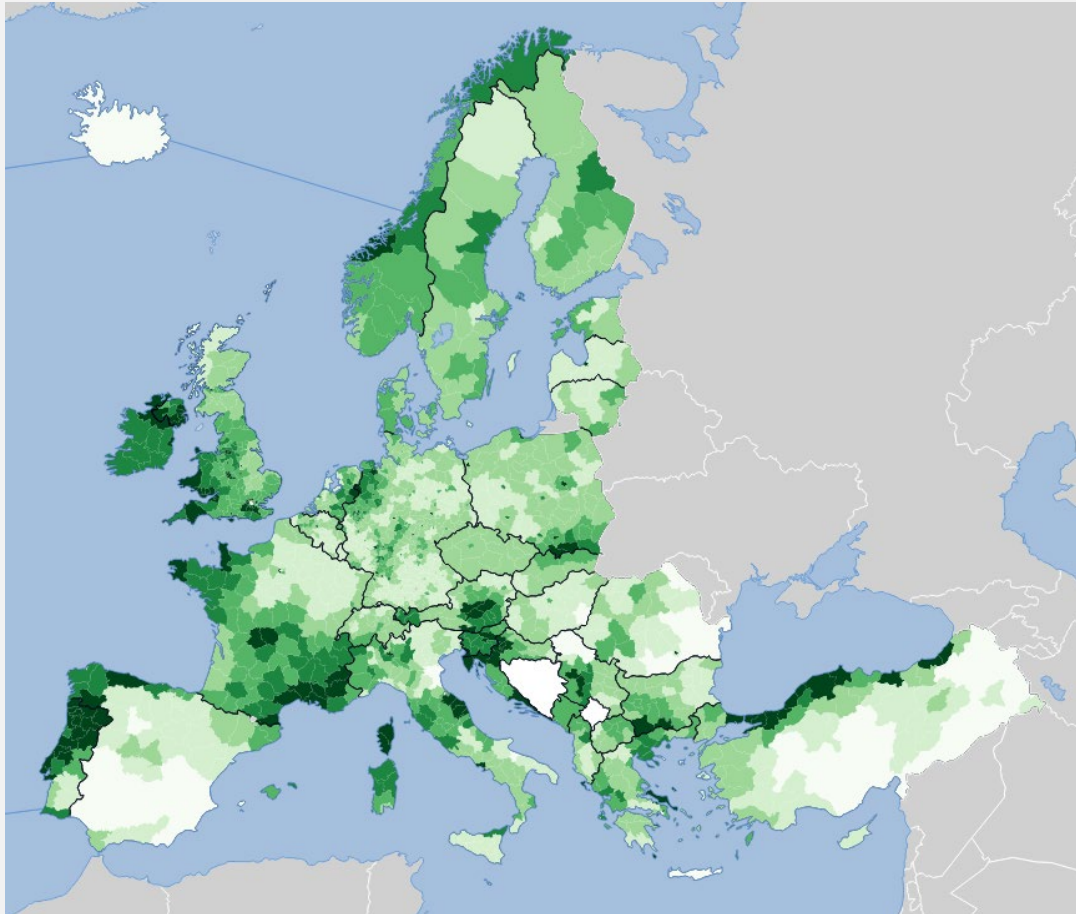


# Quantification of landscape features in agricultural areas using Copernicus products: An overview of recent developments



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## Description

This report presents a synthesis of recent work conducted within the (former, until 2022) European Topic Centre (ETC) – Biodiversity (BD), the ETC – Urban, Land and Soil (ULS) as well as the ETC – Data integration and digitalisation (DI) about landscape features in agricultural areas.

The maintenance of landscape features within agricultural areas is essential to safeguard and promote biodiversity. In view of their multifunctional role in the agricultural landscape and their perceived continuous disappearance, they have gained attention from the scientific community and policy makers. This has facilitated their uptake into the CAP impact indicator framework.

The report describes the process of defining agricultural area using Copernicus datasets and then further explores how landscape features are defined and which Copernicus data can be used to provide information on these at pan-European level.

## Glossary

Abbreviation	Name	Reference
AA	Agricultural Area	
Afta	Association for Temperate Agroforestry	<a href="https://www.aftaweb.org/">https://www.aftaweb.org/</a>
BRT	Basis Registratie Topografie	
CAP	Common Agricultural Policy	
EC	European Commission	
EEA	European Environment Agency	<a href="http://www.eea.europa.eu">www.eea.europa.eu</a>
EFA	Ecological Focus Areas	
EO	Earth Observation	
ES	Ecosystem services	
EU	European Union	
EURAF	European Agroforestry Federation	
FAO	Food and Agriculture Organization of the United Nations	
GAEC	Good Agricultural and Environmental Conditions	
HNV	High Nature Value Farmland	<a href="https://www.eea.europa.eu/data-and-maps/data/high-nature-value-farmland-1">https://www.eea.europa.eu/data-and-maps/data/high-nature-value-farmland-1</a>

HRL	High Resolution Layer	<a href="https://land.copernicus.eu/pan-european/high-resolution-layers">https://land.copernicus.eu/pan-european/high-resolution-layers</a>
IACS	Integrated Administration and Control System	
ICRAF	International Centre for Research in Agroforestry	<a href="https://www.cgiar.org/research/center/world-agroforestry-centre/">https://www.cgiar.org/research/center/world-agroforestry-centre/</a>
LF	Landscape Features	
LPIS	Land Parcel Information System	
MAC	Meetnet Agrarisch Cultuurlandschap	
RVO	Rijksdienst voor Ondernemend Nederland	
RDP	Rural Development Programme	
SWF	Small Woody Features	
UAA	Utilised Agricultural area	<a href="https://ec.europa.eu/5tilized/statistics-explained/index.php?title=Glossary:Utilised_agricultural_area_(UAA)">https://ec.europa.eu/5tilized/statistics-explained/index.php?title=Glossary:Utilised_agricultural_area_(UAA)</a>
WVM	Woody Vegetation Mask	

## 1 Introduction

For the new CAP (2023 – 2027), the European Commission introduced a new Performance monitoring and evaluation framework (PMEF) within regulation EU 2021/2115 (December 6, 2021). This framework defines a set of key objectives for the CAP, focused on social, environmental and economic goals. EU Member-States have to design their CAP national strategic plans to assess and to respond the needs related to these strategic objectives. One of the ten key objectives of the CAP 2023-2027 is ‘To preserve landscapes and biodiversity’. One of the indicators under this strategic objective is the agricultural areas covered by landscape features (I.21).

The revised PMEF supports the shift in policy focus from compliance with rules to performance and results. This new performance-based delivery model uses a set of common indicators for assessing the performance of the implementation of the CAP toward its key objectives. This set of common performance indicators includes:

- Output indicators, which will be used for monitoring the implementation of the CAP at EU level;
- Result indicators, which will be used to monitor EU Member-States’ progress towards pre-set targets;
- Context and impact indicators, which will be used to assess the overall policy performance against CAP objectives.

‘Good agricultural and environmental conditions’ are environment and climate-friendly farming practices and standards that are set under ‘enhanced conditionality’ in the new CAP framework, aiming at a higher ambition level compared to the ‘conditionality’ requirements in the previous CAP. The standard n8 (GAEC 8) foresees the retention of landscape features; a minimum share of agricultural land under non-productive features or areas, a ban on cutting of hedges and trees during the bird breeding and rearing season, and as an option, measures for avoiding invasive plant species.

The Impact indicator I.21: “Enhanced provision of ecosystem services: share of utilized agricultural area (UAA) covered with landscape features” pertains to the specific CAP objective of “contributing to halting and reversing biodiversity loss, enhance ecosystem services and preserve habitats and landscapes”.

The objective of this report is to summarise the work done by the ETC/ULS and ETC DI in support of the development of an indicator based on Copernicus data,

The work on the indicator sparked the discussion on several subsequent topics, like:

- The definition and spatial delineation of the reference area, i.e., the **agricultural area for which the indicator can be calculated**;
- The definition of landscape features in different policy documents;
- The relation between landscape features and agroforestry areas;
- The availability and feasibility of existing data that could be used to describe landscape features at European level;
- The role, definition, and the mapping of biodiversity in different agricultural landscapes;

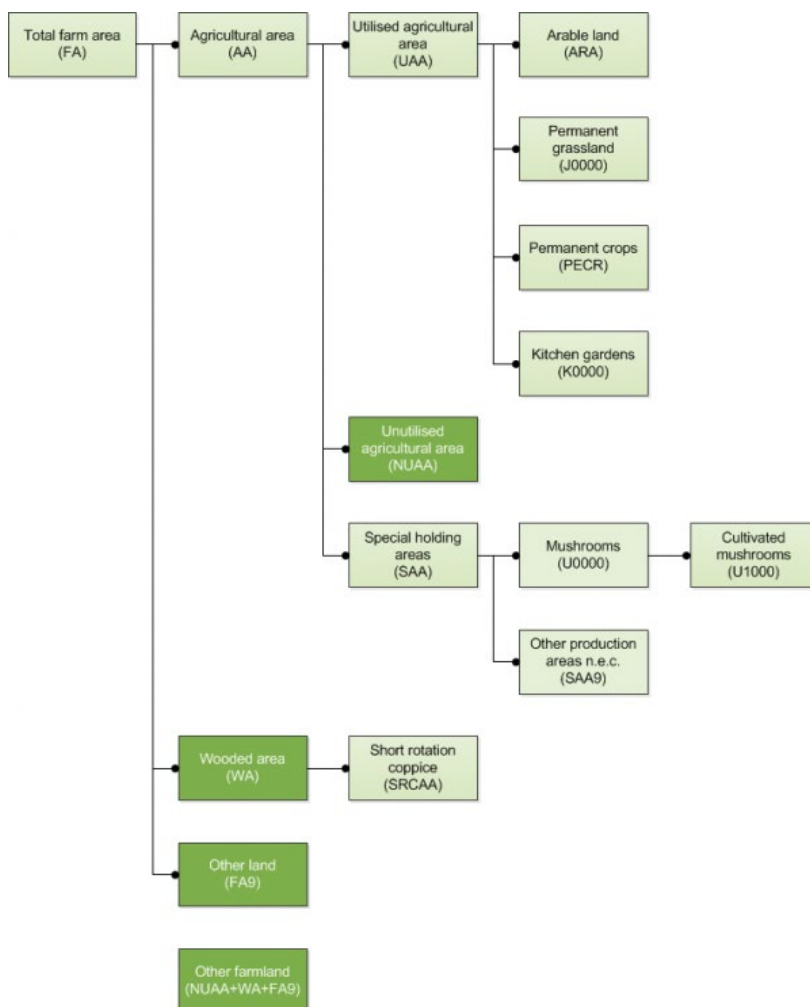
## 2 The agricultural area (AA) mask

The CAP impact indicator I.21 is defined as the “share of **Utilised Agricultural Area** (UAA) covered with **landscape features**”. The term “Utilised Agricultural Area” is used by the European Commission (Eurostat, DG AGRI) and describes the statistically utilized area used for farming. “Utilised Agricultural Area” is on its own a CAP context indicator (C.17) that is expressed as the total utilised agricultural area (UAA) in absolute terms (ha) and as the share of UAA in different categories of land use and includes the following land categories (Figure 1):

- arable land;
- permanent grassland;
- permanent crops;
- other agricultural land such as kitchen gardens (even if they only represent small areas of total UAA).

The term does not include unused agricultural land, woodland and land occupied by buildings, farmyards, tracks, ponds, etc.

To set a baseline for the I.21 indicator, it is necessary to define a spatial reference layer of agricultural area.



## Figure 1: General tree of UAA definition according to Eurostat.

Source: [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Utilised\\_agricultural\\_area\\_\(UAA\)](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Utilised_agricultural_area_(UAA)) – last accessed 02.05.23 16:24

UAA is here predominantly used as a statistical term. The areal statistic is derived from national data, thus there is no EU-wide geospatial data on UAA. In order to address this gap a spatial reference layer for agricultural area was created to accompany the indicator. This was based on available European spatial data.

### 2.1 Methodological description

The spatially explicit layer (hereinafter referred to as Agricultural Area (AA) mask) was developed under the following premises and conditions:

- IACS / LPIS spatial information is not harmonised and not accessible for all European countries and thus cannot be used as a common base for the identification of agricultural areas. Nonetheless, it can be used – where openly accessible – for cross-checking of the results of the project.
- The Corine Land Cover was used as basic geographical skeleton (i.e., the 1 hectare CLC2018 accounting layer<sup>1</sup>) due to its EU-wide coverage and its independently established mapping quality.
- The reference area was refined by using Copernicus High Resolution Layers (HRL).
- Following the same basic concept as already applied for the development of High Nature Value (HNV) Farmland layer in 2019, the development started from the spatial extent provided by CLC and areas that were included or excluded in the original CLC due to the 25 ha minimum mapping unit were successively subtracted or added, respectively.
  - CLC agriculture classes (CLC 2xx) and CLC class natural grassland (CLC 321) form the basis of delineation (see Annex).
  - From these CLC classes non-agricultural patches (which had originally been included in CLC due to the generalisation to the 25 ha minimum mapping unit) are excluded using the higher resolution Copernicus High Resolution Layer (HRL):
    - Woody vegetation (on the basis of the HRL FTY2018 100m layer) is excluded only from the following CLC classes: 211, 212, 213, 231, 242, 243, 321 – not from classes 241 and 244,
    - Artificially sealed surfaces, with a sealing degree  $\geq 30\%$  (on the basis of the Imperviousness (IMD) 100m density layer),
    - *Permanent water surfaces larger or equal to 0.5 ha on the basis of the 100m Permanent Water Density (PWD) layer* The PWD layer was created from the 10m resolution HRL WAW2018 layer: Larger or equal than 0.5 ha contiguous (8 cell neighbourhood) permanent water (class 1) areas were identified in the 10 m WAW layer in a first step. After that, the PWA layer was created by aggregation. Permanent water density  $\geq 45\%$  was used to exclude permanent water surfaces from the AA.
    -
- In the last step, agricultural areas that have been missed in CLC are added back to the AA mask:

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<sup>1</sup> <https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/5a5f43ca-1447-4ed0-b0a6-4bd2e17e4f4d>



- Greenhouses, which contribute to the agricultural area, were added to the mask in a 2-step approach:
  - by importing them from the Copernicus local component 2018 data<sup>2</sup> (Riparian Zones, N2K, Coastal Zones) (level-3 MAES code 212) and
  - by visual interpretation: contiguous areas larger than 20 hectares originally included to AA areas but filtered out by  $IMD \geq 30\%$  criteria are checked visually. If identified as greenhouse, they are added to AA areas.
- During visual evaluation, no distinction was made between glass-covered (usually permanent, often “industrial”) and plastic covered (sometimes temporary) greenhouses.

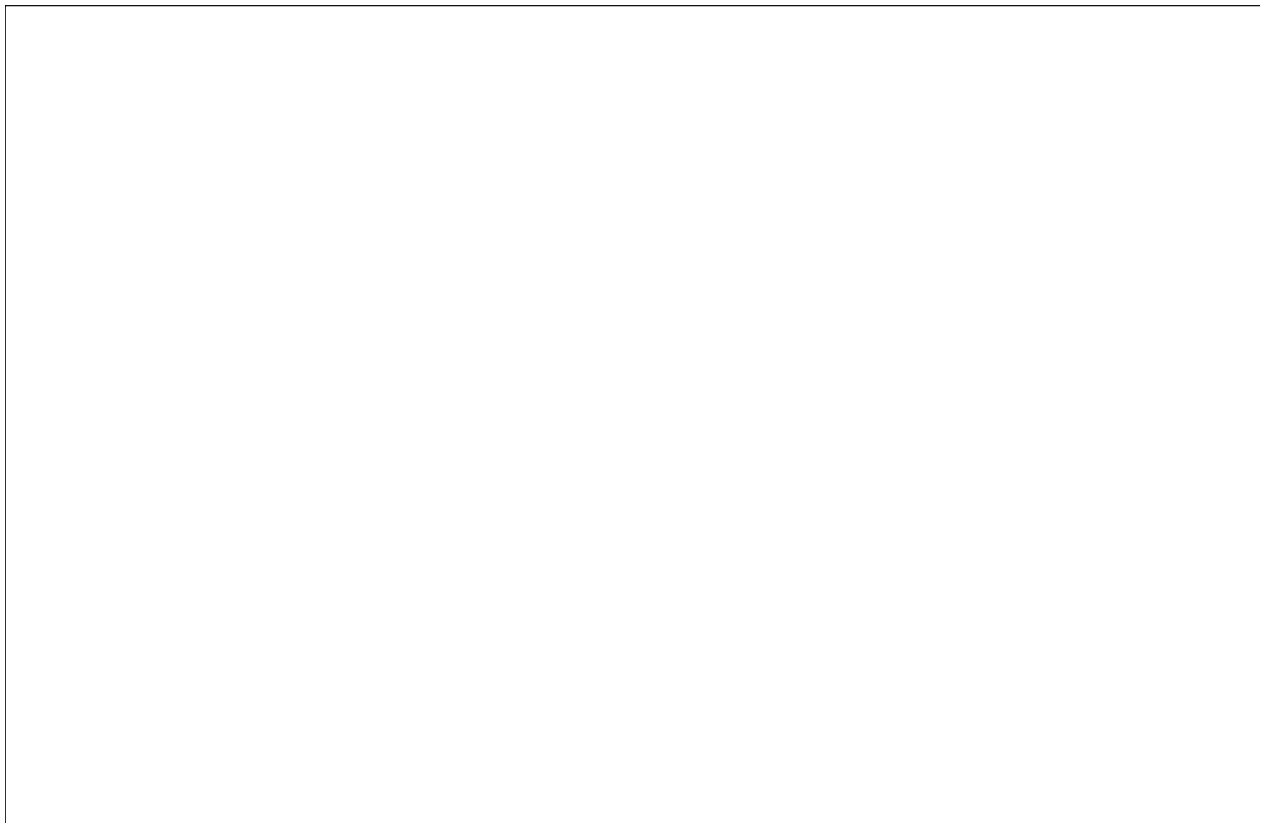
The following general principles were applied:

- Copernicus products of 2018 reference year are used.
- The AA mask is created for EEA39.
- The processing was performed on the basis of 100 m raster input layers in case of CLC, IMD, and FTY layers.
- As the WAW layer is available only in 10m version, a new 100m layer density layer was created based on the appearance of class 1 (permanent water).
- Local component vector data were rasterized first in 10m. In a second step a 100m density layer showing the appearance of MAES level 3 class 212 (Greenhouses) were created.

An overview of the mask can be seen in Figure 2.

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<sup>2</sup> <https://land.copernicus.eu/local>



**Figure 2 Agricultural area mask across EEA38 countries + United Kingdom (UK).**

**Source: ETC DI (own map)**

## **2.2 Quality assurance**

During the production process the AA mask was compared to selected national data sources as well as Eurostat statistics on Utilised Agricultural Area for different countries. Based on this comparison the mask was iteratively improved, e.g. by introducing the re-addition of greenhouses in the workflow.

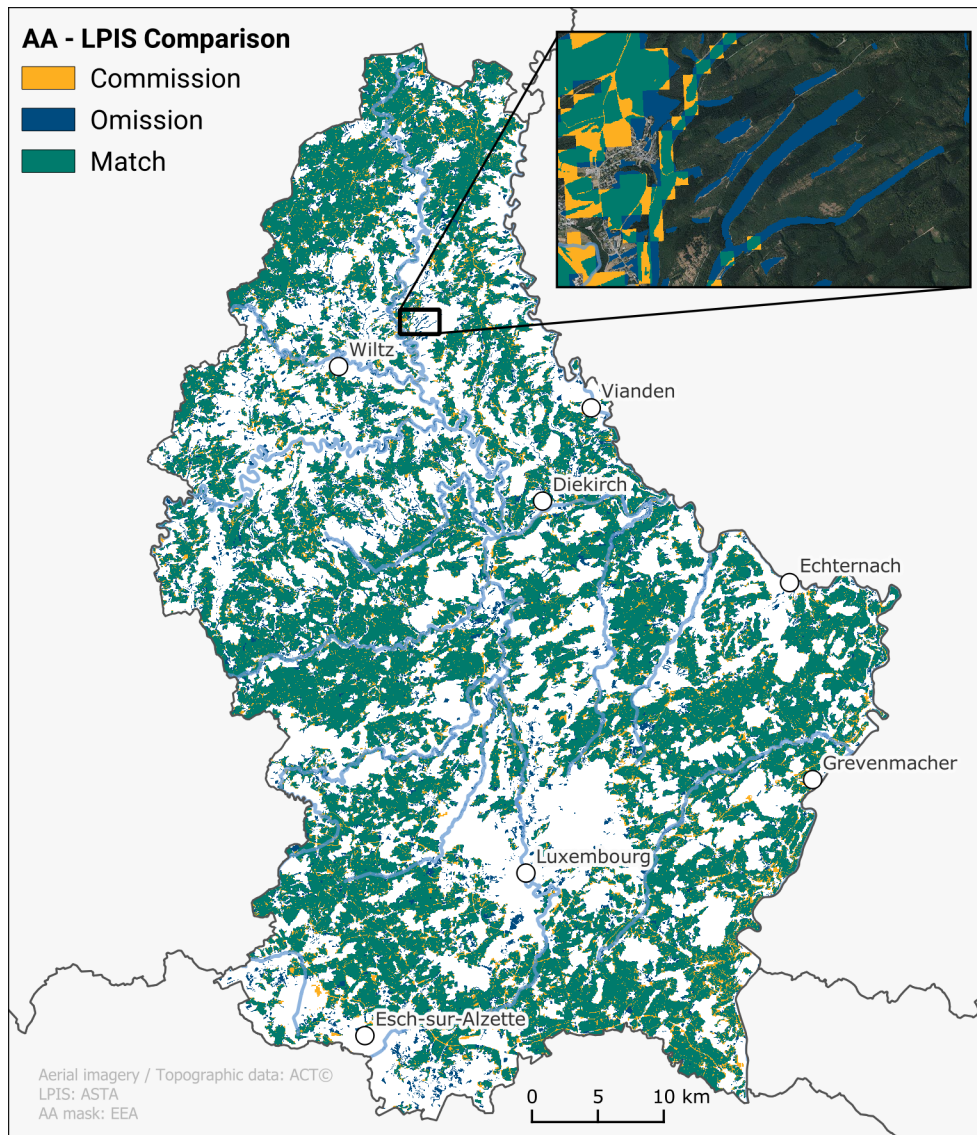
One main conclusion was that the inclusion of additional grassland based on the HRL Grassland does not necessarily lead to an improvement of the AA mask. On the contrary, in most countries the addition of HRL grassland area led to a significant overestimation of the total agricultural area compared to Eurostat, which can be related to inclusion of non-agricultural grasslands such as parks, military areas, abandoned land, and agricultural grasslands not included in the Eurostat UAA data (e.g. common grasslands).

## **2.3 Comparison to national agricultural parcel information**

The geometric and thematic quality of a first version of the mask of agricultural areas was evaluated in four countries including the Czechia (CZ), Hungary (HU), Luxemburg (LU) and Spain (ES). In all cases, the AA mask was compared to the agricultural area defined by the national LPIS database, and in Luxembourg a land use map was used in addition.

In Hungary and Czechia, the agricultural mask showed a good match with omission errors around 4% and commission errors between 4% and 8%. Errors were mostly around the borders of the different layers, implying that no significant regions were omitted.

In Luxembourg, the AA mask was compared to two different information layers: the agricultural area defined by LPIS and the agricultural area defined by the national land use (2018) map – the difference between these two layers is that grasslands are not considered in LPIS as no subsidies are requested for these. The underestimation (omission error) of the true agricultural area was around 12% compared to LPIS and around 13.5% compared to the land use map (due to the inclusion of additional grassland areas). The commission error was about 17% for LPIS and 14% for the land use map. Many of the errors occurred along the edges of existing patches (see Figure 3) and were caused by the difference in spatial resolution. Larger contiguous patches of errors were not frequent.

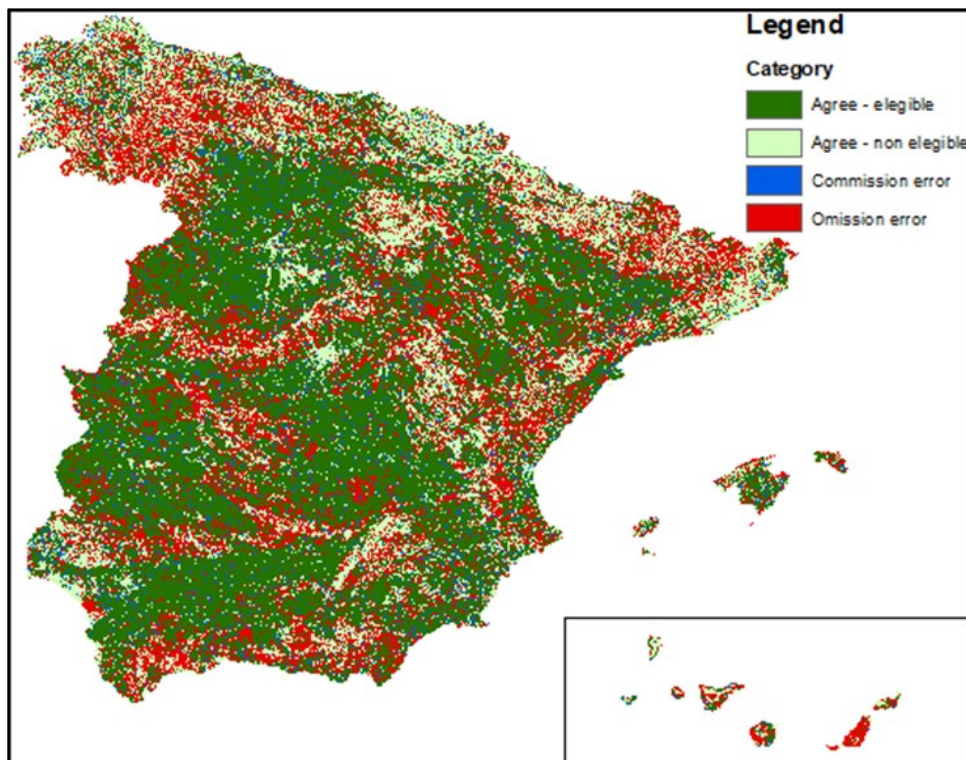


**Figure 3: Types of mismatch between the AA mask and national data for Luxembourg. Source: ETC DI (own map)**

In Spain the overall error was more significant and includes also larger patches of omission (Figure 4). The overall accuracy was 72% and with 32% of omission- and 9% commission error. The reason for the higher amount of omission errors was clearly related to the differences in classification of pastures with shrublands and / or trees between the Spanish LPIS and the Corine Land Cover. These areas are classified

by ES LPIS as pastures classes: Pasture with trees (PA), Pastures with shrubland (PR) and Pastures (PS), while they are not classified as agricultural area or natural grassland in CLC in many cases. Excluding these pasture classes from the assessment decrease the omission error to 8.7% (Table 1). This discrepancy could be reduced only if alignment between the CLC and the Spanish LPIS could be addressed, however that would be difficult as the scope, spatial resolution and thematic approach of the two databases are different, or if the AA would use national data (in combination with CLMS data), which is out of scope of the current workflow.

If the additional agroforestry areas were not considered, the omission errors were low at country and at NUTS2 level. They showed higher variability depending on the land use/land cover classes present in the area at NUTS3 level but in most cases the error was lower than 10% so in general this was acceptable. Most of the commission errors correspond to small size polygons of transport infrastructures, buildings, etc.



**Figure 4 Overview on spatial distribution of commission and omission errors for Spain.**

**Table 1 Summary of errors and accuracies for Spain.**

<b>Overall accuracy</b>	<b>71.02%</b>
<b>Commission error</b>	<b>9.17%</b>
<b>Omission error</b>	<b>32.68%</b>
Producer Accuracy	67.32%
User Accuracy	90.83%

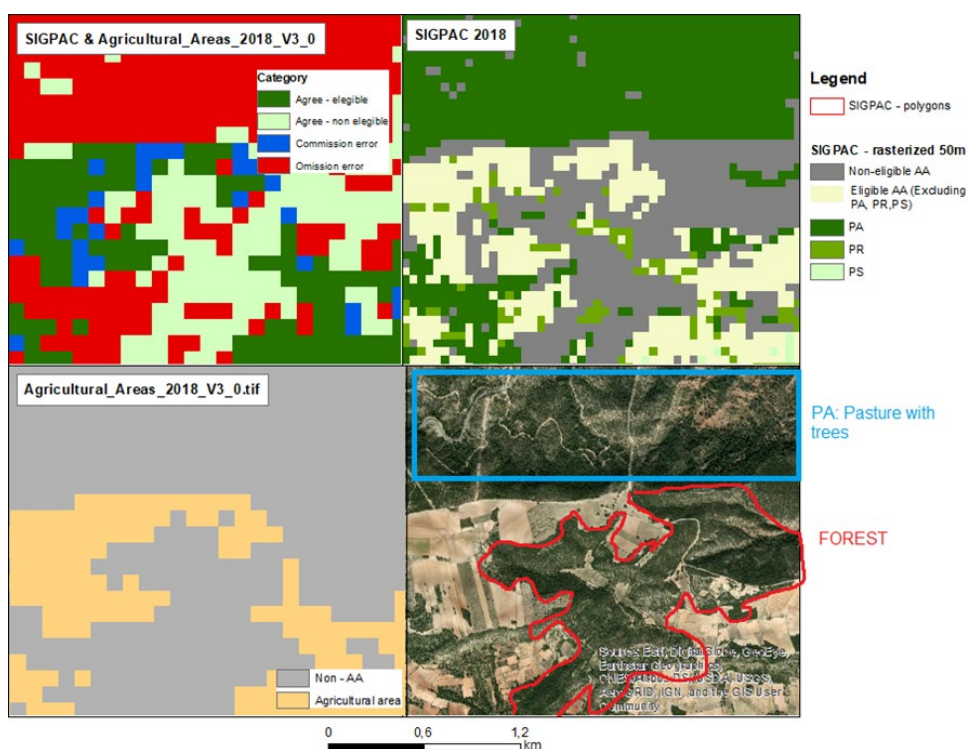
Stratification of the omission error	
Omission error excluding PA/PR/PS	8.71%
Omission error PA	63.14%
Omission error PR	60.16%
Omission error PS	30.01%

In Spain, the CLC class “agroforestry” usually thematically corresponds to “Dehesas”, a Mediterranean agrosilvopastoral land use system characterised by semi-open woodlands. As such, this “error” or thematic difference in the AA mask does not affect the “dehesas” area that is properly classified by CLC. However, Dehesas is only a sub-type of agroforestry land use in Spain. In Spain the LPIS registers three types of pastures PA (pasto arbolado/pastures with trees), PR (pasto arbustivo/pastures with shrublands) and PS (pastizal/herbaceous pastures). The agricultural management system of these pasture areas, specifically those linked to mountain agroecosystems is an extensive pastoral system. , which produces in many cases very important ecosystem services, e.g., fire prevention or biodiversity maintenance (Bernués et al., 2014).

Most of these areas are classified by CLC as forest classes (3.1.X + 3.2.4), so they are excluded from the AA mask. As Figure 5 shows, it is not possible to distinguish the PA and PR uses from forest or shrubland without having agricultural land use information . This is one of the main challenges for high certainty of the AA mask in Spain.

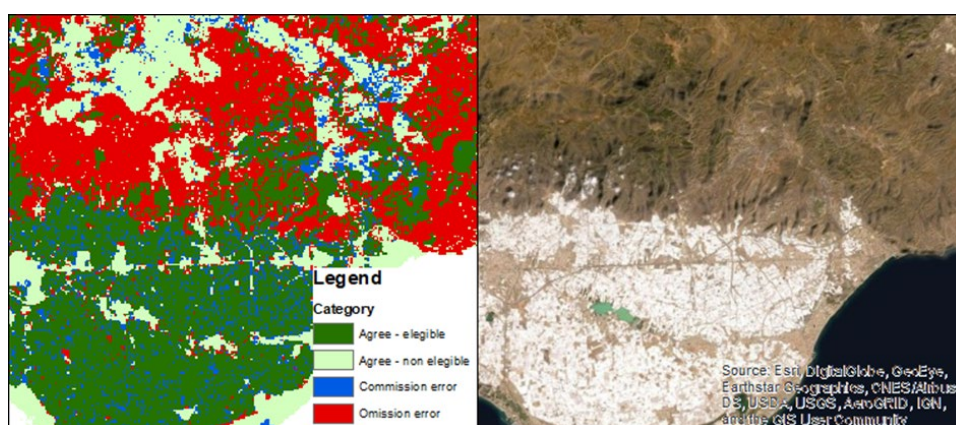
In summary, the delineation of these woody pastures, very valuable from agricultural (grazing area) and biodiversity perspectives, is difficult with the current methodological approach. In fact, the most efficient solution, and maybe the unique, would be the integration of the land use information from the national LPIS.





**Figure 5 Omission error link to PA use in Spain**

While the greenhouses were addressed in the final version of the AA mask (Figure 6), the issue of pastures with shrubland and / or trees / agroforestry areas couldn't be addressed. See also section 4.4 in this report for a further discussion of this topic.



**Figure 6 Greenhouses in the province of Almeria, southern Spain. Consistency between AA and LPIS datasets**

## 2.4 Comparison to Eurostat UAA definition

The comparison of the agricultural area defined by the AA mask and the statistical information provided by Eurostat for Utilised Agricultural Area (UAA) is shown in

Table 2. Most countries show an overestimation of the agricultural area by the AA mask between 10% and 20%. The relation between AA mask and UAA can be rather complex, as some agricultural classes in CLC (2.x.x) are not necessarily in agricultural use:

- Class 231 includes not only pastures and meadows, but also degraded grasslands under strong human influence, which are not in agricultural use, such as leftover areas after abandonment of construction sites or mineral extraction sites.
- Areas in transition can be mapped to different classes, such as the shrub cover of a natural grassland under natural succession, thus it might be coded as 321 – Natural grassland, which is included in the AA mask, or as 324 – Transitional woodland and shrub, which is not considered by the AA mask.
- Natural grasslands under nature conservation (321) are sometimes not included as agricultural areas in national definitions.
- Pastures and natural grasslands with more than 30% woody vegetation could be still considered as grasslands, according to the national definitions applied for EU CAP payments. However, the grasslands under agricultural use can be affected by a Reduction Coefficient (RC) that accounts for the percentage of scattered natural features, considered unsuitable for agriculture (woody vegetation, rocky outcrops, pools, etc). This coefficient varies from 0 to 100% for subtracting what is not herbaceous vegetation, or woody vegetation suitable for grazing or animal feed. This means that the UAA of certain polygons classified as pasture or natural grassland is the geometric area of the polygon multiplied by the RE. Then:
  - this affects all countries that apply RE on pastures or natural grasslands (e.g., Spain, Italy, Ireland, Greece, etc);
  - The approach towards the application of the RC varies from country to country. Specific RC values can be defined per each type of grassland, according to the national definitions. The RC values could also be derived individually for each of the grassland parcels, recorded in the Land Parcel Identification System.
  - the effect of this RC values on the area is bigger for countries with higher rates of pastures and natural grasslands and lower CPE (as average);
  - the AA mask is useful to identify the geographical extent of the AA in the countries, but the total area derived from it can differ from the tabular information (area values) of UAA for those countries that apply RC on pastures and grasslands and account for it in the UAA reporting.

Significant deviations between the statistics from the UAA mask and AA mask are highlighted using an opposing colour palette (red = AA < UAA / green = AA > UAA) in Table 2. The second to last column provides the absolute difference in square kilometres between the UAA and AA mask, the last column the total difference in percent (negative values indicate a smaller agricultural area value calculated from the AA mask compared to the Eurostat figures).

For Cyprus, the Eurostat data only provides the UAA for the European part of Cyprus while the AA mask covers the whole island. Therefore, the values are not comparable. In Iceland the AA mask substantially underestimates the agricultural area compared to the information provided by Eurostat. One explanation for this could be that larger amount of heathlands or bare areas are utilised for animal husbandry and may not be recognized as pastures within CLC, thus excluding these areas from the mask.

**Table 2: Comparison of agricultural areas between Eurostat (UAA) and AA mask**

<i>NUTSO name</i>	<i>Country area</i>	<i>AA_V3_1 final (AA CLC-FTY- PWA- IMD30+GRH)</i>	<i>UAA 2018</i>	<i>AA MASK (V3_1) minus UAA 2018</i>	<i>Difference (%)</i>
<b>LEVEL0_NAME</b>	<b>CTRY_AREA KM2</b>	<b>AA MASK KM2</b>	<b>Eurostat (KM2)</b>		
Albania	28,783.15	9,633.09	11,740.00	- 2,106.91	-17.9%
Austria	83,943.85	29,441.93	26,538.40	2,903.53	10.9%
Bosnia and Herzegovina	51,215.23	15,170.86	17,796.30	- 2,625.44	-14.8%
Belgium	30,660.49	15,419.12	13,560.80	1,858.32	13.7%
Bulgaria	110,983.99	53,659.11	50,302.80	3,356.31	6.7%
Switzerland	41,288.28	13,765.87	15,146.80	- 1,380.93	-9.1%
Cyprus	9,240.54	4,445.71	1,324.40	3,121.31	235.7%
Czechia	78,873.89	40,504.06	35,232.20	5,271.86	15.0%
Germany	357,471.81	190,617.26	166,451.00	24,166.26	14.5%
Denmark	43,028.50	29,895.63	26,325.00	3,570.63	13.6%
Estonia	45,297.49	12,625.89	9,846.70	2,779.19	28.2%
Greece	131,639.37	52,922.38	52,880.50	41.88	0.1%
Spain	505,875.77	260,332.20	242,019.10	18,313.10	7.6%
Finland	337,308.16	24,205.95	22,719.00	1,486.95	6.5%
France	548,897.97	304,709.58	290,201.60	14,507.98	5.0%
Croatia	56,515.96	21,729.57	14,856.50	6,873.07	46.3%
Hungary	93,012.45	59,343.71	53,437.80	5,905.91	11.1%
Ireland	69,902.24	45,532.53	45,160.40	372.13	0.8%
Iceland	102,653.47	6,002.26	15,551.00	- 9,548.74	-61.4%
Italy	300,421.34	139,894.26	129,087.50	10,806.76	8.4%
Kosovo	10,907.09	4,228.81	4,195.00	33.81	0.8%
Lithuania	64,898.89	35,619.39	29,472.30	6,147.09	20.9%
Luxembourg	2,595.44	1,238.94	1,315.60	- 76.66	-5.8%
Latvia	64,582.53	22,658.80	19,379.00	3,279.80	16.9%
Montenegro	13,878.24	2,338.42	2,568.10	- 229.68	-8.9%
North Macedonia	25,435.35	9,505.42	12,641.40	- 3,135.98	-24.8%
Malta	313.89	153.23	115.80	37.43	32.3%
Netherlands	37,382.98	22,678.75	18,224.00	4,454.75	24.4%
Norway	322,944.39	11,877.14	9,863.00	2,014.14	20.4%
Poland	311,917.32	170,045.00	145,395.50	24,649.50	17.0%
Portugal	91,854.60	40,285.52	35,914.20	4,371.32	12.2%
Romania	238,361.28	130,046.93	134,137.40	- 4,090.47	-3.0%
Serbia	77,484.42	38,205.31	34,869.10	3,336.21	9.6%
Sweden	449,369.37	35,591.03	30,003.90	5,587.13	18.6%
Slovenia	20,273.30	5,637.45	4,779.30	858.15	18.0%
Slovakia	49,025.84	20,848.74	19,195.40	1,653.34	8.6%
Turkey	779,168.80	390,860.32	382,390.00	8,470.32	2.2%



United Kingdom	244,413.34	142,649.33	173,570.00	- 30,920.67	-17.8%
<b>EEA-39</b>	<b>5,831,821.02</b>	<b>2,414,319.50</b>	<b>2,298,206.80</b>	<b>116,112.70</b>	<b>5.1%</b>

### 3 Landscape features and agroforestry: An overview of ecological value and legal definitions

The CAP I.21 indicator ( ) aims at assessing the portion of landscape features in the agricultural landscape in support of biodiversity and ecosystem services. It aims to estimate the share of agricultural land covered with landscape features.

Landscape features may include linear elements (e.g., hedgerows, tree lines, stone walls) and patches (e.g., trees groves, groups of trees or scrubs, terraces, etc.). They include woody (e.g. tree lines, tree groups, individual trees, hedges), grassy (e.g. grassy field margins), wet (ponds, ditches) and stony (stone walls) features.

Landscape features (LF) in agricultural areas support biodiversity and ecosystem services (ES) in general. They provide multiple benefits to agro-ecosystems and the wider environment, including habitat provision, mitigation of soil erosion, and improvement of soil fertility. However, landscape features have been disappearing along with the intensification of agriculture and related land parcel consolidation since the 1950s in Europe. This is one of the pressures contributing to biodiversity loss and loss of ecosystem services beneficial both to the environment and to agricultural production. Removal of small landscape features for agricultural land parcel consolidation is one of the most frequently reported agricultural pressures for habitats and species under the Habitat Directives (Article 12 and Article 17 Member States' reports and assessments; EEA, 2020). Among various impacted species, reptiles and smaller mammals are especially affected by the resulted fragmentation, which reduces landscape connectivity and leads to a loss of habitat area essential for food supply, shelter and breeding sites (EEA, 2020).

EU strategies and policies, including the Habitat Directives, the EU Biodiversity Strategy and the CAP aim to maintain, restore and re-create landscape features/high-diversity landscape features. However, the definition of landscape features is difficult, as they are diverse across European landscapes. The mentioned policies do not provide a specific definition but list examples of landscape features.

The definition of agroforestry is included in this chapter because the definition of landscape features, and especially woody landscape features raises the issue of potential overlaps with agroforestry and difficulties to define, map and distinguish landscape features within agroforestry areas. One of the issues related to defining woody landscape features is that the concept of landscape features is most meaningful in open agricultural landscapes with distinct hedgerows and/or woody vegetation patches, embedded in an agricultural matrix. It is technically and conceptually difficult to define and map woody landscape features in areas with a strong intermixing of woody vegetation and arable land and/or grassland. This is the case in agroforestry areas, therefore their mapping is relevant in this context. The overview of definitions aims to help further developments in this direction.

To operationalize an indicator on landscape features several key questions need to be clarified, for which it would be needed to:

- establish a common understanding of landscape features under the policies to which the monitoring is expected to provide data,
- gather a better understanding of the implementation of these regulations into national law and collection of examples with field data,
- set clear requirements of what “must” be addressed by the indicator and what would be “nice to have”.

### 3.1 Landscape features and ecosystem services

The provision of essential ecosystem services by landscape features is increasingly recognized (van der Zanden, Verburg and Múcher, 2013; Duru *et al.*, 2015; Špulerová *et al.*, 2018). As ecological infrastructure elements, they provide habitat for species such as farmland birds, invertebrates and mammals. Linear landscape features are often corridors for the movement of wildlife. Many landscape features were originally designed to safeguard and support agricultural production by their specific role e.g. to mark farm boundaries or to provide windbreak. There are additional benefits for production and for wildlife that have been incidental and synergetic in many cases. An example for synergetic incidental benefit is habitat provision for insects, including predators of agricultural pests and pollinators. .

As cultural service, linear landscape elements are important for tourism and heritage, because they are often part of traditional, agricultural landscapes such as the classic, enclosed Bocage landscapes of France, Wales and England (e.g. Figure 7). There are aesthetic and amenity reasons for maintaining certain types of linear features. Moreover, small-scale mosaic landscapes with landscape elements are often regarded as aesthetically attractive especially in monotonous agricultural landscapes. The hedgerow network, for example, is a characteristic and picturesque part of the English landscape (Spellerberg and Gaywood, 1993).



**Figure 7: Hedgerows in the UK.** Source: <https://www.farminguk.com/news/farmers-and-environment-to-benefit-as-ordnance-survey-creates-new-data-layer-of-hedges-44921.html>

Regulating ecosystem services (Maes *et al.*, 2013) provided by landscape features comprise carbon sequestration, protection against wind erosion, increased water filtration (in grassland ditches or field margins), pollination and pest regulation. Hedgerows were utilized in Britain to mark boundaries and to confine livestock. However, hedgerows also act as windbreaks and moderate the microclimate, which can

help to increase crop yield, reduce soil erosion, and moderate water run-off (Spellerberg and Gaywood, 1993; Power, 2010).

The most relevant spatial scale for assessing the functional characteristics, m of landscape features and the ecosystem services they provide, is at landscape level. Many ecosystem services are influenced by the landscape matrix and structure, e.g. the location and pattern of ecosystems, land use units and functional traits. The spatial patterns of landscapes have high importance in the functioning of a landscape. Moreover, the provision of ecosystem services does not always depend primarily on the properties of each specific, small ecosystem patch, but rather on the spatial interaction, flows and fluxes between these patches of landscape features and between landscape features and other elements of the landscape (such as croplands or grasslands).

Important spatial aspects include (e.g. Bastian *et al.*, 2014):

- The position or pattern of ecosystems, land cover units, landscape features and also Service Providing Areas (SPA) and Service Benefiting Areas (SBA), and their spatial interactions,
- The role of the landscape matrix within which landscape features are embedded,
- The spatial intersection of biotic (e.g. vegetation) and abiotic (e.g. soil) factors,
- Habitat connectivity,
- The spatial requirements (i.e. minimum areas) of ecosystems to deliver specific ES (e.g. the minimum size of a catchment to be able to recharge enough groundwater for the supply of adequate amounts of drinking water, or the size of a forest effective for influencing the microclimate in the vicinity),
- The different scales on which ecosystems and landscapes can be defined.

### 3.2 The ecological value of landscape features

Different regions and different land use systems comprise specific and characteristic types of LFs and only some of them are in the focus of ecological studies. The ecological value of LF have been revealed mostly due to their trend of disappearing in rural landscapes that have been increasingly designed towards intensive agricultural production or other types of land use (like housing, roads). In certain cases, landscape features are seen as hindering the dominant land use so they are at risk of elimination. In many cases they are eliminated with levity because LFs are small, they are often not even recognized ( e.g., margins of farm tracks), and the accumulative effect of removals lacks perception. In special cases, certain landscape types are characterized by the absence of LFs. In this case the openness or homogeneity is the valued feature, for example in the Spanish ‘cereal steppes’. Landscape features usually have a rather small geographical footprint compared to their functional importance. The impact of LFs often reaches out far beyond their physical size. One example is the micro-climatic effect of hedgerows, which extends far into neighbouring fields.

In special cases, certain landscape types are characterized by the absence of LFs. In this case the openness or homogeneity is the valued feature, for example in the Spanish ‘cereal steppes’.

Every single variation of (semi-)natural elements in a uniform “landscape matrix” could be seen as a landscape feature. Generally spoken it is an element of diversity in structure, which extends the diversity of habitats that can be used by organisms.

The ecological value of LFs mainly depends on their existence at all in a landscape, on their density and location and on qualitative characteristics rather than on precise quantitative geometric size of each

feature. Additionally, gaps in hedgerows can contribute to structural diversity and can fulfil specific functions.

The delivery of functions must be viewed in relation to species: e.g. specialised animal species need specific vegetation or populations of plant species as resources (e.g. specialised butterfly-species with their need of certain food-plant species), others need certain structures (raised stands surrounded by open areas for birds of prey), or physical/chemical conditions (soil insects). The function of elements in ecosystems can also vary in time, along the seasons of the year.

Moreover, biodiversity related objectives differ over the regions in Europe. In general, many different situations, conditions and combinations in a landscape provide a high number of possible habitat-types. Hence it is difficult if not impossible and may be even counterproductive (due to a homogenization effect) to define general characteristics for LFs to be of practical use.

Nonetheless, mapping and monitoring of LF is needed and for that definitions are needed. Hence habitat mappings have to be based on a definition of minimal mapping units/sizes and terminologies for the classes used<sup>3</sup>. These are mainly based on practicability, working scale and human perception, e.g. a small ephemeral water puddle in a field tractor lane will hardly be mapped as LF, even though it may have potential habitat value for amphibians and insects at a local scale. When LFs grow, they may develop new characteristics, and offer new habitat qualities. Thus, they may change the mapping class, but still have their functions (hedgerow - grove - forest). Moreover, technological, methodological limitations also influence the mapping possibilities.

Mapping the geographical/physical extent of landscape features is one approach, addressing one aspect that determines their capacity to provide benefits for biodiversity. Other characteristics of the landscape structure, spatial patterns, connectivity, quality of the landscape features also influence it. These could be monitored as well; however measuring these characteristics is even more complex and methodology has not been operationalised yet at European level.

### 3.3 Legislative definitions for landscape features set out in EU Regulations

Definitions of landscape features have been set out in different EU Regulations and related Member State level implementations:

1. **Regulation (EU) No 1306/2013** of the European Parliament and of the Council of 17 December 2013 on the financing, management and monitoring of the common agricultural policy and repealing Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000, (EC) No 1290/2005 and (EC) No 485/2008

This regulation defines, in Annex II, the content of the Good Agricultural and Environmental Conditions (GAEC) 7, i.e. Landscape, minimum level of maintenance - Retention of landscape features, including where appropriate, hedges, ponds, ditches, trees in line, in group or isolated, field margins and terraces, and including a ban on cutting hedges and trees during the bird breeding and rearing season and, as an option, measures for avoiding invasive plant species.

GAEC7 detailed definitions are set out at MS level. The overview in Table 3 shows that hedges, ponds, trees in groups/field copses are most frequently defined as part of GAEC7 in different MS.

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<sup>3</sup> EUNIS is a classification system of habitat types, structured in hierarchical levels down to fairly detailed descriptions. Eventually this system may be useful as a terminology for addressing LFs in a pan-European unified multi-lingual system. Usability needs to be evaluated. (<https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification>)

**Table 3: Inclusion of landscape feature definitions in GAEC 2019, by Member States**

Countries	Hedges	Ponds	Ditches	Trees in line	Trees in group/field copses	Isolated trees	Field margins	Terraces	Traditional stone walls	Total nr features
Austria										3
Belgium Flanders										3
Belgium Wallonia										7
Bulgaria										2
Croatia										7
Cyprus										7
Czech Republic										6
Denmark										1
Estonia										5
Finland										0
France										3
*Guadeloupe										3
*Martinique										3
*Guyane										3
*Reunion										3
*Il de mayotte										2
Germany										8
Greece										5
Hungary										4
Ireland										3
Italy										7
Latvia										0
Lithuania										0
Luxemburg										5
Malta										4
Netherlands										0
Poland										3
Portugal										5
*Azores										4
*Madeira										4
Romania										4
Slovakia										6
Slovenia										7
Spain										8
Sweden										4
UK England										5
UK Northern Ireland										3
UK Scotland										6
UK Wales										5
<b>Total per MS</b>	<b>25</b>	<b>22</b>	<b>15</b>	<b>18</b>	<b>24</b>	<b>17</b>	<b>7</b>	<b>14</b>	<b>13</b>	

Source: Authors' compilation from GAEC database.

- DELEGATED REGULATION (EU) No 639/2014** of 11 March 2014 supplementing Regulation (EU) No 1307/2013 of the European Parliament and of the Council establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and amending Annex X to that Regulation.

This regulation defines the landscape features on arable land that could be qualified as *ecological focus areas*<sup>4</sup>: i.e.

<sup>4</sup> Ecological focus areas: ecological focus areas (EFA) were part of the green direct payment scheme ('greening') under the CAP 2014-2020. Farmers with arable land exceeding 15 ha had to ensure that at least 5% of their land was an EFA dedicated to ecologically beneficial elements, selected from a menu of 'EFA types' drawn up by the national authorities from a common EU list, in order to safeguard and improve biodiversity on farms.



“Article 45 (4)

Landscape features shall be at the disposal of the farmer and shall be those that are protected under GAEC 7, Statutory Management Requirements (SMR) 2 or SMR 3 as referred to in Annex II to Regulation (EU) No 1306/2013 as well as the following features:

- a) hedges or wooded strips with a width of up to 10 meters;
- b) isolated trees with a crown diameter of minimum 4 meters;
- c) trees in line with a crown diameter of minimum 4 meters. The space between the crowns shall not exceed 5 meters;
- d) trees in group, where trees are connected by overlapping crown cover, and field copses of maximum 0,3 ha in both cases;
- e) field margins with a width between 1 and 20 meters, on which there shall be no agricultural production;
- f) ponds of up to a maximum of 0,1 ha. Reservoirs made of concrete or plastic shall not be considered ecological focus area;(g) ditches with a maximum width of 6 meters, including open watercourses for the purpose of irrigation or drainage. Channels with walls of concrete shall not be considered ecological focus area.
- g) traditional stone walls.

Member States may decide to limit the selection of landscape features to those under GAEC 7, SMR 2 or SMR 3 as referred to in Annex II to Regulation (EU) No 1306/2013 and/or to one or more of those listed in point (a) to (h) of the first subparagraph, where duly justified.

For the purposes of points (b) and (c) of the first subparagraph, Member States may include trees recognised by them as valuable landscape features with a crown diameter below 4 meters. For the purposes of point (e) of the first subparagraph, Member States may establish a lower maximum width.

For the purposes of point (f) of the first subparagraph, Member States may set a minimum size for ponds and they may decide that a strip with riparian vegetation along the water with a width of up to 10 meters is included in the size of the pond. They may establish criteria to ensure that ponds are of natural value, taking into account the role that natural ponds play for the conservation of habitats and species.

For the purposes of point (h) of the first subparagraph, Member States shall establish minimum criteria based on national or regional specificities, including limits to the dimensions of height and width”

Table 4 provides an overview of landscape feature definitions by MS.



**Table 4: Overview of landscape feature definitions in GAEC standards and EFA definitions (CAP 2014-2020)**

Feature	GAEC7 MS definitions	EFA definition (from the No 639/2014 above)
Hedges / wooded strips	<p><b>Key parameters</b></p> <ul style="list-style-type: none"> <li><u>width / length</u>: (10 of 15 MS); minimum length ranges between 5m and 25m, maximum width ranges between 2m and 15m; most frequently defined are a minimum length of 20 m and a maximum width of 10</li> <li><u>shape</u> (10 of 15 MS); most frequently defined as a 'linear', but also as 'row', 'fence' or 'compact shaped plantings', or 'dense uniform alignment'</li> <li><u>vegetation / foliage cover</u> (11 of 15 MS); two countries define that foliage should be at least 20%; most frequently vegetation is defined as predominantly woody species, or made up of trees, shrubs and bushes</li> <li><u>location</u> (5 of 15 MS); no matching descriptions: 'planted directly on a slope or in a hallow'; 'raised earthen bank, situated along margins of trees', 'along watercourses as part of land parcel', 'in or adjacent to any land which forms part of a holding'</li> <li><u>functions</u> (4 of 15 MS); most frequently defined as a barrier or boundary, but also as protection against natural disturbances (PT).</li> </ul> <p><b>Supplementary parameters</b></p> <ul style="list-style-type: none"> <li><u>height</u> (1 MS); maximum 3m</li> <li><u>area</u> (1MS); minimum 0,01 ha</li> </ul>	hedges or wooded strips with a width of up to 10 meters;
Trees – isolated	<p><b>Key parameters</b></p> <ul style="list-style-type: none"> <li><u>crown diameter</u> (5 of 14 MS), minimum ranges between 2 and 8m; most frequently defined as a minimum of 4m in crown diameter</li> <li><u>location</u> (6 of 14 MS) – surrounded by arable land</li> </ul>	(b) isolated trees with a crown diameter of minimum 4 meters;
Trees – in line	<p><b>Key parameters</b></p> <ul style="list-style-type: none"> <li><u>shape</u> (10 of 15 MS), defined as 'row of trees' (3) or 'linear feature' / 'line of trees' (6)</li> <li><u>composition</u> (7 of 15 MS), three trees (2), four trees (1) and – most frequently – five trees (4) mentioned</li> </ul> <p><b>Supplementary parameters</b></p> <ul style="list-style-type: none"> <li><u>length</u> (5 of 15 MS), ranges from 10 m to more than 75 m, maximum single mention: 15 m</li> <li><u>width</u> (5 of 15 MS), ranges from minimum 1 m to maximum 10 m.</li> </ul>	c) trees in line with a crown diameter of minimum 4 meters. The space between the crowns shall not exceed 5 meters;
Trees – in group	<p><b>Key parameters</b></p> <ul style="list-style-type: none"> <li><u>area</u> in separate column (12 of 15 MS), only maximum is indicated, different parameters, most usually in ha (max between 0.2 up to 0.5 ha)</li> </ul>	d) trees in groups, where trees are connected by overlapping crown cover, and field copses of maximum 0,3 ha in both cases;

	<ul style="list-style-type: none"> <li>• <u>location</u> (9 of 15 MS), divers description: located 'near arable land' or 'within parcels of farmland', 'clearly distinct' from arable land, 'undisturbed' and 'stand-alone'</li> <li>• <u>vegetation</u> (8 of 15 MS), mostly woody plants, trees (6), bushes (3) and shrubs (2), additionally mentioned 'other natural plant cover'; clear distinction to agricultural land mentioned twice</li> <li>• <u>area (mainly)</u> (8 of 15 MS), minimum 0.005 ha (mostly mentioned 0.01 ha to maximum 0.5 ha)</li> </ul> <p><b>Supplementary parameters</b></p> <ul style="list-style-type: none"> <li>• <u>composition</u> (4 of 15 MS), two trees (2) to four trees (1)</li> </ul>	
Field Margins	<p><b>Key parameters</b></p> <ul style="list-style-type: none"> <li>• <u>location</u> (5 of 6 MS); most frequently referred to as near arable land, with no agricultural production</li> <li>• <u>width/length</u> (4 of 6 MS); maximum width range between 2m and 20m; most frequently defined as 10m maximum</li> </ul> <p><b>Supplementary parameters</b></p> <ul style="list-style-type: none"> <li>• <u>function</u> (3 of 6 MS); diverse functions named: 'farmers temporarily place unwanted vegetation to be carted away for disposal'; 'reduction of water or wind erosion'; 'physical separation'</li> <li>• <u>shape</u> (2 of 6 MS); defined as a 'narrow, long strip of land'</li> </ul>	Field margins with a width between 1 and 20 meters, on which there shall be no agricultural production
Terraces	<p><b>Key parameters</b></p> <ul style="list-style-type: none"> <li>• <u>composition</u> (4 of 9 MS); is described as continuously sloped (2), linear(-vertical) (3) or perpendicular (1)</li> <li>• <u>function</u> (4 of 9 MS); most frequently named: reducing risk from erosion by water or wind (3) as well as the gradient of agricultural land (2) and controlling run-off (1)</li> <li>• <u>vegetation</u> (4 of 9 MS); identified as 'woody' or 'herbaceous' vegetation and 'trees of public interest'</li> <li>• <u>height</u> (4 of 9 MS); only minimum from 0,5m up to 12m</li> </ul>	N/A
Ponds	<p><b>Key parameters</b></p> <ul style="list-style-type: none"> <li>• <u>surface area</u> (11 of 15 MS); minimum surface area ranges from 0.0025 ha to 0.1 ha (exception is HR with 100 ha); most frequent minimum surface area is 0.01 ha. Maximum surface area ranges from 0.1 ha to 0.5 ha (with exception of HR with 1000 ha); most frequent maximum surface area is 0.1 ha</li> <li>• <u>natural or artificial</u> (9 of 15 MS); overwhelmingly defined as natural body of water; only few MS include artificial ponds</li> </ul>	up to a maximum of 0,1 ha. Reservoirs made of concrete or plastic shall not be considered ecological focus area
Ditches	<b>Key parameters</b>	N/A

	<ul style="list-style-type: none"> <li>• <u>width</u> (11 of 13 MS); the maximum width is indicated and ranges between 2m and 12m. Most frequently mentioned is 2m in maximum width, followed by 6m.</li> <li>• <u>function</u> (8 of 13 MS); functions is predominantly identified as 'drainage' of water (2) or arable land (4); other functions include 'irrigation' (3) or 'interrupting a slope, capturing water and diverting or absorbing it' (1)</li> <li>• <u>composition</u> (6 of 13 MS); mostly defined as ('linear' or 'build-up') depression (2), channel (2), trench (1) or watercourse (1), three times using 'open' as further description; watercourses are also explicitly excluded once</li> </ul>	
Stone Walls	<p><b>Key parameters</b></p> <ul style="list-style-type: none"> <li>• <u>composition</u> (5 of 10 MS); most frequently mentioned to be composed of rock, boulders or (natural) stone</li> <li>• <u>natural or artificial origin</u> (4 of 10 MS); defined as either natural (1), artificial (2) or both (1)</li> <li>• <u>height/width</u> (4 of 10 MS); height ranges from minimum 0.3m up to maximum 5m; Width from minimum 0.5m up to maximum 5m.</li> <li>• <u>integration</u> (4 of 10 MS); diversely integrated (e.g. as bordering to vineyards), dependent on cultural heritage</li> </ul>	Traditional stone walls

The MS-specific definitions of landscape features have been also documented by JRC in standardized manner, using the FAO Land Cover Classification System, and subsequently with the Land Cover Meta Language (ISO 19144-2) for the purpose of the annual LPIS Quality Assessment.

The following list provides a detailed description of Member states' applied definitions regarding landscape features.

**Hedges / wooded strips:** Member States' definitions of hedges vary greatly in their degree of detail, from three-word descriptions, e.g. '*hedges in general*' (Greece), to extensive definitions that include shape, vegetation, location, functions and maintenance of hedges. Ireland, for example, defines the feature as

*'a line of closely spaced bushes/shrubs and/or tree species, planted and trained in such a way as to form a barrier or to mark the boundary of an area. Traditionally they were planted on a raised earthen bank formed by digging one or two shallow trench(s), with the dug material used to form the bank in the middle. In later years the hedge is generally planted on the flat. Gappy hedges where there is at least 20% of hedgerow species (including briars, gorse etc.) dispersed along the length of the hedge is considered a hedgerow and is classified as a Landscape Feature. A hedge starts and ends at the nodes or intersection with another hedge. Hedges should be routinely maintained in order for them to be considered retained.'*

Most frequently included parameters are shape, vegetation, width and length, which are most often defined as linear in structure, with woody vegetation, with a maximum width of 10m, with a minimum length of 20 m. Some Member States also mention the limit of a 5-metre gap between parts of one hedge. None of the definitions for location of hedges matches another, but **in terms of function**, a consensus of the hedge acting as a barrier or boundary for a plot of land exists for the few Member States that included this parameter in their definition of the feature.

**Trees (individual):** Member States define the feature ‘individual trees’ most often through the minimum size of their crown diameter, with figures ranging between 2m and 8m, but most commonly defined at 4m. The feature is also often described as being surrounded by arable land as a defining characteristic. For some Member States, only the crown size is defining to the feature (‘Trees with a crown diameter greater than 4m growing by themselves’ (Scotland)). Meanwhile, the Czech Republic definition includes attributes composition, crown diameter and location:

*‘An isolated tree is a woody plant growing in isolation with a crown spread of at least 8m<sup>2</sup> located on farmed land away from a wood or forest. Woody plants that are part of a boundary strip (balk), terrace or grassy thalweg are not considered to be isolated trees.’*

**Trees in line:** In total, 15 Member States included definitions for the feature ‘trees in line’ that range from broad descriptions (‘rows of trees or shrubs of different species’ (Romania)) to the inclusion of quantifiable parameters such as length or width. Most Member States, however, used descriptive parameters such as shape and composition in their definitions. A comprehensive definition was provided by Slovakia:

*‘Trees inside or on the border of production and cultural field with agricultural crops in arable land - at least 5 trees have to be higher than 3 m. Minimum length of 30 m with regular spacing between the trees and width up to 4 m.’*

**Trees in group:** A large majority of Member States defined the feature ‘a group of trees’ by the maximum area, mostly ranging between 0.1 and 0.5 ha. Additional area ranges specify minimum areas between 0.01 ha and – most frequently mentioned – 0.1 ha. The feature is further described by its location, mainly as being ‘near’ but ‘clearly distinct’ from arable land, and the present vegetation. Croatia, for instance, provides following definition:

*‘Undisturbed and homogeneous area covered with trees and bushes, not used for agricultural purposes, on area of minimum 100 m<sup>2</sup> and maximum 1000 m<sup>2</sup>.’*

There is high consensus on the definition of present vegetation among Member States, as it is predominantly identified as trees, bushes or shrubs.

**Field margins:** Only six Member States included definitions for field margins, ranging descriptions that only include a broad location (‘a field margin is regarded as any land within on meter of the edge from the roadway platform’ (Belgium)) to the inclusions of parameters shape, width, vegetation, and location. An example is the Germany definition:

*‘Field margins are narrow, long strips with a total width of over two meters that are populated predominantly with grass and herbaceous plants and are situated within, between or adjacent to areas of agricultural land but on which no agricultural production takes place.’*

Most consensus is on the inclusion of the location of a field margin (near arable land) and the maximum width (between 2 and 20m), which are also the two parameters included in the EFA definition. While half of the Member States included the function of field margins in their description, none of the matched the other.

**Terraces:** The Member States’ definitions for terraces vary in their degree of detail. Romania (‘Terraces on agricultural land’), Greece (‘All terraces in general.’) and Slovakia (‘Retaining terraces where they exist’)

have rather simple definitions, whereas other Member States give detailed descriptions, mainly regarding the composition, function and vegetation of the feature. Czech Republic, for example, defines terraces as

*'[...] a continuous linear sloping feature comprising a terraced step that serves to reduce the risk of erosion by water or wind and reducing the gradient of part of the slope of a land-block portion, usually defining the boundary of a land-block portion. A terrace may include woody vegetation or a low stone wall (parapet). A grassy thalweg may include woody vegetation.'*

Four Member States also specify the height of the terrace, ranging between 0.5 and 12m.

**Ponds:** Most Member States define ponds by their minimum to maximum surface area, with the maximum surface area included much more frequently with a range of 0.1 to 0.5 ha. Most Member States highlighted the naturalness as defining a pond, with some specifically excluding concrete or plastic reservoirs. Belgium delivers a coherent definition for the feature:

*'A pond is an isolated body of water in a natural depression with a total surface area of less than 0.1 hectares, an excavated pit or constructed water basin which is filled with water for the greater part of the year, is not connected to a watercourse and covers at least 0.01 ha at the highest normal water level.'*

**Ditches:** The definitions of the Member States range in their degree of detail, some keeping it rather broad ('All ditches in general' (Greece) or 'ditches less than 2m wide' (Poland)), whereas others giving much detail, such as Sweden:

*'Open and mainly laid out ditch for draining of arable land, located in arable land or between adjacent arable land blocks. For the arable land blocks to be considered as adjoining, the distance from the ditch centreline may be an average of maximum 5 meters to each edge of the fields. Ditches where the water mirror exceeds 6 meters in width, is not considered as landscape elements. The ditch must in its entirety be at least an average of 0.5 meters wide, measured from the edge of the slope and at least an average of 0.3 meters deep.'*

Most common denominators for this feature are width (ranging from 0.5m as minimum to 12m as maximum), function and composition. While different terminology has been used, there is quite strong consensus for both function and composition.

**Traditional stone walls:** In the definitions, most Member States provide descriptive parameters for this feature. These include the integration of the walls, their origin or composition, such as being made from stone, rocks or boulders. Additionally, some Member States give further details on the height and width of the structures in a separate column. The definition of Italy, for instance, addresses all these parameters:

*'As traditional stone wall, it is meant a stone wall that was built a long time ago and that is well adapted to surrounding landscape. Height- Max: 5m, Min: 0.3m; Width- Min: 0.5m, Max: 5m'*

### **3. REGULATION (EU) 2021/2115 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 2 December 2021**

The CAP 2023-2027 includes more schemes for the promotion of landscape features:

- *GAEC8: The objective of the GAEC8 standard is the maintenance of non-productive features and area.*

To improve on-farm biodiversity. Its requirements are as follows:

- *Minimum share of agricultural area devoted to non-productive areas or features.*
- *Minimum share of at least 4 % of arable land at farm level devoted to non-productive areas and features, including land lying fallow.*
- *Where a farmer commits to devote at least 7 % of his/her arable land to non-productive areas or features, including land lying fallow, under an enhanced eco-scheme in accordance with Article 31(6), the share to be attributed to compliance with this GAEC standard shall be limited to 3 %. – Minimum share of at least 7 % of arable land at farm level if this includes also catch crops or nitrogen fixing crops, cultivated without the use of plant protection products, of which 3 % shall be land lying fallow or non-productive features. Member States should use the weighting factor of 0,3 for catch crops.*
- *Retention of landscape features*
- *Ban on cutting hedges and trees during the bird breeding and rearing season.*
- *As an option, measures for avoiding invasive plant species.*
- *Eco-schemes may include the enhancement of landscape features (including maintenance and creation of landscape features or non-productive areas).*

Member States can define their landscape features and related targets and policy measures under the CAP national plans.

The I.21 impact indicator ‘Enhancing provision of ecosystem services: Share of agricultural land covered with landscape features’ is part of the performance monitoring framework of the CAP 2023-2027. It is supposed to assess the performance of the CAP related to the objective to contribute to halting and reversing biodiversity loss, enhance ecosystem services and preserve habitats and landscapes.

The result indicator R.34PR ‘Preserving landscape features: Share of utilized agricultural area (UAA) under supported commitments for managing landscape features, including hedgerows and trees’ will be reported annually by Member States to help monitoring progress towards quantitative targets.

### 3.4 Reporting of landscape features at national level – examples

#### 3.4.1 Austria

In Austria, data on landscape features was made available as tabular information without spatial allocation in the CAP period 2014-2020.

The data is available in two parts of the national information system (IACS) :

- 1) Linked to the reference parcels (= total agricultural area of a holding) defined by the paying agency Agrarmarkt Austria. It comprises landscape elements (landscape element layers<sup>5</sup>) within the meaning of Article 5 of Regulation (EU) No. 640/2014) and Horizontale GAP-Verordnung (StF: BGBl. II Nr. 100/2015).

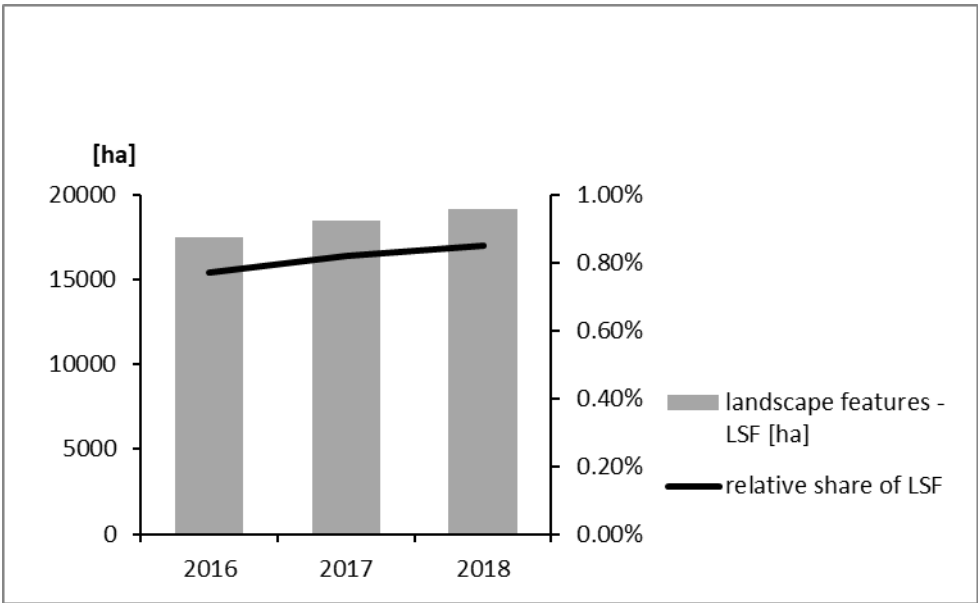
This data does not allow distinguishing between the different kinds of landscape elements; landscape elements comprise trees, hedgerows, ditches and stone walls<sup>6</sup>.

<sup>5</sup> Landscape element layer: layer containing the landscape elements digitised in GIS as a point or polygon according to the definitions in Annex 1 of the Horizontal CAP Regulation, which are located on reference areas, directly adjacent to such an area or within 5 m of a reference area

< 100 m <sup>2</sup>	Trees/bushes	≥ 2 m Ø	Punkt
≥ 50 m <sup>2</sup>	Hedgerows/riparian trees	Länge: ≥ 20 m	Polygon

When comparing the values from 2016 to 2018 (Figure 8), it is striking that both the area of landscape elements (in ha) and the relative share of landscape elements in the total agricultural area increased slightly, the latter being 0.85% in 2018.

The low values show that most probably only a small part of the existing landscape features was registered in the system.



**Figure 8: Evolution of landscape features in Austria based on the LPIS reference parcels**

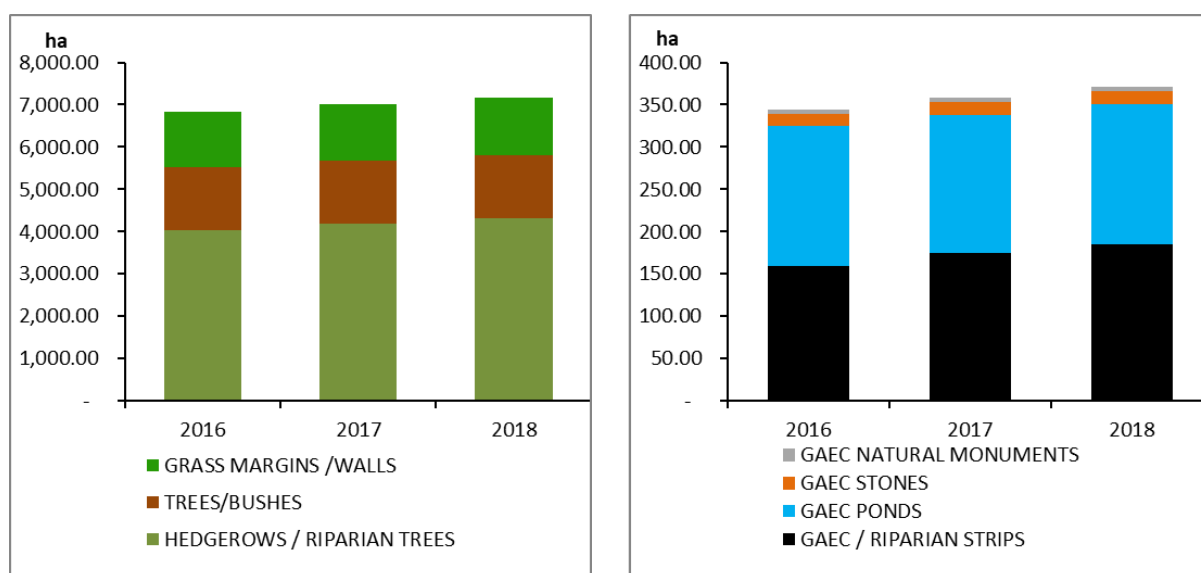
- 2) A second important data source besides the LPIS reference areas is the layer of GSAA parcels. This includes all area of the agricultural parcels recorded by the farmers who apply for funding; these areas serve as a basis for funding. The sum of these areas is smaller than the areas of the LPIS reference layer, as the LPIS reference layer includes all parcels also those without application for funding.

It can be seen that the share of landscape features is even lower in this database than in the reference area. When comparing the values from 2016 and 2018, it is noticeable that the area of

≥ 50 m²	Ditches/riparian strips	Breite: ≥ 2 m bis ≤ 10 m im Ø
≥ 50 m²	Field margins/stonewalls	
≥ 100 m² bis < 1000 m²	trees/trees-/bushes	≥ 10 m breit oder lang
≥ 100 m² bis < 1000 m²	Stones	
≥ 100 m² bis < 1000 m²	Ditches	
	Natural Monuments	Polygon
	Natural Monuments	Punkt

all landscape elements and the relative share of landscape elements in the total agricultural area without alpine pastures (from 0.32 % to 0.33 %) increased slightly (Figure 9).

The increase is mainly due to the increase in hedges and riparian strips, field margins and embankments and GAEC ditches and riparian strips. However, this is only a minor increase and could also be due to the appearance of landscape features in the system due to ongoing maintenance of the layer or additional applications.



**Figure 9: Evolution of landscape features in Austria based on the IACS reference areas**

### 3.4.2 The Netherlands

The location and size of landscape features in The Netherlands are registered in different national databases, but completeness of such datasets is an issue. A reliable and complete dataset of landscape elements is still missing in The Netherlands.

There are different institutions that register landscape elements in The Netherlands. Data from 'Rijksdienst voor Ondernemend Nederland' RVO (rvo.nl) and the Dutch Kadaster are the most homogeneous, of high quality and most useful.

RVO is the CAP payment Agency and oversees the Dutch LPIS. In the Dutch Land use Parcel Information System (LPIS) only landscape elements that are targeted through CAP payments are registered ((van Doorn *et al.*, 2016)). The Dutch Kadaster produces the topographical database 'Basis Registratie Topografie' (BRT) that includes the most detailed topographical data layer (Top10NL). Top10NL is the most complete dataset covering approximately 80% of all small landscape features in *surface area* at national level. However, when taking the *number* of landscape features the figure is less positive as 80% of isolated trees and 30% of linear features are missing according to van Doorn *et al.*, 2016.

Beside these 2 data sets there is also a database MAC (Meetnet Agrarisch Cultuurlandschap) generated by LandschapNL, a foundation whose central aim is to maintain the cultural landscape in the Netherlands. In this MAC monitoring system all small landscape features are registered in 85 areas, spread over the Netherlands (a total of 42,000 ha agricultural cultural landscape). The starting point of the MAC registration is the landscape element data that is already included in the BRT (Top10NL) data. In MAC this Top10NL data is then supplemented to 100% completeness within the 85 areas (so-called plus mapping



KLE Kadaster). In the 85 areas there is a complete picture of all landscape elements present. Data collection in the 85 areas is repeated and enables monitoring of landscape elements. It provides a sample database that is representative for all main landscapes of the Netherlands but does not provide a full coverage of the area of the Netherlands nor of the agricultural area.

In Table 5 a more detailed overview is given of the currently available spatial data sources containing landscape element information.

**Table 5: Overview of Dutch data sources containing information on landscape elements (elaborated from Doorn et al., 2016)**

Data source	Type of elements included	Completeness
<b>BRT-Top10NL:</b> this is the digital topographical base layer of the Land Registry (cadastre). It can be used at scale levels between 1: 5,000 and 1: 25,000. The file is uniform and consistent. It has national coverage. The landscape elements registered in it cover rows of trees and (small) forests in TOP10NL.	In principle all type of landscape elements are registered from point, linear and surface elements.	Comparison with the MAC in the 85 sample areas showed that 21% of the point elements, 67% of the linear elements and 83% of the surface landscape elements were registered.
<b>MAC (Meetnet Agrarisch Cultuurlandschap)</b> generated by LandschapNL. In a sample of 85 areas, which are representative for all cultural landscapes in the Netherlands all landscape elements are mapped on a regular basis (every couple of years). The starting point of registration is the landscape element data that is already included in the Top10NL. This TOP10NL data is then supplemented to 100% completeness within the 85 areas (so-called plus mapping KLE Kadaster).	All landscape elements in the Netherlands: solitary trees, hedges, wood embankments, tree rows and groups of trees, traditional orchards.	100% coverage in the 85 sample areas. However no full national coverage as it is a sample database.
<b>Dutch Land use Parcel Information System (LPIS)</b> At this moment in LPIS only landscape elements that are targeted through CAP payments. The BRP contains information about crops as well as about landscape elements, which are targeted either through CAP payments under EFAs or in agri-environmental payments in Pillar 2 of the CAP.	Landscape elements that can be registered under EFA are:  Green landscape elements: <ul style="list-style-type: none"> <li>a. hedges or hedgerows with a maximum width of 10 m;</li> <li>b. isolated trees with a crown diameter of at least 4 m;</li> <li>c. trees in a row with a crown diameter of at least 4 m. The space between the crowns is not more than 5 m;</li> <li>d. trees in group with overlapping crowns and tree groups in the field, on an area of maximum 0.3 ha;</li> <li>e. <i>field margins with a width between 1 and 20 m on which no agricultural production takes place;</i></li> </ul> Blue landscape elements:	Only 4% of all landscape elements in the Dutch agricultural landscape

	<p>f. natural pools of up to 0.1 ha. Reservoirs made of concrete or plastic are not considered as ecological focus area;</p> <p>g. <i>ditches with a width of up to 6 m, including open water courses for irrigation or drainage.</i></p> <p>The landscape elements targeted in Agri-environmental payments include solitary trees, hedges, wood embankments, tree rows and groups of trees, traditional orchards.</p>	
<p><b>Information Model Nature (IMNa).</b> The IMNa is based on the Nature and Landscape Index. This index is the common, nationally uniform “natural language” that describes the types of nature, agricultural nature and landscape in the Netherlands. The IMNa contains object-oriented geo-information about habitats targeted through agri-environmental payments.</p>	<p>Green or blue patch elements with a maximum size of 0.5 hectare. The Top10NL and also the BGT are providing input data on landscape elements into this IMNa system. In IMNa this information is further enriched with quality information on floristic and faunistic quality and function and management information collected through field visits. IMNa covers all Natura2000 areas and some areas outside Natura2000 with specific nature values.</p>	<p>Not known, but the IMNa only covers area with high nature conservation value that can be targeted through CAP and other nature management conservation support schemes. It does not have a full national coverage.</p>
<p><b>De Basisregistratie Grootschalige Topografie (BGT) is the Key Register Large-Scale Topography.</b> It is a uniform topographic basic layer covering the whole Dutch territory registering all physical objects on a scale of 1: 500 to 1: 5,000. The purpose of the realization is that all government organisations use this same basic set of large-scale topography.</p>	<p>In principle all types of landscape elements are registered from point, linear and surface elements.</p>	<p>A subset of landscape elements is registered. How much is not known.</p>

Based on the MAC data collected in the 85 sample areas an extrapolation was made to estimate the total landscape element surface in the Netherlands in Doorn et al., (2016). This resulted in a total area coverage with landscape elements of 117,000 ha which is 3.5% of the total agricultural land surface in the Netherlands. If we compare this with the total area registered as landscape element in the Dutch LPIS in 2017 we can conclude that only 4% of the landscape elements in the Netherlands are currently registered in this database.

The limited registration of landscape elements in the Dutch LPIS is no surprise as it only contains landscape elements that are declared by farmers as EFAs or elements whose maintenance is supported through agri-environmental payments under Pillar 2 of the CAP. The Netherlands did not choose to target maintenance of landscape elements through GAECs. This is another reason for the limited registration in LPIS.

As to the EFA landscape elements the group of landscape elements a farmer can choose from is also a clear smaller subset of the total landscape elements. For example, ditches are excluded and tree groups are only included when located in arable land.

Last but not least a reason why so few landscape elements are registered in LPIS is because very few farmers choose landscape elements as EFAs. According to latest monitoring data on greening, this amounts to not even 1 % of the farmers with a greening obligation.

### 3.5 Agroforestry

Agroforestry has various broader and narrower definitions, partly overlapping with the scope of woody landscape features, therefore mapping of woody landscape features requires clear definitions of both agroforestry and woody landscape features. Woody landscape features need either clear distinction from agroforestry or clarifying and embedding possible overlaps with specific woody elements of agroforestry areas in definition of woody landscape features. Moreover, definition and mapping of woody landscape features within and adjacent to traditional agroforestry areas (similarly as in some other heterogeneous land cover areas) are not straightforward and require a different approach technically and conceptually than in other, more open agricultural areas if at all relevant and needed.

Traditional agroforestry areas can provide benefits for biodiversity as a land use system, as part of high nature value farming. Monitoring of their area and other characteristics could be preferable separately from monitoring woody landscape features. To be able to do this, mapping of agroforestry areas needs to be improved.

#### 3.5.1 Definitions of agroforestry areas

The ecological benefit of woody landscape features within the traditional extensive agroforestry areas is very specific and different than in open agricultural areas with typically low coverage of trees or in intensive agroforestry areas. The traditional agroforestry areas as a whole system and part of high nature value farming areas have their own biodiversity benefits, which can be linked to the whole area rather than to the individual woody features. At the same time, tree/shrub cover density can be one of the important indicators of the contribution of these areas to biodiversity.

Policies, policy documents include specific references to agroforestry as well, which also makes the distinction very relevant. It is needed to be able to answer policy questions, while there are still data gaps and need for clarifications for definitions.

This means that:

- The mapping of (different types of) agroforestry areas is necessary for an adequate mapping and quantification of woody landscape features (beyond its own relevance), and
- A different mapping and assessment approach could be beneficial for woody landscape features and agroforestry. For this, a European-wide mapping of agroforestry areas is needed.

Based on this rationale, the report aims to provide an overview of scientific and legislative definitions of agroforestry and the current status of data availability and mapping challenges and possibilities, in the context of mapping of woody landscape features.





**Figure 10 Spreewald biosphere reserve © by Michael den Herder. Traditional silvopastoral systems have been restored in the Spreewald biosphere reserve. AGFORWARD project. Attribution-NonCommercial-ShareAlike 2.0 Generic (CC BY-NC-SA 2.0). <https://www.flickr.com/photos/agforward/14198568230/Definitions and classifications>**

Over time, several definitions have been given for agroforestry systems by different organisations. In the ETC/BD scoping document (Feced, 2015) a first overview was made of these definitions and this was further elaborated by (Elbersen and van Eupen, 2019). The key characteristics that appear in all definitions of agroforestry systems involve:

1. Two or more species of plants (or plants and animals), of which one is at least a woody perennial (which are summarized in the ICRAF definition as trees, shrubs, palms, bamboos, etc).
2. A combination of woody perennials with agricultural crops and/or livestock.

Elbersen and van Eupen (2019) showed in their review that there are also differences in definitions that allow for a narrow and broad interpretation of what agroforestry systems are.

Firstly, in three definitions (by the International Centre for Research on Agroforestry (ICRAF), Food and Agriculture Organization (FAO), EU Art. 23) it is explicitly mentioned that the two or three activities take place on the 'same land', 'same area of land' or the 'same unit of land'. In the European Agroforestry Federation (EURAF) definition the wording 'in the same area of land' is also used, but it also adds that '*trees can be inside parcels or on the boundaries (hedges)*', so this definition potentially includes woody landscape features. In the definition of AGFORWARD, (2023) no reference is explicitly made to where the

two or three activities take place. The Association for Temperate Agroforestry (AFTA) definition seems to be most clear and broad in terms of how spatially integrated the woody perennial and the agricultural systems can be as they do not use the wording of - same land – but specifically indicate towards *five basic types of agroforestry practices: windbreaks, alley cropping, silvopasture, riparian buffers and forest farming*. So, this implies that in the approach of AFTA and EURAF, agroforestry systems also include systems where trees/hedges and agricultural activities take place beside each other but not necessarily within a same parcel of land. These definitions can also include woody landscape features.

Secondly, in most definitions (ICRAF, FAO, AFTA, AGFORWARD) the importance of the ecological/biological interaction is mentioned. Specifically, in the definition and ICRAF, FAO and AGFORWARD also add the economic interaction of the woody perennial and the agricultural systems. The specific mention of these interactions also applies to systems where woody perennials exist beside the field, like windbreaks or riparian buffer strips in the definitions of AFTA. It is important to emphasize that beyond productive trees (e.g., used for harvesting food, grazing, firewood), the ecosystem services delivered by woody features in benefit of production (e.g., windbreaks, shelterbelts, shade trees, trees for soil reclamation and conservation such as for erosion control in terraces) are also considered as ‘economic’ interaction.

Thirdly, in some definitions it is explicitly made clear that woody perennials refer both to trees and shrubs, like in the AGFORWARD, ICRAF-WAC and AFTA definition. In the EURAF and EU Art. 23 measure 8, the trees are central, but shrubs are also indirectly included as reference is made to hedges which can occur on the boundaries of parcels.

The relation between landscape features and agroforestry areas is clear in general. There is however no consensus on whether a field with trees and hedges only on the boundaries still qualifies as an agroforestry area.

Elbersen and Eupen (2019) propose the following definition: A land use system where woody perennials are (deliberately) combined with agricultural crops and/or livestock on the same land management unit.

In Elbersen & Eupen (2019) it was shown that there are many classifications of agroforestry areas, and these were then integrated in an overview table (Table 6) where a distinction is proposed in a narrow and a broader definition of agroforestry areas.

**Table 6: Review of agroforestry classes according to a narrower and a broad approach**

Main types/classes	First land use	Sub types	Additional qualifiers for narrow interpretation	Additional qualifiers for broad interpretation
Agrisilvicultural or silvoarable systems	Agricultural	New agroforestry systems	Combination of annual and perennial crops and trees within the same parcel, e.g. alley cropping, scattered trees , tree line belts.	Combination of annual and perennial crops and trees and/or shrubs within the same farm, inside parcels or on the boundaries. e.g. alley cropping, scattered trees , tree line belts, crops and hedges and/or treelines

		Agroforestry of high nature and cultural value	Combination of annual and perennial crops and trees within the same parcel, e.g. alley cropping, scattered trees, tree line belts.	Combination of annual and perennial crops and trees and/or shrubs within the same farm, inside parcels or on the boundaries. e.g. alley cropping, scattered trees, tree line belts, crops and hedges and/or treelines
Silvopastoral systems	Agricultural and forestry	New agroforestry systems	Combination of grazing with domesticated animals and/or pastures with trees within the same parcel, e.g. scattered trees and pasture, grazed orchards, olive groves, vineyards, nut tree plantations.	Combination of grazing with animals and/or pastures with trees and/or shrubs within the same unit of land/farm. E.g. same as in narrow definition but also grazing on rangeland with shrubs
		Agroforestry of high nature and cultural value	As above, but characterised by high biodiversity, low inputs and/or presence of semi-natural vegetation and features. Typical traditional systems such as dehesa, montado, grazed oak woodlands in Mediterranean, other traditional wood pastures, reindeer husbandry in forest land	As above, but characterised by high biodiversity, low inputs and/or presence of semi-natural vegetation and features. E.g. the same as in narrow definition but also bocage agroforestry and reindeer husbandry in open landscape.
Agrosilvopastoral	Agricultural and forestry	All	Combination of grazing, cropping and trees within the same parcel, e.g. alley cropping, scattered trees, tree line belts.	Combination of grazing, cropping and trees and/or shrubs within the same unit of land.
		Agroforestry of high nature and cultural value	As above, but characterised by high biodiversity, low inputs and/or presence of semi-natural vegetation and features. Typical traditional systems	As above, but characterised by high biodiversity, low inputs and/or presence of semi-natural vegetation and features. Typical traditional systems
Riparian buffer strips	Agricultural	All	not included in narrow definition	Cropping and or grazing and/or pastures with riparian buffer strips of trees and/or shrubs within the same unit of land
Forest farming	Forestry	All	Included in narrow definition: Forested areas used for production or harvest of natural standing specialty crops for medicinal, ornamental or culinary uses, mushrooms, truffles and beehives.	Forested areas used for production or harvest of natural standing specialty crops for medicinal, ornamental or culinary uses, mushrooms, truffles and beehives.



Home gardens	All land uses possible: urban, agricultural, forest, recreational	All	Not included in narrow definition as the status as farming activity is not clear and usually takes place in urban areas	
Other	, nature, other	All	not included in narrow definition	Multipurpose tree lots with apiculture or aquaculture within the same unit of land.

### 3.5.2 Legislative definitions for agroforestry areas

Agroforestry is acknowledged in a wide spectrum of policy fields as a smart approach for sustainable land use. It is also acknowledged by targeted policy measures and this implies that there are legislative definitions for agroforestry areas.

In the previous CAP, definitions of agroforestry were provided in Article 23 of the Rural Development Regulation 1305/2013. For the purposes of Article 23, agroforestry systems were defined as ‘land use systems in which trees are grown in combination with agriculture on the same land’ and are further explained in the Agroforestry Measure Fiche: “Agroforestry means land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same parcel or land management unit without the intention to establish a remaining forest stand. The trees may be arranged as single stems, in rows or in groups, while grazing may also take place inside parcels (silvoarable agroforestry, silvopastoralism, grazed or intercropped orchards) or on the limits between parcels (hedges, tree lines).”

From the Rural Development Programme (RDP) definition it was clear that the agroforestry systems referred to landscape scale systems where woody perennials, so not only trees, are integrated with crops and/or areas maintained for livestock animal. There was no specification relating to where the woody perennials need to be placed as they can be both within the field or in between fields.

In the CAP 2023-2027, agroforestry systems are defined as “where trees are grown in agricultural parcels on which agricultural activities are carried out to improve the sustainable use of the land”. The framework definitions of ‘agricultural area’ should ensure that Member States cover agroforestry systems. Agroforestry systems are mentioned in the regulation and supported by the CAP as one of the specific sustainable farming practices. Agroforestry is one of the potential agricultural practices that can be supported under eco-schemes. There, agroforestry is used in a specific sense, including establishment, maintenance and management of landscape features and establishment and maintenance of high-biodiversity silvo-pastoral systems. Support for management commitments can give dedicated financial support for establishment of agroforestry systems. Agroforestry can be supported also through support for investments. Forestry interventions should contribute to widening the use of agroforestry where appropriate. Agroforestry areas are included in afforested land under the result indicator R.17 ‘Afforested land: Area supported for afforestation, agroforestry and restoration, including breakdowns’.

## 4 Mapping landscape features: Review of available pan-European spatial data

This section is a review of the available Copernicus data sets which could potentially serve as input for the mapping of landscape features, including woody and other features. Due to scale, spatial resolution, and wall-to-wall coverage only the high-resolution layers are reasonable candidates. There is no available

spatial data for all landscape feature types. The most recent LUCAS campaign (LUCAS 2022) includes a dedicated module on landscape features that can be utilised to support mapping initiatives. It includes information on woody, grassy, stony and wet features (plus temporary herbaceous and cultural features) from around 93,000 LUCAS points. This data was not yet available at the time of compiling this report.

This chapter also summarises available information about mapping agroforestry areas in support to differentiate landscape features and agroforestry and to improve stratification of agricultural land in the context of mapping and quantification of landscape features.

## **4.1 High Resolution Layer (HRL) Small woody features (SWF)**

Small Woody Features (SWF) 2018 data are part of the Copernicus Land Monitoring (CLMS) High Resolution Layer (HRL) portfolio and provide an update of the previous Small Woody Feature product for the 2015 reference year, following a 3-year monitoring cycle.

The HRL on SWF has been released for the reference year 2015 and 2018. Between the two versions, the product specifications have evolved, and the products are not fully comparable. Still the first tests done with the 2015 SWF data set provided useful insights which were considered later when working with the 2018 data.

### **4.1.1 Specifications SWF 2018**

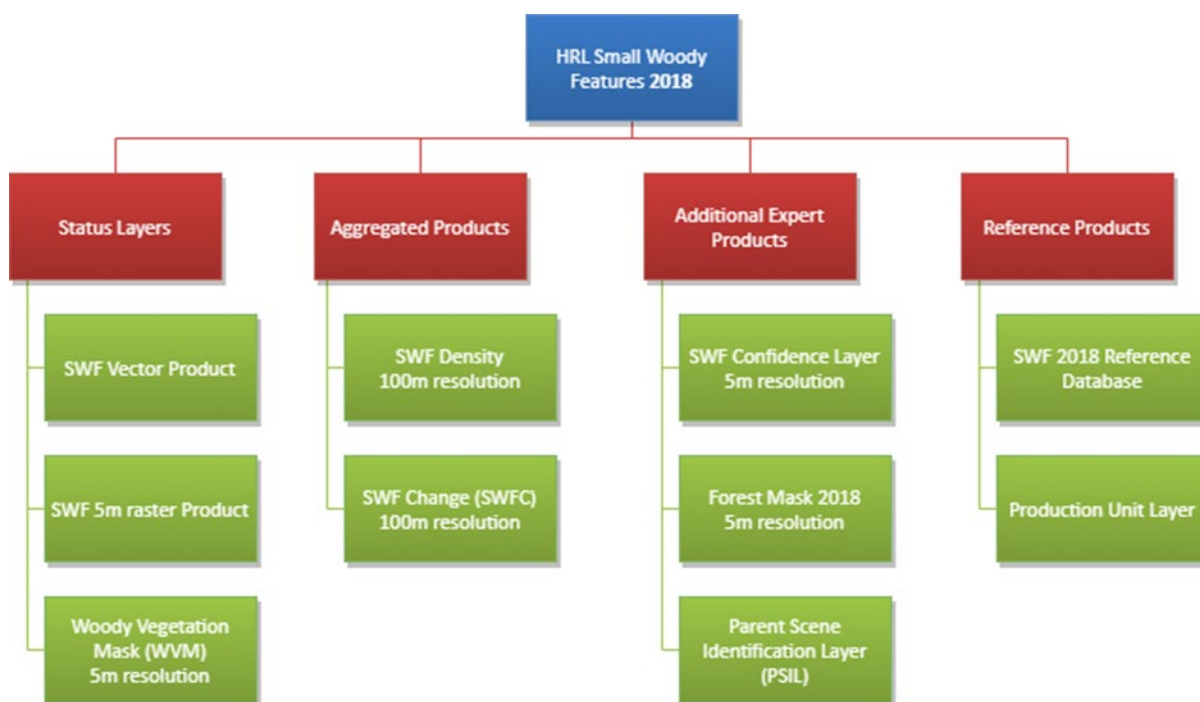
The HRL Small Woody Features 2018 portfolio (Figure 11) comprises three main status layers, provided both in pan-European LAEA projection and in national projections:

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

The simplified conceptual scheme of the complex SWF production portfolio may be characterized by three main steps:

3. Separation of all tree-covered areas from the non-tree covered part → “All Woody Features”
4. Excluding large contiguous tree covered areas → Woody Vegetation Mask (WVM)
5. Excluding woody features not corresponding to certain geometric specifications → Small Woody Features (SWF)





**Figure 11: Overview of the SWF 2018 portfolio. Source: SWF 2018 User manual**

The WVM is a product that depicts woody vegetation without height, size, or shape differentiation. It is based on Very High Resolution (VHR) imagery (2-4 m for four spectral bands: blue, green, red and NIR) from 2018.

It is the parent layer for the SWF layers, which are extracted applying length and area thresholds via a decision tree towards linear and patchy features within the WVM.

The WVM includes the following woody vegetation structures:

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

A more detailed overview of the elements which are in- and excluded can be seen in Table 7. From these products, aggregated and change products (combination with SWF 2015 status layer) are 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.

**Table 7: Elements to be included or excluded in Small Woody Features 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</li> <li>• isolated / scattered patches of trees</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>

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 those linear and patchy features which were disconnected due to the geometric rules applied. However, after the production AWF was considered confusing by the users and has therefore been removed from the SWF 2018 product. The geometric rules are adapted to the revised SWF 2018 technical specifications, as presented in Table 8. The property of compactness follows the definition of Bogaert *et al.* (2000) and resembles and improved area-perimeter ratio.

**Table 8: Geometric specifications of SWF 2018**

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

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.

The differentiation between linear, patchy or out of specification features included in the product is not visible in the final 2018 products 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.

#### 4.1.2 *Quality assessment / feedback*

SWF2018 product was validated internally by Service Provider team<sup>7</sup>. Validation was only conducted for the SWF layer and therefore does not apply to the WVM.

The sample design was based on a stratified sampling approach using the LUCAS (Land Use/ Cover Area frame statistical Survey) sampling grid and pertaining LUCAS points to select sampling windows of 100 x 100m squares. These are referred to as primary sampling units (PSU). These sampling windows were then further subdivided into secondary sampling units (SSU) which resemble twenty points randomly distributed within the PSU window.

Based on the internal validation for EEA39 areas, including the French Overseas Departments and Regions, the SWF2018 product shows high Overall Accuracies at both levels: weighted Overall Accuracy (OA) of 94.09% at the Primary Sampling Unit (PSU) level with a confidence interval of +/- 0.22 at 95% confidence level; and weighted OA of 91.79% at (Secondary Sampling Unit) SSU level with a confidence interval of +/- 0.10 at 95% confidence level.

This validation was accompanied by a qualitative look and feel verification of the ETC-DI. This involved a systematic check of six 200x200 km tiles distributed across different regions of Europe. The quality check included an assessment of the geometric accuracy as well as thematic correctness of sampled polygons.

Within the look and feel verification, the quality control of the SWF 2018 products focused on the WVM rather than the SWF layer. WVM was considered previously as an intermediate product and therefore not included within the SWF final product's validation process. In general, the qualitative look & feel verification results indicate acceptable quality concerning overestimation of WVM areas (commission) and good quality concerning underestimation of WVM areas (omission).

WVM depicts woody vegetation without height, size, or shape differentiation. Its aim is to allow the user to apply their own geometric ruleset in order to derive customised feature selection. To limit overlaps of small woody features with large and densely tree covered areas, the production workflow included a masking step utilising a Forest Mask for 2018. This mask was created using the combination of HRL 2018 TCD and CLC2018 layers, following as much as possible the FAO forest definition. As the Forest Mask 2018 was created by an independent, lower resolution dataset using a complex and therefore less transparent procedure, it could be observed that the appearance of valid woody features could be partly unpredictable, especially around forest fringes. Classification issues could be observed for example in circumstances where shadows of larger trees fall onto fields and permanent crops.

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<sup>7</sup>Validation report of the final dataset of Small Woody Features 5m raster product. Service contract: EEA/DIS/R0/20/006

Furthermore, the application of complex geometric rulesets (and changes of the rules between 2015 vs 2018) did not provide equally reliable quality results for all regions in case of the SWF products.

Based on the available information about the products and their quality assessments, it is recommended to use the Woody Vegetation Mask instead of the Small Woody features layer for the indicator woody landscape features in agricultural areas.

The verification exercise concluded that the quality of the 2015-2018 change layer appeared to be predominantly poor in the test areas. This was somewhat anticipated due to the different production specifications. Therefore, this change layer is not recommended to be used for monitoring purposes. Instead, the upcoming change layer 2018-2021 will have to be investigated when it becomes available.

## 4.2 HRL Water and Wetness

### 4.2.1 Specifications Water & Wetness layer

The combined Water and Wetness product is a thematic product showing the occurrence of water and wet surfaces over the period from 2009 to 2018. These layers are based on multi-temporal and multi-seasonal optical high-resolution satellite imagery. In addition, these layers are also based on radar information (Sentinel-1 data) with a geometric resolution of 10m on a pan-European basis. A multitude of optical and SAR imagery is used, covering a prolonged time series of 7 years, which aim at capturing the intra-annual dynamics as much as possible within a given area and lead to one image composite per season (each season covered by 3 months) and year during the observation period. They form the basis for the following products:

- The main Water and Wetness (WAW) product with defined classes of (1) permanent water, (2) temporary water, (3) permanent wetness and (4) temporary wetness.
- The additional expert product: Water & Wetness Probability Index (WWPI)

The products show the occurrence of water and indicate the degree of wetness in a physical sense, assessed independently of the actual vegetation cover and are thus not limited to a specific land cover class and their relative frequencies.

### 4.2.2 Quality assessment

The WAW was tested if it could provide information on ditches and small ponds (< 0.1ha) which are part of landscape features to be maintained.<sup>8</sup>

Outcome from the test was that ditches are not realistic to be captured due their small width (see also

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<sup>8</sup> Albeit not necessarily accounted for in Eurostat's UAA definition.

Table 4). Small ponds should be possible to map based on their size specifications but a differentiation between natural and artificial (made of concrete or plastic) ponds is not possible, which is a limitation. The issue of artificial reservoirs arises especially in Mediterranean regions where such reservoirs are used for irrigation water and firefighting.

### 4.3 Mapping agroforestry areas

Given the diversity of agroforestry systems, with varying tree cover density and different uses of trees within fields and/or bordering areas, mapping them is not easy. Both statistical data and Earth observation (EO) data (Copernicus) have limitations for direct mapping of these areas.

One important challenge is that agroforestry areas are not only located in areas that are defined in statistical and/or EO products as agricultural, but also in areas registered or mapped as forest areas. This is related to tree cover density. In the working definition of forest areas used by FAO, UNECE, Forest Europe, the Eurostat and the EEA, forest is defined as: *'Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 %, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use'*.

To distinguish forest from 'other wooded land', the working definition of this latter category (also based on the working definition of forest areas used by FAO, UNECE, Forest Europe, the Eurostat and the EEA) is *'Land not defined as 'forest', spanning more than 0.5 ha, with trees higher than 5 m and canopy cover of between 5 % and 10 %, or trees able to reach these thresholds, or with a combined cover of shrubs, bushes and trees above 10 %. It does not include land that is predominantly under agricultural or urban land use'* (FAO, 2020). It is likely that many agroforestry areas also overlap with this other wooded land category.

It is this category of land that can (partly) overlap with agricultural land, mostly agroforestry areas, up until the minimum tree density for forestry begins and this can vary across countries (see Table 9). The size limit of forest land in national definitions can range between 0.05-1 hectare in combination with a tree crown cover range between 10% to 30% and a minimum tree height range between 2 m and 5 m (see Table 9). This implies that there is a large variation in the way countries divide land over agricultural, other wooded and forest land and this also gives differences in policy targeting.

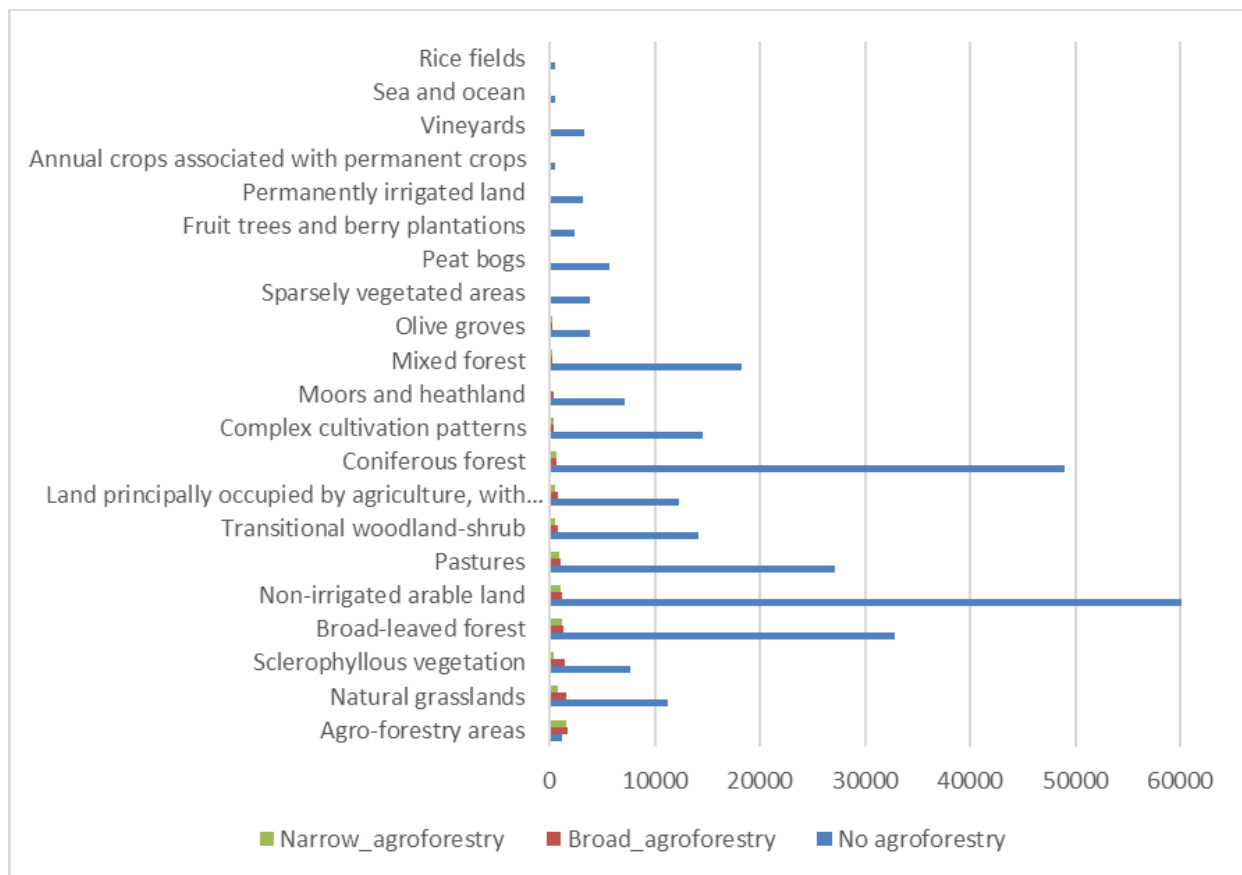
**Table 9: Minimum values for area size, tree crown cover and tree height per member state for the definition of forest (original source is Annex 5 of the Decision 529/2013/EU) (copied from AGFORWARD deliverable 8.23 (Mosquera-Losada et al., 2016a))**

Country	Area (ha)	Tree crown cover (%)	Tree height (m)	Country	Area (ha)	Tree crown cover (%)	Tree height (m)
Belgium	0.5	20	5	Luxembourg	0.5	10	5
Bulgaria	0.1	10	5	Hungary	0.5	30	5
Czech rep	0.05	30	2	Malta			
Denmark	0.5	10	5	Netherlands	0.5	20	5
Germany	0.1	10	5	Austria	0.05	30	2
Estonia	0.5	30	2	Poland	0.1	10	2
Ireland	0.1	20	5	Portugal	1	10	5
Greece	0.3	25	2	Romania	0.25	10	5
Spain	1.0	20	3	Slovenia	0.25	30	2
France	0.5	10	5	Slovakia	0.3	20	5
Italy	0.5	10	5	Finland	0.5	10	5
Cyprus				Sweden	0.5	10	5
Latvia	0.1	20	5	UK	0.1	20	2
Lithuania	0.1	30	5				

In the forest definition of FAO the same minimum tree cover threshold of 10% is applied as in the approach to identify agroforestry areas by Zomer *et al.* (2009) and AGFORWARD Herder *et al.* (2016) . A clear distinction between agroforestry areas and forestry areas can therefore only be made if sufficiently

reliable spatial land use data is available to identifying the agricultural land use, which is missing at European level. There are no European wide data sets that provide a full delineation of agroforestry areas. There are however several data sources that do provide options to approximate their spatial extent, and these will be discussed below.

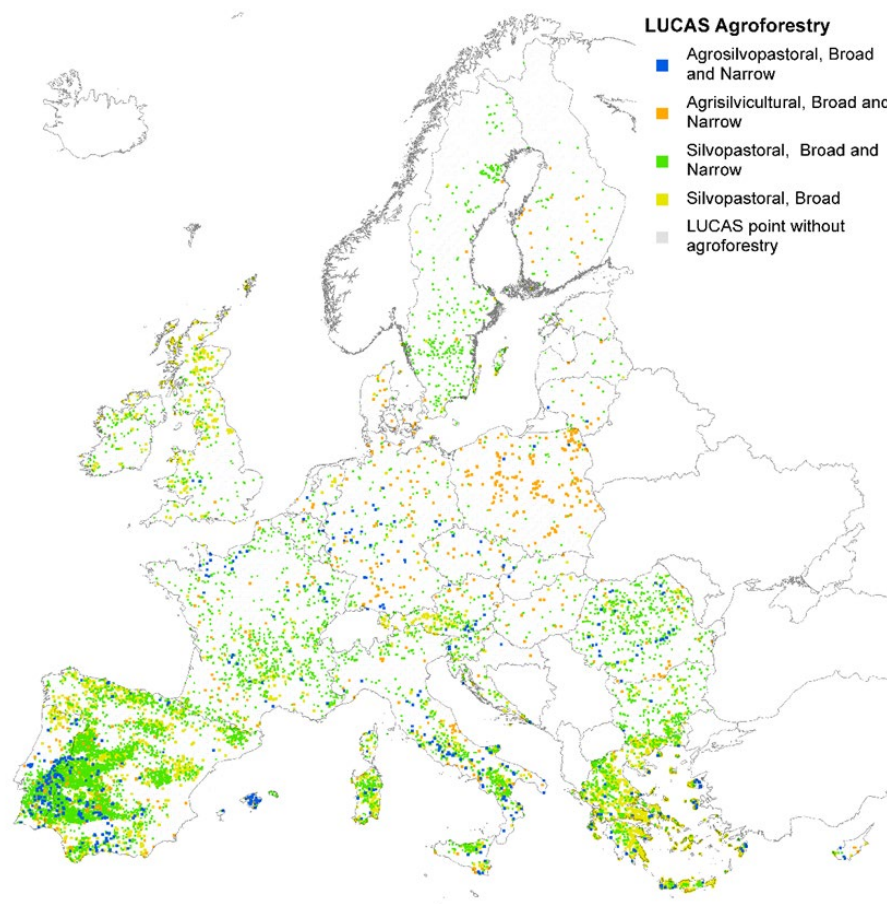
In Corine Land Cover there is an ‘agroforestry’ class. However, the comparison to LPIS data discussed in Section 2.3 for Spain already showed that this “agroforestry” CLC class usually thematically correspond to “Dehesas” in Spain. Dehesas is only one of the types of agroforestry areas in Spain and many other agroforestry areas are not covered by this CLC class. Discrepancy has been shown also with LUCAS point data on agroforestry (Figure 12) by overlaying LUCAS agroforestry point data with CLC classes.



**Figure 12: Result of the overlay of LUCAS points classified in agroforestry and no-agroforestry with CLC classes (copied from Elbersen & Eupen, 2019)**

Elbersen and Eupen (2019) mapped agroforestry areas using LUCAS 2011-2012 data and tree cover density data building also on the results from the AGFORWARD project (Den Herder et al., 2016). In this mapping they first defined agroforestry areas in a broad and more narrow definition (see Section 3.4). It gave a good overview of where certain types of agroforestry areas mostly occur (see Figure 13), however a full area coverage of the agroforestry areas could not be provided with the LUCAS data as it only provides point data and no full area coverage.





**Figure 13: Lucas points classified as one of the three agroforestry types in the narrow and broad definition (copied from Elbersen & Eupen, 2019)**

#### 4.4 Conclusions on the use of Copernicus data for mapping landscape features

The Copernicus Small Woody Features product can be used to map woody landscape features within agricultural land. It is one of the potential information sources for the development of the CAP impact indicator I.21 Enhancing provision of ecosystem services: Share of agricultural land covered with landscape features. From the assessments done, the following conclusions and considerations can be derived:

- The SWF2018 product portfolio presents a great potential to provide high quality and detailed spatial information on woody landscape features of Europe in 5m resolution.
- The SWF2018 features a lower degree of omission error and higher degree of overestimation (commission).
- A comparison of the HRL SWF with national data in The Netherlands and in Luxembourg shows a low degree of commissions and a higher degree of omissions. The difference is mainly due to the different minimum mapping units.
- The SWF layer is provided within a 5x5m grid database. The SWF layers only includes a part of the landscape features: woody features such as hedgerows, tree lines and isolated trees, groups of trees. Stonewalls, field margins, ponds and ditches are not part of the layer.
- The HRL on Water and Wetness is not suitable to provide data on small ponds as the important differentiation into artificial and natural water bodies is not possible.



- The minimum mapping units of the SWF layer are larger than the possible minimum size criteria for the landscape features.
- A differentiation of individual landscape features is no longer possible in the grid database, only total area can be derived.
- Based on the available information about the products and their quality assessments, it is recommended to use the Woody Vegetation Mask instead of the Small Woody features layer for the indicator woody landscape features in agricultural areas.
- Corine Land Cover data can be used to approximate traditional agroforestry areas but it does not provide comprehensive mapping of them. Further datasets and more targeted mapping of traditional agroforestry areas beneficial for biodiversity would be needed to map them separately from woody landscape features.

In conclusion, the HRL SWF is the only available wall-to-wall pan-European spatial data set with a sufficient level of spatial detail to reply to the needs of the CAP I.21 indicator. Despite certain limitations (i.e. 5x5 m pixel, only a selection of the LF) the SWF layer can be used to map and characterise agricultural areas. However, to provide the required information on the progress of integrating biodiversity issues into agricultural practices, the indicator must also be able to detect trends.

The assessment of the HRL SWF data showed that while an acceptable level of accuracy could be obtained for the products, there were a range of issues to be observed within the 2018 layer, partially relating to error propagation from layers utilized in production as well as landscape specific issues.

The mapping of woody landscape features is more straightforward in 'well-structured' landscapes for which the concept was originally developed, and less for other landscape types, which calls for consideration of alternative approaches for the indicator development.

Overall, the quality of the change layer was considered poor, and many changes were due to either omission or commission errors in either the 2015 or 2018 layer. In the latter case, a change in product definition have also contributed to this and it has yet to be seen how a change layer for the period 2018 - 2021 would perform.

## 5 Development of the indicator agricultural area covered by woody landscape features

The agricultural area (AA) mask was intersected with the WVM and SWF layers respectively to estimate the share of landscape features within agricultural areas across Europe. Due to mismatch in spatial scales between the AA mask (100m) and WVM and SWF (5m) raster layers, the intersection was conducted at the level of the aggregated WVM and SWF layers (100m).

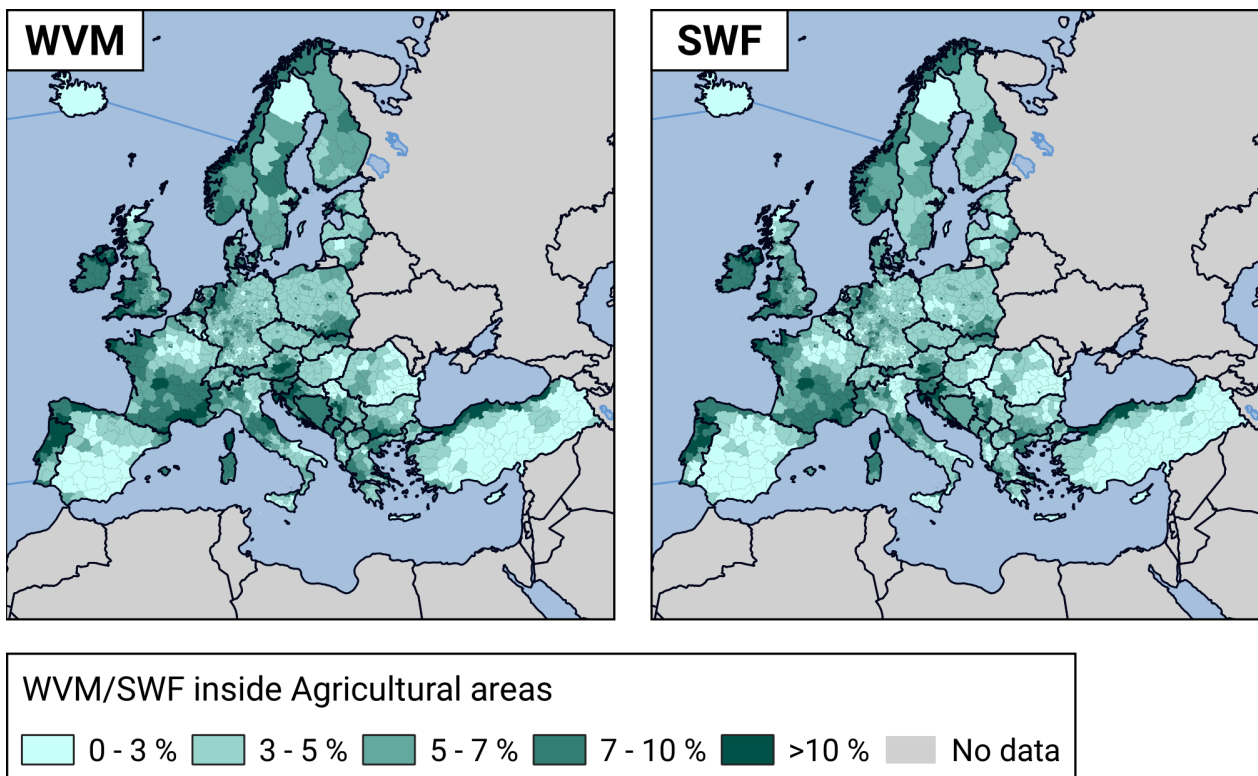
Raster value statistics were summarized at NUTS3 level using the “exactextractr” library (Baston, 2020) within R 4.1.2 (R Development Core Team, 2021).

Across EEA39 approximately 4.2% and 4.7% of agricultural area is covered by woody vegetation identified by the SWF and WVM layers, respectively. Considering only EU27 member states does not substantially affect the calculated overall coverage (WVM: 5.0% | SWF: 4.5 %). The SWF is the child layer of the WVM, which is derived by the application of a geometric rule set to the WVM layer (c.f. Table 8). The definition of this rule set is critical to the estimation of landscape features using the SWF layer as it determines the spatial characteristics of the woody elements inside the SWF layer.

### 5.1 Differences between WVM and SWF

The average difference in terms of absolute area proportion per NUTS region between WVM and SWF is marginal ( $\mu$ : 0.55% SD: 0.37%). This indicates that most woody vegetation identified by the WVM indeed remains in the SWF layer (Figure 14). The overall share in the entire EU terrestrial territory is 4.98 % based on WVM (and 4.47% based on SWF).

The highest proportions of WVM on AA were detected in Melilla (ES) (35.6%), southern Corsica (FR) (32.0%) as well as along the Turkish Black Sea coast (29.8%). About 8% (n=88) of all EU27 NUTS regions exceed the 10% mark of WVM on AA and about half of EU27 NUTS regions feature more than 5% of WVM on AA coverage. Non-EU countries featured higher WVM on AA proportions with approximately 20% (n=70) regions exceeding the 10% WVM on AA and 65% (n=227) above the 5% mark.



**Figure 14 Coverage of AA by SWF/WVM layer within EEA39. Data has been compiled at the level of NUTS3 using aggregated 100m layers. Map class boundaries were defined using custom classification.**

Larger differences between the SWF and WVM layers occur mainly due to the exclusion of coherent forest patches exceeding the 0.5 ha threshold (Figure 15). Such forest patches are present in all EU27 member states and do not appear to be particularly abundant in specific regions.

Despite the application of the geometric size thresholds in the SWF layer, many patches within the SWF exceed this threshold due to special exemptions (4.1) applied to ensure connectivity between (both linear and patchy) features. These additional features include isolated patches between 0.15 – 5ha, from which the features above 0.5 ha exceed the lower size limit of forest patches. Although this approach can help to avoid excluding relevant landscape features to the layer, it has the drawback that it may not be directly evident to the user why specific patches have been either in- or excluded from the SWF layer. At the end, it rightly excludes certain features that are out of the definition (> 0.5ha) of (small) landscape features but not all of them.



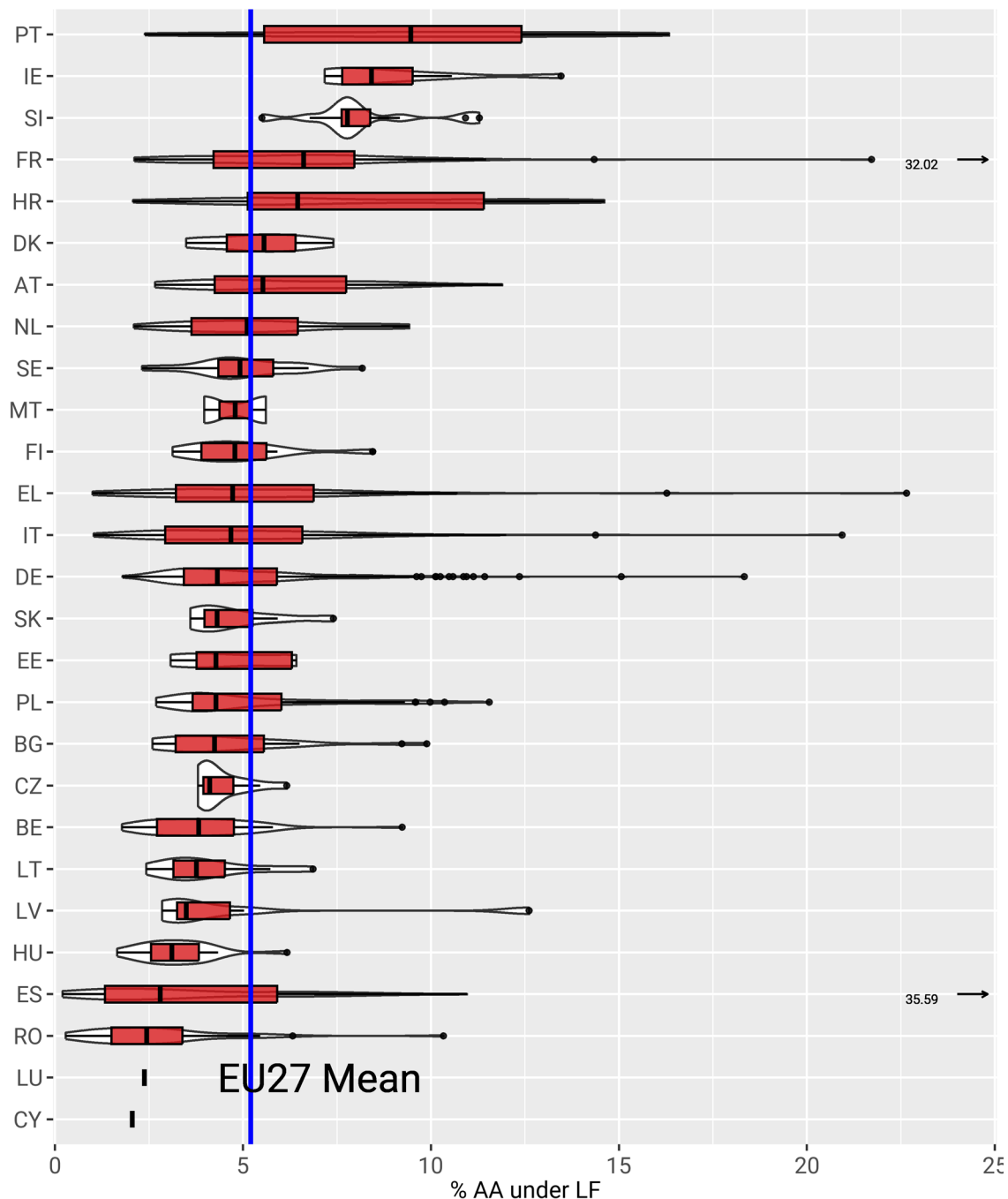
**Figure 15 Comparison of WVM (l), SWF (r). Patch in the centre of the image, as well as small linear patches (West) were removed from SWF layer due to size restriction. (WGS 84: 50.041, 6.454).**

Therefore, after the assessment of the SWF and the WVM of the 2018 portfolio, it can be recommended to use the Woody Vegetation Mask (WVM) to map ‘woody landscape features within agricultural area’ in Europe. This layer includes woody landscape features detected and identified with a clear methodology. A dedicated rule set to exclude big woody features that are not relevant for policies could be possibly developed based on clearer definitions to be agreed among stakeholders.

## 5.2 Country level assessment

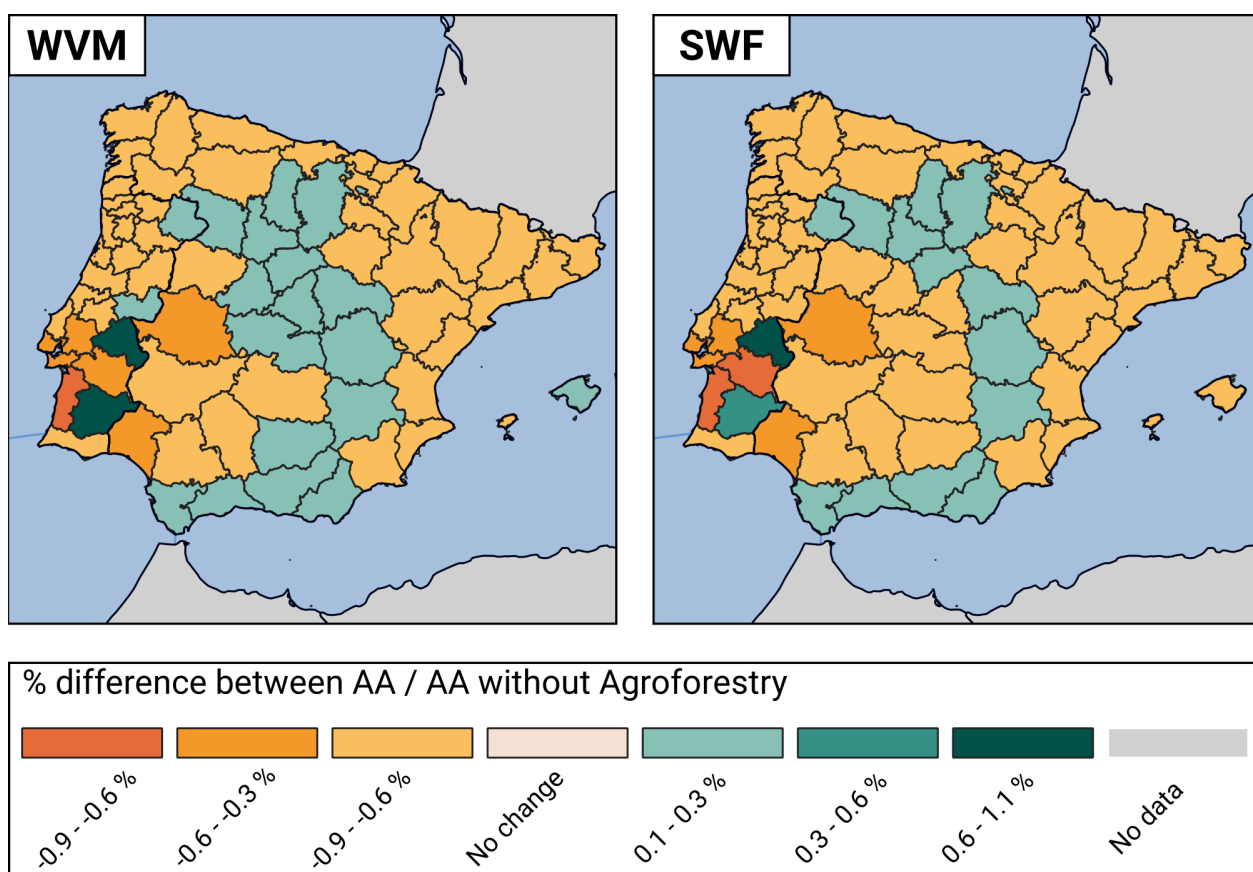
Within EU27 comparison, the share of woody landscape features in agricultural land ranges between 2.64% (Cyprus) and 9.3% (Ireland). Most of the EU countries contain between 3-6% of woody landscape features within their agricultural area (Figure 16). Eight countries show values between 3% and 5%, 11 countries between 5% and 7%, and 4 countries have more than 7% agricultural area covered by woody landscape features.

Ireland (>9%) has the highest share followed by Slovenia, Portugal, Croatia and France (>7%). Cyprus, Romania, Luxembourg and Spain contain the lowest proportions (< 3 %). Countries that feature cultural heritage landscapes with a traditionally strong use of hedgerows for fencing, herding and other agricultural purposes (FR, IE, UK) are consequently characterised by higher proportions of WVM. A prominent example for such feature rich landscape are the Bocage woodlands of France. However, such historic land use is not particularly limited to France and the British Isles but has also shaped the agricultural landscapes of some Northern and South-East European countries (NO, BA, HR, ME). Including or excluding the agroforestry CLC class (2.4.4.) from the agricultural area mask resulted in minor differences at national level (ES 2.77 to 2.90, IT 5.39 to 5.36, PT 8.24 to 9.02), which confirms no significant impact.



**Figure 16 Violin plot: Boxplot superimposed on value distribution histogram (white)) – The Boxplot summarizes the quantile distribution of AA under LF in EU Member States, while the white area indicates the density of occurring values.**

An overlay of the WVM and SWF layer with the regular AA mask and a modified mask that excluded the CLC Agroforestry class (Class code:244) indicated only minor differences (< 0.5%) between the two layers for the two major agroforestry nations Portugal and Spain (Figure 17 showing Spain and Portugal). This shows that the technical and conceptual difficulties to define and detect woody features in those landscapes does not affect significantly the derived indicator values at NUTS3 or country level.



**Figure 17 Percentage (%) difference between WVM and SWF under AA including and excluding CLC 244 (Agroforestry) class in NUTS3 regions of Spain and Portugal.**

## 6 Links between agricultural landscape types and landscape feature presence

Agricultural landscapes in Europe feature a variety of different landscape features, including woody, stony, grassy and water-based features. The common attribute of these features is their low or no agricultural productivity.

Un-productive woody landscape features are not directly used by economic activities, but they can indirectly contribute to agricultural production through the ecosystem services and by the accidental harvest (fruits or biomass) they deliver. As to the moment a European-wide remote sensing product is unlikely to conclusively capture the detailed level of information required to distinguish different landscape features. Here, local knowledge is needed for identification of features associated ecological processes, land management and the landscape type. This is especially relevant for evaluation of changes, for example, in certain cases, a gain in woody vegetation might be associated with processes of land abandonment rather than a shift in agri-environmental management.

Intensive agricultural land management tends to focus on maximising production levels and efficiency, eliminating space for nature and replacing ecosystem services by using external inputs such as pesticides, artificial fertilisers, irrigation and machinery. Therefore, landscapes dominated by intensive agriculture are usually characterized by larger parcels and less landscape features. On the other hand, there are extensive landscapes with high amount of semi-natural vegetation. Between the two theoretical extreme cases of extensive and intensive there are landscapes with varying amount of space for nature.

In order to characterise the distribution of woody features within different agricultural classes the WVM layer was overlaid with Corine Land Cover clipped to the boundaries of the AA mask. Although CLC is a mixed land-cover / land-use classification and not per se a typology of agricultural landscapes it provides a good overview of the physical distribution of the mapped features by landscapes dominated by different land use/land cover classes. Furthermore, it allows to highlight the proportion of WVM within the different CLC classes and identify whether the woody vegetation is particularly associated with specific agricultural classes within different countries (Figure 18).

Woody landscape features were comparably most abundant in ‘heterogeneous agricultural areas’ (CLC Class codes 241 – 243). This was to be expected, given the mixed landscape composition of these classes. However, this pattern could not be observed for all countries. Ireland, for example, features the overall highest proportion of landscape features within the EU and the dominant portion of these are located on pastures. Woody vegetation on pastures appeared to be more abundant in comparison to other classes in FR and NL. DK, SK, SE and HU are the only countries where a larger proportion is located on arable land rather than heterogeneous areas. With the exemption of AT, higher proportions were not located on natural grasslands. Intersections of WVM and Agroforestry areas (CLC Class Code 244), were also comparably low. Only PT featured a higher portion.

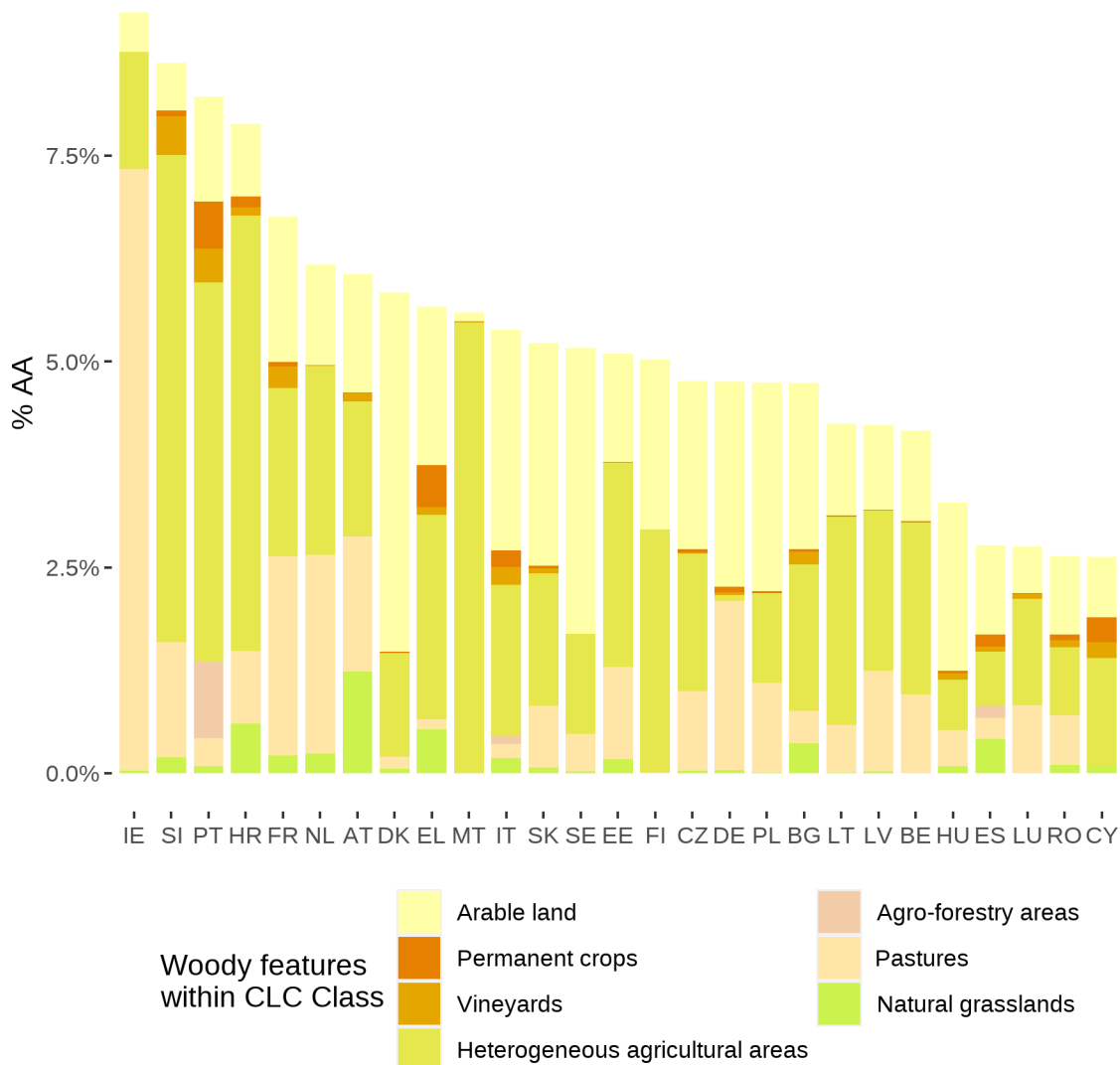




Figure 18 Distribution of woody features across agricultural area classes (Modified CLC Level 1 & 2 Legend) per country.

Figure 19 shows an excerpt of Figure 18 for the three CLC Level 2 classes, ‘Arable land’, ‘Pastures’ and ‘Heterogeneous agricultural areas’ for better comparison.

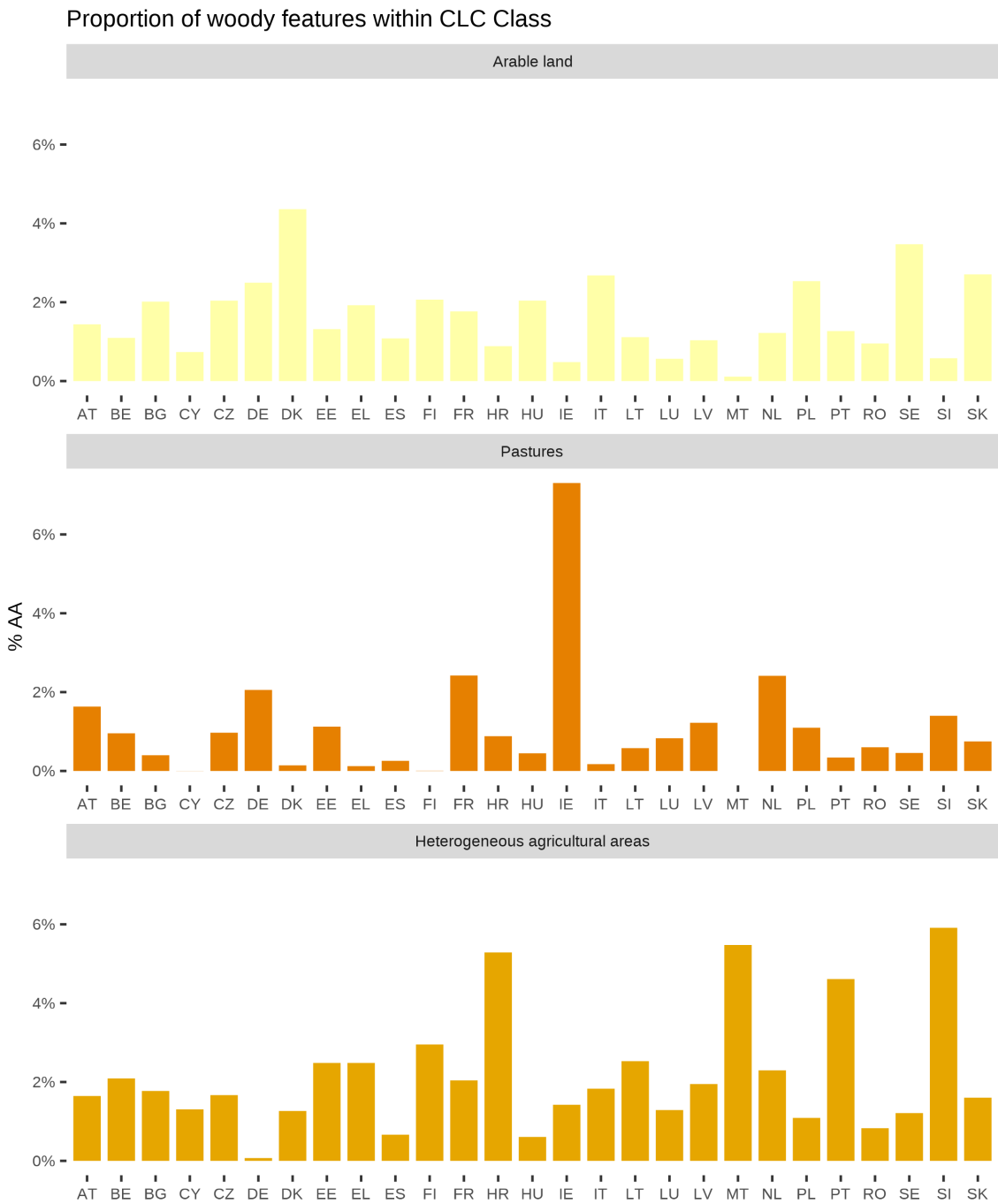
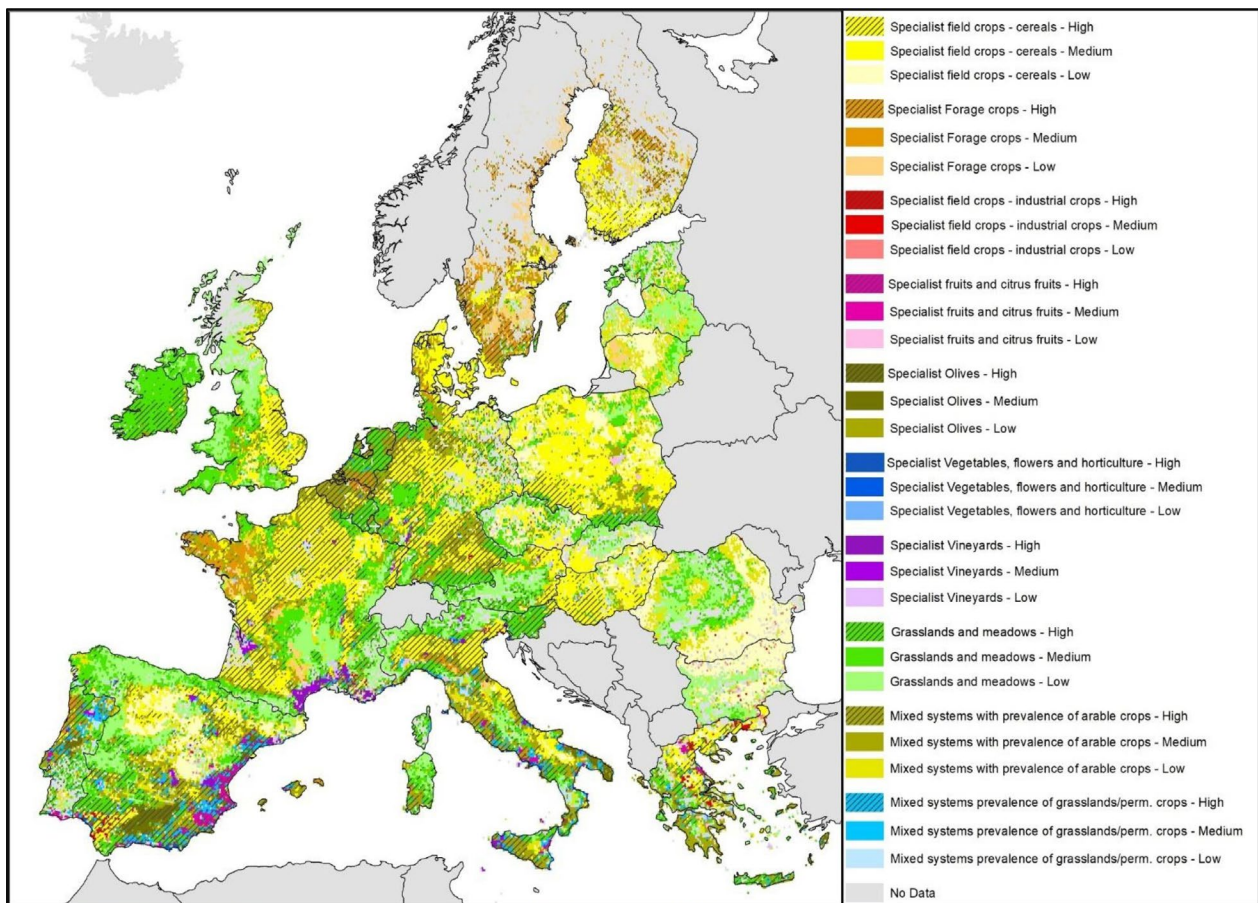


Figure 19 Proportion of WVM inside selected CLC classes.

Beyond using CLC for this purpose, we used the typology of agricultural areas proposed by Rega *et al.* (2020) that is based on energy input and management intensity (Figure 20).



**Figure 20 Energy and management intensity-based crop management systems © Rega *et al.* 2020**

A comparison with the WVM (clipped to the AA mask) showed that WVM were lowest in olive groves and fruit tree plantations (Table 10). This mirrors the results from chapter 5 indicating that there was no considerable overlap with agroforestry areas. The highest amounts of WVM were found in forage crops, grasslands, and vineyards. Mixed systems with arable crops, grasslands and permanent crops features similar SWF density values. Higher SWF density in lower management intensity was only observed in six of the ten subgroups.

**Table 10 Results of the intersection of crop management systems (Rega et al. 2020) with the 100m SWF clipped to AA mask.**

Crop system	WVM inside AA Area (km2)	AA Area (km2)	Prop. WVM / Crop System
Grasslands and meadows - High	10302.8062	155675.49	6.6%
Grasslands and meadows - Low	8137.8229	129559.59	6.3%
Grasslands and meadows - Medium	11560.7623	156194.78	7.4%
Mixed systems with prevalence of arable crops - High	6492.8033	128136.06	5.1%
Mixed systems with prevalence of arable crops - Low	6174.7885	123508.92	5.0%
Mixed systems with prevalence of arable crops - Medium	7429.2827	124919.07	5.9%
Mixed systems with prevalence of grasslands - High	93.9702	2190.58	4.3%
Mixed systems with prevalence of grasslands - Low	444.7692	7695.09	5.8%
Mixed systems with prevalence of grasslands - Medium	200.6049	3076.83	6.5%
Mixed systems with prevalence of permanent crops - High	725.4839	16775.15	4.3%
Mixed systems with prevalence of permanent crops - Low	539.0269	9077.93	5.9%
Mixed systems with prevalence of permanent crops - Medium	608.5623	14684.02	4.1%
Specialist Forage crops - High	1484.6033	20746	7.2%
Specialist Forage crops - Low	1351.6229	19655.92	6.9%
Specialist Forage crops - Medium	1713.7139	20872.44	8.2%
Specialist Olives - High	148.972	11081.39	1.3%
Specialist Olives - Low	626.7048	13701.56	4.6%
Specialist Olives - Medium	328.8552	12560.84	2.6%
Specialist Vegetables, flowers and horticulture - High	38.1307	1044.43	3.7%
Specialist Vegetables, flowers and horticulture - Low	67.791	913.48	7.4%
Specialist Vegetables, flowers and horticulture - Medium	34.2993	897.72	3.8%
Specialist Vineyards - High	508.9568	7170.92	7.1%
Specialist Vineyards - Low	477.0491	7411.31	6.4%
Specialist Vineyards - Medium	413.4459	6895.67	6.0%
Specialist field crops - cereals - High	11235.9187	258656.21	4.3%
Specialist field crops - cereals - Low	8228.3241	246691.74	3.3%
Specialist field crops - cereals - Medium	11555.4748	257480.76	4.5%
Specialist field crops - industrial crops - High	102.2436	2878.64	3.6%
Specialist field crops - industrial crops - Low	128.7124	3190.84	4.0%
Specialist field crops - industrial crops - Medium	144.0558	3687.05	3.9%
Specialist fruits and citrus fruits - High	140.4577	6179.99	2.3%
Specialist fruits and citrus fruits - Low	139.4887	3848.05	3.6%
Specialist fruits and citrus fruits - Medium	202.4341	5577.8	3.6%

While this typology accounts for management intensity it does not focus on the provision of space for nature. In the context of a landscape feature indicator, the potential environmental benefits of the features should ideally be considered, however there is no available information on that specifically.

Traditional, extensive agroforestry and other extensive landscapes historically have produced a large diversity of different landscapes. These may feature very different spatial configuration patterns and spectral properties in EO images. However, as agroforestry is practiced in both intensive and extensive manner today, different management practices contribute to maintaining biodiversity to a varying degree.

Differentiating biodiversity friendly from intensively managed agroforestry remains a challenge by earth observation tools and will likely require in-situ data for the foreseeable future. On the other hand, the agroforestry areas maintaining biodiverse ecosystems could be recognised as areas contributing to the objective of preserving biodiversity and landscapes with another approach such as a separate indicator.

It is an ecological, landscape planning and policy question, where, and in which areas the increase of woody or other landscape features should be encouraged and incentivised more, which are the key areas. Table 11 provides an overview of the extent of agroforestry areas in Europe.

**Table 11: Stratification of agroforestry.** Source: Agforward project inside EUPARL Briefing [https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651982/EPRS\\_BRI\(2020\)651982\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651982/EPRS_BRI(2020)651982_EN.pdf) - last accessed 06.10.22 8:57

System	Country	Extent (hectares)
Mediterranean oak tree agroforestry	<i>Dehesa</i> in Spain	3 606 151
	<i>Montado</i> in Portugal	1 059 000
	Grazed woodlands and oak and other agroforestry on agricultural land in Greece	1 895 583
	Pyrenean oak ( <i>Quercus pyrenaica</i> ) in Spain and Portugal	122 000
	Grazed oak woodlands in Italy	279 263
	<b>Sub-total</b>	<b>6 961 997</b>
Other wood pastures and meadows	<i>Larix decidua</i> (European larch) in Italy	102 319
	Lövängar, hagmarker in Sweden	100 000
	Other parkland, woodland, wood-pasture, <i>Hudewald</i> , <i>Haka</i> and <i>metsälaidun</i> in the UK, Germany, Austria, Switzerland, Hungary, Finland	200 320
	<b>Sub-total</b>	<b>402 639</b>
Reindeer husbandry	Finland, Sweden, Norway	<b>41 400 000</b>
Hedges and scattered trees	France and parts of the UK and Belgium	<b>472 074</b>
Agroforestry with fruit trees	Germany, Switzerland, Austria, Romania, Croatia, Czechia, France, the UK, Denmark, Italy, Greece, Poland, Portugal	1 226 867
with olives	Portugal, Greece, France, Italy and Spain	538 865
with pine-trees	Italy and Portugal	535 842
with vines	Italy, Spain and Portugal	275 635
with chestnuts	Portugal, France, Italy, Greece, Hungary, Romania, Slovakia, Slovenia, Spain and Switzerland	111 083
with carob trees	Italy, Portugal, Spain and Greece	92 200
	<b>Sub-total</b>	<b>2 780 492</b>
Shelterbelts (windbreaks)	Hungary	<b>16 415</b>
Alley cropping	France	<b>6 300</b>
Trees with livestock	Netherlands	<b>3 000</b>
<b>Total</b>		<b>52 042 917</b>
<b>Total (excluding reindeer)</b>		<b>10 642 917</b>

## 7 Summary

The assessment of the share of agricultural land covered by landscape features at pan-European scale remains constrained by data availability. Although parcel level information on agricultural area and landscape features could be ideal to quantify landscape features on agricultural areas, this information is generally not widely available in suitable and/or standardised format.

This gap in terms of agricultural area (parcel) information has been bridged by the activities of the recent years, which have culminated in a spatially explicit reference layer, the agricultural area mask.

For the assessment of landscape features using remote sensing tools and available datasets, there are clear limitations concerning the scope of elements that can be targeted from the defined range of potential features. In general, only woody elements of sufficient size can be targeted. Other feature types, such as ditches are unlikely to be considered by means of earth observation data in the near future due to their small width. Larger ponds can be easily mapped using EO data, however, there are some limitations regarding the assessment of their value for biodiversity, especially in view of the ecosystem services potentially provided by such elements. As to the moment, the differentiation of natural ponds or artificial ponds surrounded by riparian, semi-natural vegetation from artificial ones with cemented or plastic walls remains a challenge.

The use of the SWF portfolio as basic input for the I.21 indicator presents itself without an alternative. As such, it is important to understand whether this indicator is equally applicable for all agricultural landscapes across Europe or whether the mapping of landscape features needs to be limited to specific target land use and land management. This is especially important in the context of varying biodiversity value of woody elements in different agricultural and biogeographical contexts such as open landscapes dominated by arable land or pastures or grasslands, landscapes dominated by permanent crops or heterogeneous landscapes, or semi-natural agroforestry areas.

Therefore, a logical next step is to further assess and study the impact and distribution of WVM/SWF in different agricultural landscapes. Beyond the typology provided by Rega et al. 2020 a dedicated typology of landscape structure might be more suitable to understand patterns of biodiversity relevant woody features. In this regard, the LUCAS landscape features module may also provide additional opportunities for further analysis.

The separate mapping of (different types of) agroforestry areas and (woody) landscape features within other agricultural areas could also support a more straightforward definition of the CAP indicator I21. As the ecological benefit of woody landscape features largely depend on the type of agricultural landscape they belong to, it makes sense to map and assess (in the future) agroforestry and (woody) landscape features differently. Clear definitions for agroforestry areas and (woody) landscape features are indispensable in this sense.

## 8 Outlook

A new product lineage of Copernicus High Resolution Layers is currently (Status: May 2023) under development - the Vegetated Land Cover Component. This portfolio includes a dedicated crop type layer as well as a grassland mowing product.

Both layers address many of the previous shortcomings of lacking information on crops cultivated within arable land and permanent crops. Rendering them well suited as a primary component for - and potential successor of - the AA mask and linked indicator portfolios. This is especially relevant given the circumstance that the 'traditional' CLC mapping process will be abandoned in favour of a new, more automated approach, thus eliminating the basis for the existing AA mask after 2024.

Although the new product will essentially cover all cultivated area it could be that it does not physically overlap with (non-productive) landscape elements such as woody vegetation. Still, this will require more in-depth analysis given that woody vegetation might be omitted from the layer at least partly.



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## 10 Annex 1 CLC classes

CLC_LVL3	CLC_LABEL
111	Continuous urban fabric
112	Discontinuous urban fabric
121	Industrial or commercial units
122	Road and rail networks and associated land
123	Port areas
124	Airports
131	Mineral extraction sites
132	Dump sites
133	Construction sites
141	Green urban areas
142	Sport and leisure facilities
211	Non-irrigated arable land
212	Permanently irrigated land
213	Rice fields
221	Vineyards
222	Fruit trees and berry plantations
223	Olive groves
231	Pastures
241	Annual crops associated with permanent crops
242	Complex cultivation patterns
243	Land principally occupied by agriculture with significant areas of natural vegetation
244	Agroforestry areas
311	Broad-leaved forest
312	Coniferous forest
313	Mixed forest
321	Natural grasslands
322	Moors and heathland
323	Sclerophyllous vegetation
324	Transitional woodland-shrub
331	Beaches dunes sands
332	Bare rocks
333	Sparsely vegetated areas
334	Burnt areas
335	Glaciers and perpetual snow
411	Inland marshes
412	Peat bogs
421	Salt marshes
422	Salines
423	Intertidal flats
511	Water courses
512	Water bodies

521 Coastal lagoons  
522 Estuaries  
523 Sea and ocean  
999 NODATA

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