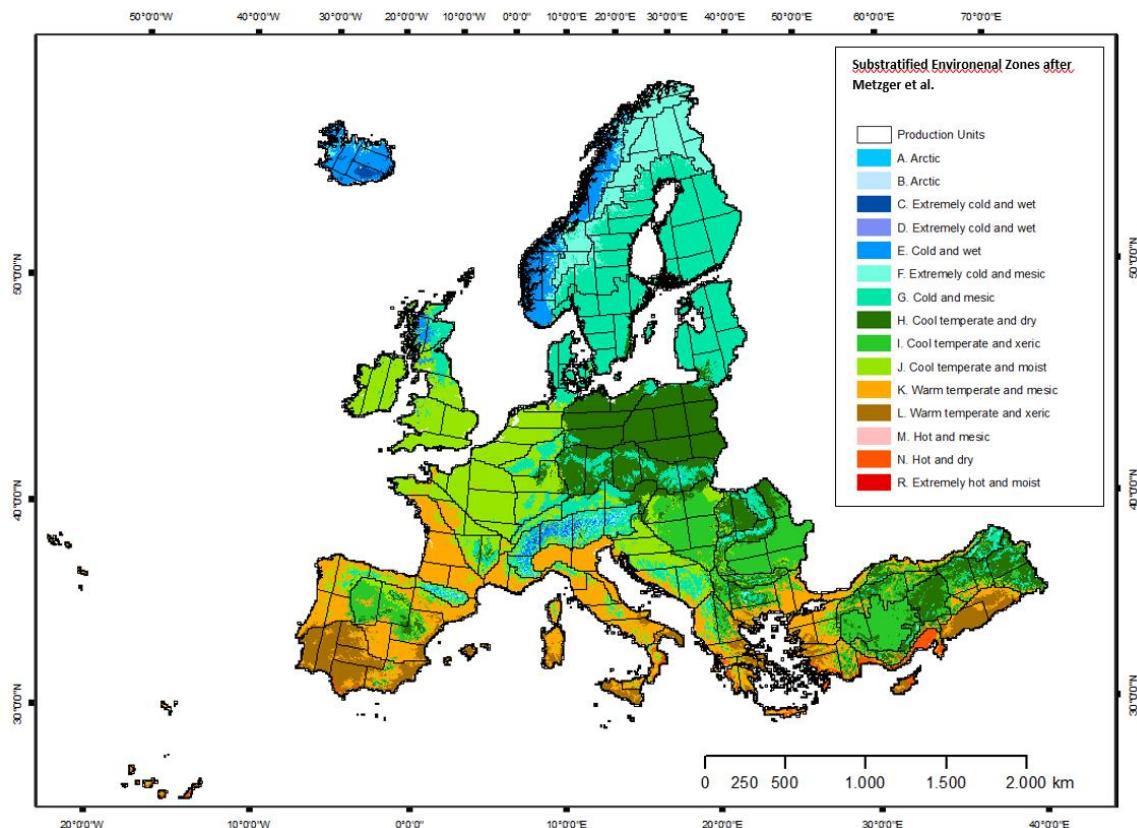


Figure 16: Production units for the classification workflow of the HRL GRA product portfolio

The production of the HRL GRA products uses a slightly simplified division (Figure 16) of the original global environmental zones (Figure 15). It respects regional characteristics as well as needs of an efficient and automated production workflow.

Workflow description

The HRL 2018 has been produced to a large part in the MUNDI cloud environment, since it allows for a centralised and concurrent large-scale processing of extensive EO data volumes, ancillary and In-situ data. Storage resources are provided by OTC. Preparatory tasks as well as the calculation of additional and reference/expert user products have been produced in a local environment.

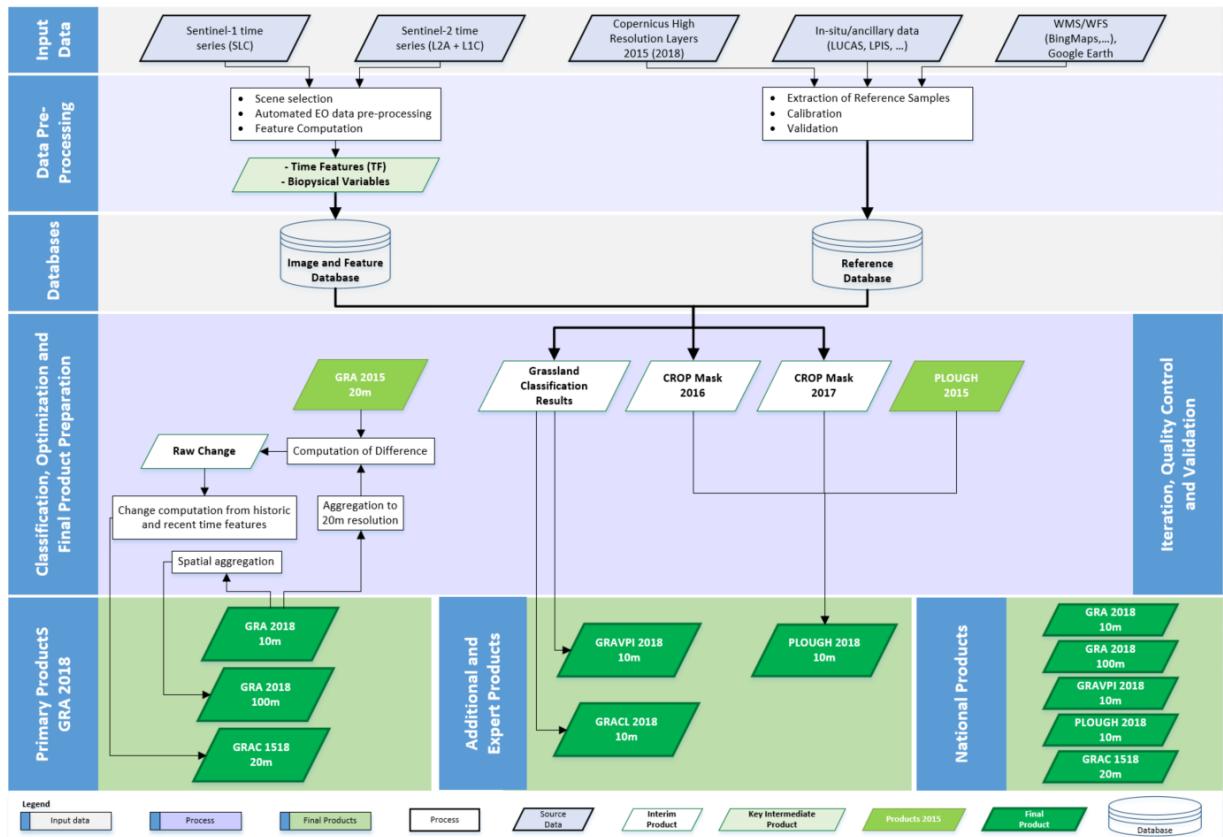


Figure 17: Workflow for the HRL GRA 2018 product portfolio

A. Input data and pre-processing

The input data for all classifications are predominantly S-2 L2A-data (2018 and 2017) and S-2 LC1-data (2016) and S-1 data for the respective years. All data have been pre-processed with state of-the-art pre-processing steps:

S-2 data pre-processing:

- Check of geometric consistency + geometric adaption
- Atmospheric correction (Bottom of Atmosphere)

- Topographic normalisation
- Cloud masking (based on Sen2cor Scene Classification Layer for 2018 or BRCOYA for 2016)
- Derivation of indices (such as NDVI, NDWI, IRECI, BRIGHTNESS, NBR)

S-1 pre-processing steps:

- Calibration + Co-registration
- Amplitude extraction
- Data “clearing” (removal of bad data through rain, lay over, shadowing, foreshortening)
- Multi-temporal filtering
- Derivation of indices (such as NDVVH, RVVH, DVVH)

The subsequent scene selection includes several parameters like cloud cover (S-2) or tile coverage (S-1 + S-2) and could be adapted as needed.

B. Population of Data Bases

Time Feature Calculation, preparation of Biophysical Variables:

One component of the classification step and main input for most of the products are series of temporal features (time features) derived either from single bands or from indices of the pre-processed EO data. The temporal and spectral evolution of each pixel is thereby summarized through a series of statistical parameters, such as mean, minimum, maximum, standard deviation, percentiles or interpolated values. These statistical parameters allow for characterization and differentiation of distinct patterns of seasonal, short term and long-term changes induced by the high dynamics of vegetation during the growing cycle (canopy density, vitality of the plants, chlorophyll status and expansion). Time features of optical data turned out to be the more suitable data for accurate detection of vegetation. The benefit of combining S-1 and S-2 time features is particularly useful in areas where optical data was not sufficiently available (due to permanent cloud cover), but can also lead to negative impacts on the classification results depending on landscape topography.

Since phenological cycles and land cover characteristics differ across European countries, a flexible adaptation of the set of time features, as well as the time window for their calculation, from one regional and biogeographical strata to another is mandatory. Time Features and Biophysical variables build the **Image and Feature Database** which serves as main component and input for classification.

Preparation of ancillary Data:

The second component are ancillary/reference data used for the extraction of training samples, for calibration and for validation tasks, taken from the LUCAS database, from LPIS data, OSM data, from previous and current HR Layers as well as from VHR data. These data build the **Reference Database** as second important input for classification, as well as for subsequent quality controls and potential iterations, and for validation purposes.

C. Classification and optimization

The classification consists of several iterations using various temporal subsets of time series from S-2 and S-1 bands and/or indices and a most suitable time window out of the Image and Feature Database

plus training samples from the Reference Database. The setting could change according to conditions in different biogeographic regions. Varying climate conditions, soil characteristics, changes in growing periods and also farming management foster adaption in order to derive most accurate classification results. Internal quality control and checking with the initial reference data initiate several iterations of classifications for optimized results.

For HRL Grassland 2018, the classification step comprises 3 classifications:

- ***Binary grassland/non-grassland classification for the 2018 reference year***
- ***Binary cropland/non-cropland classification for the 2017 reference year***
- ***Binary cropland/non-cropland classification for the 2016 reference year***

D. Production of status Layers

The cropland classifications are part of the optimization workflow of the final grassland layer. In the grassland definition (see thematic details under chapter V. Product Description), only grassland that has not been ploughed for a certain amount of years is valid grassland and therefore part of the grassland layer. The PLOUGH 2018 serves as “rolling archive” and displays all grassland patches that have been ploughed, as the assumption is that these grassland areas are only temporary and thus invalid grassland in the sense of the working definition of the HRL Grassland Layer.

The identified ploughing events on grassland patches in 2017 and 2016 are part of a stand-alone product, PLOUGH 2018. It continues PLOUGH 2015 providing information on ploughed (and thus invalid) grassland for the years 2015, 2014, 2013, 2012, 2011 and 2010. The newly created PLOUGH 2018 continues with the years 2016 and 2017, while 2010 and 2011 have been removed.

E. Production of Grassland Change Layer

Step 1: For the production of the grassland change layer, HRL GRA 2015 and HRL GRA 2018 (resampled to 20m) are combined in a first step and the plain geometric differences between the two layers are calculated. The resulting raw change layer reflects where both HRLs show grassland or non-grassland and where the two layers differ in the extent of the classified grassland.

Step 2: Differing areas (potential gain and loss) are isolated. The result is a binary mask (map-to-map mask), showing unchanged and potentially changed areas.

Step 3: To distinguish between potentially real changes and changes coming from the technical differences of the two input layers (spatial resolution, MMU, production workflow), classes gain and loss are addressed separately:

- a. For the confirmation of grassland loss a change indicator based on relevant time features from both reference years is calculated, that shows areas of significant decrease in vegetation signal, pointing to a potential loss of grass cover.
- b. For the confirmation of grassland gain the historic information from PLOUGH 2015 is used as additional data source to sort out changes arising from different technical conditions. As grassland stability is mandatory by definition, the ploughing information for the historic

reference years can be used to find areas that are potential grassland gain. Areas that have been removed from the HRL GRA 2015 because of recent ploughing events, but are classified as grassland in 2018 are considered as newly developed grassland if they fulfil the criterion of 6 years' stability. In that case these areas are considered to be confirmed gain of grassland vegetation cover.

Step 4: Verified gain and loss areas are filtered with a minimum mapping unit (MMU) of 1ha, in order to be consistent with the MMU of the HRL GRA 2015. Refinement steps during post processing include additional reference data such as the EU-DEM for plausibility checks.

The final change layer displays areas of verified Grassland Gain and Grassland Loss, of unchanged Grassland and unchanged Non-Grassland in both years, plus Unverified Grassland Gain and Unverified Grassland Loss where change could not be confirmed during the workflow.

F. Expert and Reference products

Production of PLOUGH 2018

The ploughing indicator for the 2018 reference year was produced following the rolling archive principle, reusing the information of PLOUGH 2015 resampled to 10m. Classes 6 and 5, showing ploughing events in the historic reference years 2010 and 2011, were removed and the remaining classes 4 – 1 were recoded to classes 6 – 3, referring to ploughing events in the period from 2012 – 2015. The recoded PLOUGH 2015 is then complemented by newly derived ploughing information for the years 2016 (new class 2) and 2017 (new class 1) which base on time features of the whole vegetation period of each reference year. The coding of the PLOUGH 2018 can be seen in the technical details section, under Plough 2018.

Production of GRACL 2018

The grassland confidence layer is a reference product that shows how confident the classifier was in its decision for a pixel to be grassland. This product is automatically calculated during the grassland classification process and shows the described information for all grassland pixels in the final HRL GRA 2018.

Production of GRAVPI 2018

The grassland vegetation probability index 2018 combines the information from GRACL with the information about the available EO data within the time window (i.e. the vegetation period) used for the grassland layer classification. The information about EO data availability is stored in an interim product of the classification procedure, the time series completeness layer (TSCL). The TSCL indicates the completeness of the image time series based on the availability of cloud free observations per month during the growing period. The final GRAVPI values are derived by combining the confidence value for each grassland pixel with the TSCL value.

Consequences of changed technical specifications

The technical specification for the HRL GRA 2018 changed compared to its predecessor. Especially the enhanced spatial resolution of now 10m (20m in 2015) and the decrease of the MMU from 1ha in 2015 to 0.03ha in 2018 enabled significant improvements in the grassland detection.

These are:

- more detailed grassland detection: green border areas, linear features, small-scale grassland patches
- better and more accurate representation of outlines/shapes: better look & feel due to a comprehensive presentation of landscape structure
- increase in displayed grassland area: HRL Grassland Status Layer 2018 gives around 25% more grassland than in 2015

A subsequent MMU filtering of 0.03ha (single pixels and patches of 2 pixels connected via their edges) further enhances the look and feel of the resulting product without losing meaningful information.



Figure 18: details of HRL GRA 2015, 20m with MMU of 1ha (left) and HRL GRA 2018, 10m with MMU of 0.03ha (right)

The example above illustrates the improvement of the Grassland Status Layer, providing more detailed information for the user.

Strengths and Limitations

The HRL portfolio comes with a sound and state of the art methodology and provides users with highly accurate information of permanent grassland areas in the pan-European context. It is the first cloud-free Grassland Status Layer. However, there are limitations due to

- a) EO data availability + quality in certain regions
- b) In-situ data availability
- c) General climate condition and/or unforeseen weather events

Despite the rapid growth of available data in the recent years there are still regions where data availability is a limiting factor, such as the far Northern Scandinavian region or the Départments d'outre-Mer (DOM). The amount of available EO data is lower and the data often of less quality due to generally higher cloud cover. Further aspects are the processing level of the EO data which is still quite heterogeneous. Depending on area and time period, the classification bases on S-2 L2A or S-2 L1C data, involving at the same time different cloud masking procedures and thus slightly differing cloud masking results. S-2 L2A data shows terrain overcorrection which causes commission errors of grassland in mountainous regions with tree cover (overcorrected spectral characteristics appear very bright and thus falsely resemble grassland). Co-registration issues do also have an impact on the classification results. The lack of multi-temporal co-registration of S-2A and S-2B leads to omission or commission within classification due to slight shifts in the spectral information of single pixels.

Data calibration, classification, quality control and validation all depend on the timeliness, accuracy and reliability of ancillary and in-situ data. At the moment, both, availability of up-to-date reference data as well as reliability are still an issue. Although the Random Forest Classifier is able to handle outliers to a certain extent, intensive preparation is necessary in order to guarantee a valid classification. Some regions still lack in-situ data (LUCAS data, for example, do not cover all EEA39 and show insufficient density in some regions) and coverage, access and reliability are in general an issue in the pan-European context.

Long-term climate conditions as well as seasonal or exceptional weather events have implications for the detection of grassland. The Mediterranean region for example is challenging due to sometimes extreme drought during summer months and shifted vegetation periods even in small scale; Northern Scandinavian or Alpine regions are challenging due to short growing periods and lasting snow cover. The European drought in summer 2018 affected vast areas in many EEA39 countries and had an impact on the grassland detection since large grassland areas showed only very little characteristic spectral signals. The changed appearance of grassland led to scattered classification results which had to be refined in further post-processing steps that compensated for lacking spectral information within the very dry regions.

VII. Quality assessment

Internal Validation

All HRL products are subject to internal validation. This section provides guidance on how the products are validated by defining suitable indicators or metrics. Although the validation is internal, independency is sought as far as possible. Since HRL Grassland is produced by a consortium of partners, each area produced was validated by a different partner to guarantee impartiality und objectivity.

The accuracy requirement for the HRL GRA Status Layer defines a minimum of 85% Overall Accuracy (OA) on pan-European level, as well as for each biogeographic region, and a minimum of 80% OA for the HRL GRA Change layer.

The classification correctness should be 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 this grid of LUCAS points ensures traceability and coherence between the different layers.

The response design is the photointerpretation of each sample unit and is based on the independent assessment at the unit level. The reference data are the (HR) images used in the production, the VHR_IMAGE_2018, 2015 and 2012 dataset as well as time series of google earth. It is necessary to have the time line as complete as possible to be able to assess the required stability of grassland and differentiate between grassland and other vegetation. The subsequent evaluation of the validated samples then allows for drawing conclusions on the thematic accuracy of the product.

Thematic accuracy

HRL GRA Status layer

Thematic accuracy is usually presented in the form of an error matrix, illustrating the main parameter of evaluating the interpretation of the validation samples. The different accuracies (Overall thematic accuracy, Producer's and User's Accuracy) as well as 95% confidence interval are provided in the tables below. Using a standard grid usually ends up in an uneven distribution of validation points. Grassland covers only around 18% of the land cover while non-grassland is clearly dominating. The resulting imbalance of points and the potential bias in an evaluation is compensated by area weighting. Area weighting is good practice to give a realistic representation of the accuracy of the GRA Status Layer.

Table 2: Unweighted Accuracies for the Grassland Status Layer 2018 (including DOMs)

		Reference Data			User's Accuracy	95%-level Confidence Interval
		Grassland – 1	Non-grassland – 0	Total		
Map data	Grassland – 1	4976	996	5972	83.32%	+/- 0.95%
	Non-grassland – 0	201	5763	5964	96.63%	+/- 0.46%
	Total	5177	6759	11936		
	Producer's Accuracy	96.12%	85.26%			
	95%-level Confidence Interval	+/- 0.53%	+/- 0.85%		Overall Accuracy	89.97%
					Kappa	0.80

Table 3: Area-weighted Accuracies for the Grassland Status Layer 2018 (including DOMs)

		Reference Data			User's Accuracy	95%-level Confidence Interval
		Grassland – 1	Non-grassland – 0	Total		
Map data	Grassland – 1	904.98	181.14	1086.12	83.32%	+/- 0.95%
	Non-grassland – 0	164.44	4714.89	4879	96.63%	+/- 0.46%
	Total	1069	4896	5965		
	Producer's Accuracy	84.62%	96.30%			
	95%-level Confidence Interval	+/- 0.98%	+/- 0.45%			
				Overall Accuracy	94.21%	+/- 0.58%
				Kappa	0.80	

The tables above illustrate the high quality of the Grassland layer for the reference year 2018. Latest evolution in data availability and quality, a sophisticated workflow, increased resolution and decreased MMU resulted not only in more grassland being detected – in terms of area - but also in grassland being detected more accurately and more comprehensively, compared to HRL 2015. Differentiation between grassland and critical land cover such as cropland has also highly improved. Compared to HRL 2015, the UA for Grassland increased significantly, indicating that issues which in 2015 caused omission errors could be addressed and significantly be reduced in HRL 2018. In sum, the targeted Overall Accuracy of 85% has been exceeded.

HRL GRA Change layer

As first product of its kind, the GRA Change Layer had to address several constraints, caused by the fact that change has to be derived from two very differing input layers for the reference years of 2015 and 2018. HRL 2015 and HRL 2018 strongly differ in

- technical specifications: change in resolution from 20m to 10m and change in MMU from 1ha to 0.03ha
- data base: limited number of scenes from different sensors in 2015 vs. full time series of (exclusively) Sentinel data in 2018
- approach: image classification in 2015 vs. deep learning algorithms in 2018

These factors led to large differences between the two HRLs and thus a large amount of changes resulting from a pure map-to-map comparison, going way beyond what can be expected in terms of real changes within three years. An elaborate workflow (as described in chapter VI) integrating additional change indicators from time features of both reference years, further refinement steps and a dedicated post-processing helped to overcome many of the constraints.

Besides unchanged areas, the final change layer now displays classes labelled as Grassland Gain/Grassland Loss or as Unverified Grassland Gain/Unverified Grassland Loss. “Unverified” are those areas, where both layers differ but change could not be confirmed during the workflow. It can be concluded that these areas are no changes but induced by the extremely different prerequisites of both grassland layers. Consequently they have no significance for the validation. In turn, areas where change could be confirmed, have been subject to the accuracy assessment. As permanent grassland is a generally stable land cover type, the proportion of verified change is very low in a 3-year interval: only 0.04% of the total area of EEA39 indicate confirmed change, whereof 0.03% is Grassland Loss and only 0.01% is Grassland Gain.

The assessment of change in grassland areas in general requires a lot of experience and knowledge about grassland appearance under variable conditions. At the same time it places high demands on the availability and quality of reference data. As for change, the criterion of grassland stability is the most important one. In order to detect potential breaks in an existing stable grassland area or to verify an evolving stability of potentially new grassland areas, the complete time line back to year 2010 has to be considered. Since reference data are mostly mono-temporal and, besides that, show insufficiencies in some regions (i.e. Scandinavia, Turkey), either because the time line is incomplete or because of low quality, the identification of the actual land cover and the verification of change can be challenging. With further evolution in availability and quality of reference data, these potentially limiting factors will be minimized in the future.

The evaluation results of this first Grassland Change Layer are satisfying: the targeted Overall Accuracy of >80% could be exceeded, giving an unweighted OA of 89.08% and an area-weighted OA of 99.30%. The area-weighted User’s Accuracy for the class Change is 58.27% with a confidence interval of +/- 1.98% at 95% confidence level; the area-weighted UA for Non-Change is 99.32% with a confidence interval of +/- 0.18% at 95% confidence level. Producer’s Accuracies are not displayed because they cannot be calculated in a meaningful way due to the very small proportion of the changed compared to the unchanged areas.

QA/QC procedures

All procedures of technical Quality Assurance (QA) and Quality Control (QC) are implemented consistently and under the coordination and supervision of the project’s Quality Manager. Within the overall QA/QC scheme dedicated technical QA/QC was 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 is a key improvement to previous implementations as a **more systematic and objective QA/QC mechanism** is ensured.

Quality assurance follows the ISO9001 standards for Quality Management⁵ and the INSPIRE data quality elements and comprises of dedicated procedures of ongoing quality checks (QA breakpoints) during implementation of the production chain, in order to keep persistent control over the various stages of production, assure fitness-for-purpose of the end-products and 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 is given to the target thematic accuracies to be achieved for each product, as well as to the issues of product consistency (spatial and temporal) and homogeneity.

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 following 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.

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⁵ ISO 9001:2015

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Links:

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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
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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

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”)

Examples and meaning of full product names for final products:

GRA_2018_010m_eu_03035_V1_0.tif

Grassland status layer, 2018 reference year, 10m spatial resolution, pan-European product in European projection (EPSG: 3035), first final version.

GRA_2018_010m_eu_03035_V1_1.tif

Grassland status layer, 2018 reference year, 10m spatial resolution, pan-European product in European projection (EPSG: 3035), first final version, second delivery after small changes.

Annex 2: File naming nomenclature of HRL GRA 2018 products:

Descriptor	To be written as	Meaning	Comments
	GRA	Grassland	Abbreviation to be used for main Lot 3 product
	GRAC	Grassland change	Abbreviation to be used for the new grassland change product
	GRAVPI	Grassland Vegetation Probability	Additional Lot 3 products
	PLOUGH	Ploughing Indicator	
	GRACL	Confidence Layer	
	GRADCL	Derived Correction Layer of the GRA Mask	
	GRATFIL	Time Feature Identification Layer	Key intermediate products for Lot 3
	GRAPUL	Production Unit Layer	
	GRATF	Time Features	
	GRADSL	Data Score Layer	
	GRADDL	Data Density Layer	
	GRATSCL	Time Series Completeness Layer	
	GRAPSIL	Parent Scene Identification Layer	
	WAWRA	Rolling Archive	Geospatial Database of Lot 4 intermediate layers
REFERENCE YEAR	2012	Reference year 2012 (+/- 1 year)	
	2015	Reference year 2015 (+/- 1 year)	
	2018	Reference year 2018 (+/- 1 year)	
	0609	Change 2006-2009	Only for change products
	0912	Change 2009-2012	
	1215	Change 2012-2015	
	1518	Change 2015-2018	
	0612	Change 2006-2012	New change time period to be in line with CLC 6-years update cycle
REFERENCE SEASON	2016_1	Dec 2015-Feb. 2016	For the seasonal water and wet masks in Lot 4
	2016_2	Mar. 2016-May 2016	
	2016_3	Jun. 2016-Aug. 2016	
	2016_4	Sept.-Nov. 2016	
RESOLUTION	010m	10m spatial (pixel) resolution	
	020m	20m spatial (pixel) resolution	
	100m	100m spatial (pixel) resolution	
EXTENT	al	Albania	2-letter abbreviation for the country (in national)
	at	Austria	

Descriptor	To be written as	Meaning	Comments
	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	
	euExxNxx	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	
	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 (geodetic parameter dataset code by

Descriptor	To be written as	Meaning	Comments
			the European Petroleum Survey Group) http://www.epsg-registry.org/
VERSION	V1_0	First 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”).

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 need to be created in order to login and to 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 color 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 4: 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 (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