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Classification and quantification of landscape features in agricultural land across the EU

A brief review of existing definitions, typologies, and data sources for quantification

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Contents

Foreword

The following report presents an inventory on the state of play of existing information on agricultural landscape features at EU level with a cut-off date of summer 2021. The different information sources are compared in terms of the LF types recognized and their definitions, and a consensus typology with simplified definitions is proposed. Particular emphasis is laid on the two key data sources considered for the production of the upcoming CAP indicator: the Copernicus SWF (Small Woody Features) products and the LUCAS surveys (Land Use/Cover Area frame Survey), with a thorough analysis of the existing products (SWF HRL 2015, LUCAS Transects 2015), and an outlook to the upcoming products (SWF HRL 2018, LUCAS LF 2022) not available yet at the time of writing. This work is complemented by an outlook to quantifications, documenting the process for LUCAS Transect (2015) data, a key resource for historical (pre-2022) LF quantifications.

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This report is primarily based on an iMAP4AGRI deliverable (D7.2), and also greatly benefited from advice and comments by colleagues from DG AGRI, DG ENV, DG ESTAT and the EEA. Andrea Hagyó was an author of the early versions of this deliverable as a technical expert at the JRC in 2020, and later provided comments to the final versions in her new role at the EEA.

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Abstract

Agricultural landscape features are small fragments of natural or semi-natural vegetation in agricultural land which, compared to their relatively small size, provide important contributions to ecosystem services and biodiversity. They have long-standing historical and cultural roots in the agricultural landscapes of Europe, but with the advent of intensive agriculture, landscape features became threatened. Nevertheless, landscape features can have a major role in making European agriculture more resilient to the key environmental challenges of the 21st century, including climate change and biodiversity decline.

One of the critical difficulties for protecting, restoring, or monitoring landscape features in agricultural areas is the lack of a harmonised understanding on its definition and main types. Operative assessment and monitoring require an EU-level harmonized methodology, tightly linked to the ecological functions of landscape features (i.e., the characteristics underlying their capacity to provide ecosystem services) in order to ensure that the resulting indicators will respond to the fundamental policy goals.

In this report we provide an overview on the various ways how the concept of landscape features is present in EU policy documents, and the available datasets that can provide consistent information at the EU-level. We will lay particular emphasis on landscape feature typologies applied by these data sources: what kind of types they distinguish, and how these types relate to each other. The size limits applied by the various type definitions are also explored. We give examples how the available data sources can be used to estimate the area of landscape features in Europe, which also illustrates the importance of harmonized definitions and typologies. Finally, we propose a simple harmonized typology and methodology, based on the commonalities of the existing solutions and ecological considerations, which can be used for future policy applications.

1 Introduction

Agricultural landscape features (or henceforward simply *landscape features*, LF) **are small fragments of non-productive natural or semi-natural vegetation in agricultural landscape which provide ecosystem services and support for biodiversity**. This definition includes several non-productive elements of European agricultural landscapes, such as hedges, ponds, ditches, trees in line or in group or isolated, field margins, terraces, dry-stone or earth walls, planted areas, individual monumental trees, springs or historic canal networks. Traditionally, such elements were important elements of agricultural landscapes, closely linked to traditional agricultural management practices that historically have modified existing features or actively created them (Poschlod & Braun-Reichert, 2017). Their existence had a function: they provided services to the farmers, who used them for their wood, to create shelter for crops and livestock as well as windbreak barriers, to delimit parcels, or to be able to cultivate land with steep slopes (Eurostat, 2013). These elements also often involved bits of the landscape that was not worth to be cultivated due to unfavourable natural conditions (too wet, stony etc.), thus preserving fragments of natural vegetation. In other words, landscape features used to provide important ecosystem services to the local agricultural communities.

With the advent of modern agriculture, in the 20th century, some of the traditional functions of landscape features seemed to diminish: for example, rural populations were less and less reliant on hedgerows for fencing their livestock, or firewood from field coppices. Nevertheless, other functions, like windbreaks and erosion protection remained intact, and "new" functions, like the maintenance of agricultural biodiversity were increasingly recognized instead. Today it is widely acknowledged that landscape features have a significant beneficial impact on the neighbouring agricultural lands and the entire human economy in the form of ecosystem services. These (direct and indirect) impacts include improved air quality, water quality, water quantity, reduction of greenhouse gas emissions, carbon sequestration, climate change adaptation, regulation of soil erosion and soil quality, support biodiversity and pollination, as shown in a synthesis of recent meta-reviews (Pérez-Soba, 2018). In this way, landscape features in farmland may help to comply with various policy targets, including climate change mitigation, the conservation of biodiversity, the protection of water resources, and the reduction of pollution. In fact, as agricultural areas occupy around 47% of EU27,[1] landscape features, and the services provided by them have gained new importance in addressing the key environmental challenges of the 21st century. No surprise that the role of LFs in agricultural land is recognized in several key Strategies and Directives of the EU environmental policy, including for example the Biodiversity Strategy, the Water Framework Directive, or the Nitrate Directive.

Landscape features are not only beneficial for the broader society, but they also provide direct contributions to the neighbouring agricultural fields, in the form of regulating ecosystem services. Most importantly, LFs provide habitats for a number of beneficial organisms, including pollinators and the natural enemies of agricultural pests, which have a crucial contribution for agricultural productivity. Furthermore, LFs can also improve field productivity by increasing fertility and water availability. Moreover, traditional landscape features have an important cultural value, e.g. the bocage landscape in France or the typical dry-stone walls in Ireland or Malta.

Figure 1. Examples of landscape features

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[1] based on CORINE Land Cover 2018 (https://agridata.ec.europa.eu/extensions/DashboardIndicators/Environment.html)

Source: Adobe Stock

Given the important agricultural, ecological and cultural role of LFs, European policy frameworks are increasingly setting requirements to **protect, maintain, restore**, and **create** LFs. However, the fact that LFs are the 'non-productive' elements in a generally productive agricultural landscape creates additional complexities for their management and regulation. In a sense, landscape features behave like economic 'commons', which provide public benefits threatened by self-interest (Hardin, 1968). In this context the main purpose of EU regulations is to prevent a new 'tragedy of the commons'. This is not an easy task, given the diversity of LF types combined with the diversity of historical, social, cultural and political contexts into which these LF types are embedded in the various Member States (MS). These circumstances make it particularly difficult to design policies that address all LF types across all of the agricultural landscapes in the whole EU territory. This makes it necessary that the regulations aiming at protecting, maintaining, restoring, and creating landscape features need to be tailored to the local circumstances.

Nevertheless, an efficient EU policy on landscape features needs to have another component that cannot be handled in a completely uncoordinated way. An efficient governance needs to rely on **measurement** and **monitoring**: the progress towards the targets needs to be regularly evaluated, so that the policies or their implementation can be updated if necessary. The quantification and ecological assessment of LFs is important not only for the Common Agricultural Policy (CAP), but also for aspirations related to policy on the environment and climate – as set out, for example, in the European Green Deal[2], the EU Biodiversity Strategy for 2030[3] and technical documents on carbon farming[4]. For this purpose, an EU-level harmonized methodology is needed, which can provide key information on the landscape features in agricultural land. This methodology needs to be tightly linked to the ecological functions of the LFs (including technical details, e.g., definitions, typology, geometric limits, etc. need to reflect the added value of the assessed features in terms of ecosystem services), in order to ensure that the resulting indicators will reflect the policy mandate of the whole exercise (i.e., they will be 'fit for purpose'). Consequently, to allow for a LF quantification it is necessary to conceptualize agricultural land in a given context and to define the LFs to be included, thus creating a LF typology (see Sections 1.2.1 and 1.2.2).

1.1 Landscape features in EU policies

The importance of landscape features has been recognized by several major European sectoral policies. The **Common Agricultural Policy (CAP)** has included LFs in its instruments for tailoring payments to the farmers since 1992 (Al-Khudhairy, 2000), and the importance of their maintenance has been acknowledged in the Agenda 2000 and the cross-compliance system introduced in 2005.

In the current CAP period (2014-20), LFs are promoted to achieve the objectives of sustainable management of natural resources, maintaining rural areas and landscapes across the EU and tackling climate change, with a focus on biodiversity, habitats, greenhouse gas emissions, soil and water.

The current CAP promotes the retention, maintenance and/or creation[5] of landscape features in agricultural land in three ways:

- Cross Compliance sets requirements related to landscape features in the Good Agricultural and Environmental Conditions (**GAEC 7**) and the Statutory Management Requirements (**SMR2** "Conservation of Wild Birds", and **SMR3** "Conservation of Natural Habitats and of Wild Flora and Fauna") which protect landscape features[6];
- Greening measures include the "maintenance of Ecological Focus Area" (**EFA**);
- Rural Development Programmes include the **Sub-measure 4.4.** "Support for non-productive investments linked to the achievement of agri-environment-climate objectives" and the **Measure 10**: "Agri-environment-climate measures".

The Regulation (EU) No 1306/2013 establishes the baseline for the maintenance of landscape features. GAEC 7 establishes that: Farmers shall retain landscape features "*including where appropriate, hedges, ponds, ditches,*

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[2] COM(2019) 640 final

[3] COM(2020) 380 final: this Communication sets out a target that at least 10% of the EU's agricultural area should be taken up by "high-diversity landscape features" by 2030

[4] See, for example, Commission sets the carbon farming initiative in motion | Climate Action (europa.eu)

[5] Retention: no removal of landscape features; maintenance: any intervention on landscape features (e.g. trimming, pruning); creation: plantation of new landscape features

[6] Regulation (EU) No 808/2014

trees in line, in group or isolated, field margins and terraces". EU countries define which landscape features shall be part of the requirement. The regulation also takes into account sectorial regulations that establishes conditions for biodiversity: the Birds Directive (2009/147/EC, considered in **SMR 2**) and the Habitats Directive (92/43/EEC, considered in **SMR 3**).

One of the greening measures is maintaining an 'ecological focus area' of at least 5% of the arable area of the holding on farms with more than 15 hectares of arable land. Since the aim of EFAs is to protect and improve biodiversity on agricultural land, **landscape features are eligible to be declared as EFA**. According to the Regulation 1306/2013, landscape features protected in GAEC, SMR 2 and SMR 3 can be considered Ecological Focus Areas. Additionally, it gives a list of features with specific characteristics that can be included in the EFA.[7] EFAs shall be located on arable land or adjacent to arable land (Regulation 639/2014). Member States define the type of landscape features that can be declared as EFA by the farmer.

Under **Sub-measure 4.4**. of the Rural Development Programmes (RDPs) "Support for non-productive investments linked to the achievement of agri-environment-climate objectives" EU Member States can support investments for the creation of new landscape features and the **Measure 10**: "Agri-environment-climate measures of the Rural Development Programmes" (RDPs) is another way to protect and promote landscape features in farms. The uptake of these measures is voluntary, and their eligibility conditions are set in the national/regional RDPs.

The new CAP (post 2020) also aims at protecting landscape features to achieve the **specific objective 6** "*Contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes*". There are similar measures to the previous CAP, adapted to a new framework based on the following instruments:

- The so-called "enhanced **conditionality**" in replacement of Greening and Cross-compliance. Income support will be linked to mandatory sustainable farming practices and standards like GAEC and SMR. The current CAP instruments for landscape features protection, GAEC7 and EFA, will be combined in the new CAP as one measure, **GAEC 8**, prescribing a *"**minimum share of agricultural area devoted to non-productive areas or features**"* (in three different scenarios), as well as the *"retention of landscape features"*, a *"ban on cutting hedges and trees during the bird breeding and nesting season"*, and *"as an option, measures for avoiding invasive plant species"*[8].
- The eco-schemes, which support voluntary interventions that are beneficial for the climate and the environment
- In the new CAP, Rural Development will continue to support the creation and restoration of new landscape features under the **investment intervention**, through non-productive investments and, the maintenance of landscape features under the **Environmental, climate and other management commitments**.

Besides the CAP, there is legislation in other EU policy areas protecting landscape features:

The **Habitats Directive** ("Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild flora and fauna") states that "*Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving the ecological coherence of the Natura 2000 network, to **encourage the management of features of the landscape which are of major importance for wild fauna and flora**. Such features are those which, by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species.*"

Similarly, the **Birds Directive** (2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds") states that "*Member States shall take the requisite measures to preserve, maintain or re-establish a sufficient diversity and area of habitats for all the species of birds referred to in Article 1. The preservation, maintenance and re-establishment of biotopes and habitats shall include [...] (b) upkeep and management in accordance with the ecological needs of habitats inside and outside the protected zones...*"

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[7] Regulation 639/2014 (Art. 45) lists the following LF as eligible for EFA: hedges, isolated trees, trees in line, trees in group, field margins, ponds, ditches, traditional stone walls. Terraces and buffer strips (which are not listed as LF) are also eligible for an EFA status.

[8] Regulation (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021 establishing rules on support for strategic plans to be drawn up by Member States under the common agricultural policy (CAP Strategic Plans) (Annex III)

As described above, some articles of these two pieces of legislation are also linked to the CAP through SMRs (SMR2-3, in the old CAP, and SMR3-4 in the new CAP, respectively).

The Habitats Directive is also an important instrument for achieving a target regarding LFs set out in the **EU Biodiversity Strategy for 2030** (COM 2020(380 final)): *"To provide space for wild animals, plants, pollinators and natural pest regulators, there is an urgent need to* ***bring back at least 10% of agricultural area under high-diversity landscape features****. These* ***include, inter alia, buffer strips, rotational or non-rotational fallow land, hedges, non-productive trees, terrace walls, and ponds****. These help enhance carbon sequestration, prevent soil erosion and depletion, filter air and water, and support climate adaptation. In addition, more biodiversity often helps lead to more agricultural production. Member States will be suggested to translate the 10% EU target to a lower geographical scale to ensure connectivity among habitats, especially through the* ***CAP instruments*** *and* ***CAP Strategic Plans****, in line with the* ***Farm to Fork Strategy****, and through the implementation of the* ***Habitats Directive.*** *The progress towards the target will be under constant review, and adjustment if needed, to mitigate against undue impact on biodiversity, food security and farmers' competitiveness."*

Outside EU policy *per se* but nonetheless relevant to the present discussion: the **European Landscape Convention**[9] aims to "*promote landscape protection, management and planning, and to organise European co-operation on landscape issues*". It states that policies in various areas, among them agriculture, have an effect on landscape features. It specifically lists the landscape features that could be found in agricultural land, e.g., "*hedges, planted areas, dry-stone or earth walls, terraces, individual monumental trees, springs or historic canal networks*" and it calls for the use of instruments such as legal protection, grants and training to owners and farmers for the upkeep, replanting or integration of landscape features (Council of Europe, 2000).

This demonstrates that a new policy framework is evolving linking several initiatives and policies leading now to a common need of monitoring of LFs across sectoral policies and the need for consistent data.

1.2 Monitoring landscape features

All EU policies need to be accompanied by adequate **measurement** and **monitoring**. This is the only way to check whether the policy is achieving its desired purpose, and to identify options for improvements. A systematic EU-level monitoring of landscape features can thus support the implementation of all the policies discussed in the previous section.

As part of the common monitoring and evaluation framework (CMEF) of the CAP 2014 -2020+, a set of common output, result, impact and context indicators have been defined to support the assessment of the performance of the CAP. Although several interventions/ measures can address the issue of LFs there is no distinct indicator (output, result, impact, context) that directly allows the monitoring of landscape features, they are only indirectly captured, e.g. via the EFA indicators.[10]

With the new CAP and the new focus on policy performance comprehensive, complete, timely and reliable information on EU agriculture and rural areas is required. Existing data sources need to be adapted and strengthened to match better with the new policy and where needed, new data sources should be explored and mobilised in order to reduce the burden for farmers and administrations, while at the same time improving policy evidence base. (SWD(2018) 301 final PART 1/3).

Therefore, the new CAP includes a more targeted **Performance and Monitoring Evaluation Framework (PMEF)**, consisting of several types of indicators. Among the *context* and *impact* indicators, which shall be used to assess the overall policy performance on a multi-annually basis, specific objective 6 is targeted with **'Share of agricultural land covered with landscape features'**, which is labelled as both I.21 and C.21 following the structure of the new framework. The concept of LF also occurs in several *result* indicators, which monitor the practical aspects of CAP implementation. R.34 ("Preserving landscape features") quantifies the share of agricultural area under financial commitments for managing LFs in the MS. The area of LFs planted with a biodiversity objective can also be reported under R.32 ("Investments related to biodiversity "), and the area of newly planted woody LFs can be accounted under R.17 ("Afforested land"). Investments in LF will be summarized in R.26 ("Investments related to natural resources").

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[9] The European Landscape Convention (coe.int)

[10] https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/technical-handbook-monitoring-evaluation-framework_june17_en.pdf

Within the PMEF, the *context and impact* indicators are the ones that will be used to evaluate the efficiency of the CAP with respect to its original environmental and social goals. This demands reliable EU-level data streams with clear and operative definitions that are well-connected to the original policy mandates. For landscape features there is just one context and impact indicator planned, the I.21-C.21 indicator (henceforward I.21) which will primarily be measured as the '*share of agricultural land covered with landscape features*' (expressed in %). While the total area of LFs in an agricultural landscape is not their only characteristic that determines their capacity to contribute to ecosystem service flows, this is clearly the most critical information gap that needs to be addressed first. A harmonized and operational monitoring framework for LF area can also set the foundations for assessing other relevant characteristics of LFs (e.g., their condition, or connectivity), and in the future I.21 is also foreseen to host a second "specific indicator" describing '*landscape elements structure*', which '*could be complemented with some statistics to reflect on spatial configuration of features*'[11]. But even for LF area assessments there are several interlinked challenges that need to be solved reassuringly before a 'LF structure' indicator could be reliably implemented at the EU level.

To quantify the I.21 indicator in a robust way, both the nominator (LFs) and the denominator (agricultural land) need to be carefully defined and contextualized. The definition of LF needs to be supported by a simple and **functional LF typology**, which can be used operatively across all EU MS. The exact details of these key elements shall be determined in line with a few key considerations:

- enable and support simple, objective, and operative assessment (i.e., pragmatic approaches and clear decision rules that can be applied in all relevant contexts);
- avoid duplication of efforts (re-assessing information that can already be known from existing data streams);
- ensure compatibility with existing approaches & data as much as possible (e.g., align with the type of LFs enlisted in the policies).

Once the area of interest and the LF typology are defined the computational approach for the quantification needs to be agreed upon (spatial and temporary resolution, accuracy, etc.) to achieve a qualified indicator which will be measurable with a reasonable cost/ benefit ratio and responsive to change.

1.2.1 Concepts of agricultural land

There are various concepts of defining agricultural land depending on context and methodology. For the sake of comparability of different LF quantifications within agricultural land it will be essential to agree on a comprehensible definition and reproducible methodology to derive the area of interest wherein LFs are located. Existing concepts mostly draw on land-use categories and/or are purpose driven (e.g. food production).

Commonly **agricultural land** is understood as area devoted to agriculture, the systematic and controlled use of other forms of life—particularly the rearing of livestock and production of crops—to produce food, fibre and bio-fuels for humans. It is thus generally synonymous with farmland or cropland, as well as managed (grazed or mown) grassland.

In the current (2014-20) CAP regulation No 1307/2013 agricultural area is defined as "*any area taken up by **arable land, permanent grassland** and permanent pasture, or **permanent crops***"[12], with the following components:

- Arable land: land cultivated for crop production or laying fallow, including set-aside areas under commitments for rural development;
- Permanent crops: non-rotational crops, other than permanent grassland, that occupy the land for 5 year or more, including short rotation coppice and nurseries,
- Permanent grassland: land not included in the crop rotation and used to grow grasses or other herbaceous forage (natural or sown) for 5 years or longer, possibly including grazed trees and/or shrubs which produce animal feed (MS choice).

In the Delegated regulation No 640/2014, according to Articles 9 and 10, there is leeway for Member States to include landscape features and trees within the **eligible agricultural area** for direct payments, when they are

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[11] PMEF - Draft indicator fiches (as of Aug 2020)

[12] in the context of agri-environment-climate measures Member States can freely extend this definition (Regulation 1305/2013)

protected by GAEC 7, if they are scattered within a maximum density (100 plants/ha), if a pro-rata system is applied on permanent grassland parcels.

Similarly to the current CAP, the new regulation[13] also defines agricultural area as the combination of "*arable land, permanent crops and permanent grassland, including when they form agroforestry systems on that area*"[14] however it also opens the door for definitions at national level, better fitting the specific context[15]. Nevertheless, it still sets a minimum framework for the MS:

- 'Arable land' shall be land cultivated for crop production or areas available for crop production but lying fallow; in addition, it shall, for the duration of the commitment, be land cultivated for crop production or areas available for crop production but lying fallow that have been set aside (…);
- 'Permanent crops' shall be non-rotational crops other than permanent grassland (…) that occupy the land for five years or more and that yield repeated harvests, including nurseries and short rotation coppice;
- 'Permanent grassland' (…) shall be land that is used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in the crop rotation of the holding for five years or more and (…) may include other species such as shrubs and/or trees which can be grazed and (…) which produce animal feed.

In a **statistical sense** agricultural area can be seen as composed of similar components as from the CAP direct payments perspective. The definition of agricultural area by the Food and Agriculture Organization (FAO) of the United Nations, for example, acknowledges the following three components: [16]

- Arable land: land under temporary agricultural crops (…), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years);
- Permanent crops: land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees); and
- Permanent meadows and pastures: land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

This is very close to the concept used by EUROSTAT to define "utilised agricultural area" used for agricultural statistics. **Utilised agricultural area (UAA)** includes the following land categories: 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.[17]

For the quantification of LFs in agricultural land a pragmatic approach is needed, since depending on the data sources the statistical concept of UAA might not be fully applicable. The statistical concept of UAA refers to the land-use, and includes areas used for any agricultural activity, including activities performed in buildings and greenhouses. Furthermore, the statistical concept of)also often requires time-series to observe changes related to performed activities (sowing, ploughing, crop rotation etc…). The assessment of landscape features also needs a clear scope in terms of agricultural land use, which is not identical to the concept of UAA. In order to clearly focus on the agricultural context, three cases have to be separated.

- Forestry use: non-productive landscape features falling in the typology described below and fulfilling certain size limits can be distinguished from forest parcels.
- Anthropogenic uses (e.g. urban or industrial): landscape features located in such areas are not of agricultural interest, while bordering elements can belong both to agricultural and urban areas.
- Semi-natural (agroforestry) systems should also be distinguished, as in this case the woody component is integral part of the system as "deliberately" included by the farmer or land manager, differently from landscape features part of an agricultural matrix dedicated mainly to crop production.

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[13] Regulation (EU) 2021/2115, Art. 4 (2)

[14] The preamble of Strategic Plan regulation defines agroforestry systems as areas "*where trees are grown in agricultural parcels on which agricultural activities are carried out to improve the sustainable use of the land*", which should also be covered by the MS definitions of 'agricultural area' (id. (14)))

[15] id. Art. 4 (3))

[16] https://www.fao.org/waicent/faostat/agricult/landuse-e.htm

[17] https://ec.europa.eu/eurostat/web/products-datasets/-/tag00025

1.2.2 Landscape feature typologies

Defining what will be accounted or not as a landscape feature is of central importance for any reporting mechanism. There are, in principle, two main approaches to defining landscape features. Legislation, strategies etc. often provide a list of examples (e.g., "*buffer strips, rotational or non-rotational fallow land, hedges, non-productive trees, terrace walls, and ponds*"[18]), without an exact specification what should be involved under each of the listed subtypes. This approach can be very efficient for instruments aimed at protecting or restoring LFs, because it leaves enough flexibility to the Member States to adapt the instruments to their particular ecological and socio-cultural contexts.

However, when it comes to an EU-level monitoring network there is a need for a functional definition for landscape features, which tightly connects the concept to its main policy mandate (ecosystem services) and enables a simple and operative survey. This functional definition needs to distinguish broad LF types based on their key functional characteristics, which determine how they interact with the local flora and fauna, as well as their possible biophysical, aesthetic, and cultural roles. Accordingly, several **functional LF classes** can be distinguished (Table 1), which can easily be linked to the lists of elements in agricultural land recognized by the various data sources and policy documents. This list of functional LF classes closely builds on the typologies used in the forthcoming EMBAL and LUCAS LF surveys (see Sections 2.2.2-2.2.3 and 3.3-3.4).

Table 1. The proposed Functional Landscape Feature classes cross-walked to the LF types commonly recognized in policy documents

Functional LF (FLF) class	**Examples for commonly recognized subtypes**
Woody features	Isolated trees, Tree lines and avenues, hedges, woody strips, trees in group, field coppices and riparian woody vegetation
Grassy features	Grassy strips, field margins, embankments, buffer strips, grassed 'thalweg'
Wet features	Inland channels of fresh water, standing small water bodies such as natural or man-made ponds, ditches.
Stony features	Dry stone walls, terrace elements, rock outcrops, natural or artificial stacks of stone.

While concerning the type of elements in agricultural land that are considered landscape features there is a common understanding, other aspects of the definition, including geometrical delimitations (size ranges) are more controversial and heterogeneous in the policy documents. Size plays an important role since landscape features are perceived as embedded in the agricultural landscape and not a landscape type on its own like a mosaic of forest patches and agricultural parcels. A future common LF typology for Europe shall also provide a harmonized approach to these geometric specifications, which is consistent, operative, and firmly relies on ecological and data availability considerations.

Another specific case is represented by grassy elements, which qualify as landscape features only when included in a matrix of crops (arable and permanent) in the form of field margins, strips and small patches under a certain dimension limit. Bigger grassland parcels should not be included as normally productive and providing different ecosystem services.

In the following chapters we first provide an overview of the various past, present, and future data sources that can be relevant in the context of an EU-level LF monitoring (Chapter 2). This overview will then be complemented with a more detailed analysis of the specific typologies and geometric specifications that each data source comes with (Chapter 3). Finally, the report will be concluded with examples on how the area of LFs can be estimated at the EU level, thus illustrating the inherent challenges, and the influence of the methodological choices (definitions, geometric rules, etc) on the final indicator.

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[18] EU Biodiversity Strategy for 2030 Bringing nature back into our lives. COM/2020/380 final

2 Current and upcoming information sources

Currently there is no single, comprehensive database which could be used to get a consistent overview of LFs at the EU level. Nevertheless, for an optimal governance of LF policies such an overview is absolutely necessary. The first step towards a policy-relevant monitoring system is an overview of the options for the consistent quantification of the area of different types of landscape features at MS level, and possibly at regional level (NUTS2).

In theory, there are two main options for creating a suitable overview at the EU level, both of which come with their own advantages, technical challenges, and limitations:

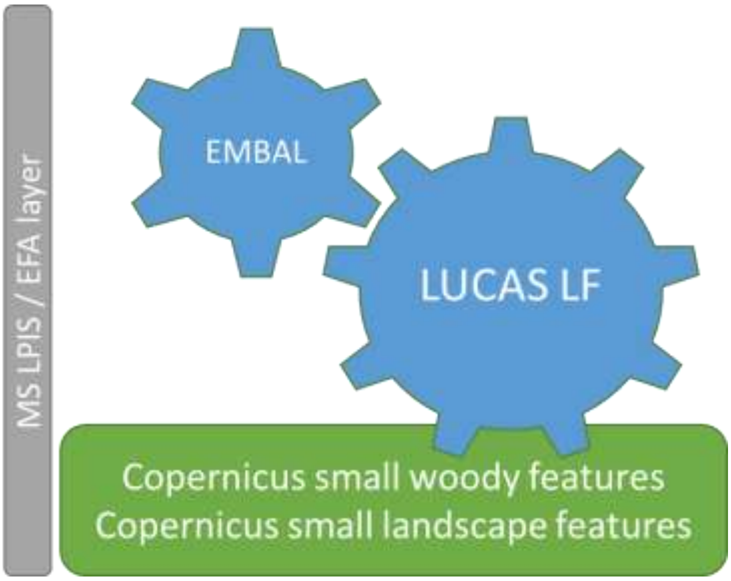
- LFs can be **mapped** on the basis of very high resolution remote sensing data; or
- the area of LFs can be estimated from detailed field observations in an area-frame **statistical survey**.

For an area estimation data from remote sensing and statistical survey can also be combined in the form of a regression estimator, which is often seen as the best choice to get an unbiased area estimation with a reasonable spatial and thematic resolution (Olofsson et al., 2014). On the other hand, considering other characteristics of LFs these options have quite different strengths and weaknesses: while field visits seem to be the only option to get information about the condition (e.g. plant composition) of the LFs, their connectivity can only be explored using wall-to-wall mapping techniques.

In addition to the EU-level data sources, there are several similar data sources at the MS level, which are also created in response to the policy attention to LFs. However, these data sources are extremely fragmented in their thematic focus, their typologies, and the geometric specifications applied. Furthermore, many of these data sources are created in the context of the daily administration of the CAP, or other LF-oriented policies, which means that they should not be used for evaluating the performance of the same policies. This includes administrative and geographical data, based on farmer's declarations, available as EFA layer and linked to GAEC 7 requirements as well as data from the Farm Accountancy Data network (FADN). Nevertheless, it is still useful to have an overview of the data sources available, and the approaches chosen by the MS, so we will also include these data sources in this brief overview below.

The two main data types are currently somewhat covered by the existing Copernicus products (mapping based on remote sensing data), and the LUCAS transect data (statistical survey). But **none of the existing data sources provide yet comprehensive information** on all of the main LF types. To overcome some of the shortcomings and to provide data for the future PMEF there will be a dedicated LUCAS LF module for the surveying campaign 2022. There are also further developments in the frame of the Copernicus program to better capture LFs (methodological improvements of the SWF products and use of eXtremely High Resolution (XHR) satellite data), which are also included in the following stocktaking.

Figure 2. Current and upcoming data sources for landscape feature quantification at European level



2.1 Mapping products based on remote sensing

Agricultural landscape features are, by definition, small and heterogeneous objects, so they are "unobserved" to most of the traditional land cover / land use mapping products, such as the CORINE land cover (CLC) datasets. Mapping project that aims to address all LF types in a reliable way needs to have a very high spatial (sub-meter) resolution[19].

Accordingly, in an EU context the most relevant remote sensing products are the Copernicus High Resolution Layers, which are part of the pan-European component of the Copernicus Land Monitoring Services coordinated by the European Environment Agency (EEA). The Pan-European High Resolution Layers (HRL) aim to provide information on specific land cover characteristics in a way that is complementary to existing mainstream land cover / land use mapping, including CLC datasets.

Here we review such products based on optical remote sensing. Theoretically, other types of remote sensing (e.g. Sentinel 1 SAR, or lidar data – cf Kakoulaki et al, 2021) can also be used, which is a yet unexplored but potentially important option for detecting LF.

In an EU context the most relevant remote sensing products are the Copernicus High Resolution Layers, which are part of the pan-European component of the Copernicus Land Monitoring Services coordinated by the EEA. The Pan-European High Resolution Layers (HRL) aim to provide information on specific land cover characteristics in a way that is complementary to existing mainstream land cover / land use mapping, including CLC datasets.

The HRLs are produced from satellite imagery through a combination of automatic processing and interactive rule-based classification. Since the 2015 reference year, the production is increasingly based on time series of satellite images from a number of different sensors, including the combination of optical and radar data. The main sources are now (since the 2018 reference year) the Sentinel Satellites (in particular Sentinel-2 and Sentinel-1). In addition to high resolution (HR) data, since 2015, also very high resolution (VHR) imagery for some of the products is used. Since 2018, the products have increased in resolution to 10 meters, thus following the source resolution of the Sentinel-2 imagery.[20]

There is currently just one Copernicus HRL product that was specifically developed to address the mapping of landscape features, the **Small Woody Feature (SWF)** layer, which only covers the woody features from the functional typology of LFs (Table 1). However, some other Copernicus products still contain useful information on other landscape feature types, and some new Copernicus products are still in the development phase. With adequate planning and implementation these future products can be a game changer for the EU-level monitoring of LFs.

2.1.1 The Copernicus HRL Small Woody Features (SWF) product

The main purpose of the Copernicus **Small Woody Features (SWF)** HRL product is to provide homogeneous information on small woody features across Europe. The layer was produced first in 2018 (reference year 2015) by EEA, but it is planned as a product with a 3-year repeat cycle and the SWF layer for the reference year 2018 will become available in the course of 2021.

The SWF 2015 vector layer is derived from VHR satellite imagery from a number of optical sensors (Pleiades 1A/B, WorldView-2, WorldView-3, GeoEye-1, Deimos-2 and Spot6/7) for the 2015 reference year (+/- 1 year) using satellite images made available in the ESA Copernicus Data Warehouse (with image resolution ≤ 1m panchromatic, 2 to 4m multi-spectral). The product was created using image classification algorithms (Convolutional Neural Networks) with a series of definitions and classification rules documented in the product specifications.[21]

The SWF layer captures woody linear structures, such as hedgerows, scrubs or tree rows along field boundaries, riparian and roadside vegetation, patches of trees and scrub. The layer does not include other elements such as grassy elements (grass margins), wet elements (ditches, channels, ponds), or artificial landscape elements (roads, stonewalls, etc.), which amounts to a significant fraction of all landscape elements.

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[19] In line with the characteristic size of the objects to be mapped (as discussed later, see e.g. in Table 7) a sub-meter spatial resolution is necessary to detect all LF occurrences reliably. For some LF types that are typically larger in size (e.g. woody LF), mapping products that are based on slightly coarser resolutions (few meters) might still be relevant, because they can capture a significant fraction of the relevant objects.

[20] https://land.copernicus.eu/pan-european/high-resolution-layers

[21] https://land.copernicus.eu/pan-european/high-resolution-layers/small-woody-features/small-woody-features-2015?tab=metadata, https://land.copernicus.eu/user-corner/technical-library/hrl_lot5_d5-1_product-specification-document_i3-4_public-1.pdf, https://land.copernicus.eu/user-corner/technical-library/hrl-small-woody-features-2015-validation-report

Moreover, the SWF layer covers the whole terrestrial area of its pan-European coverage, including many non-agricultural areas (e.g. urban or semi-natural landscapes). “Agricultural SWF” can be extracted from the SWF layer with an appropriate agricultural area mask, which is necessary to target only landscape features within the agricultural context.

Figure 3. Screenshot from the SWF 2015 data viewer, region in northern Germany

Source: https://land.copernicus.eu

2.1.2 Other relevant existing and future Copernicus HRL products under development

While the SWF layer only provides information about the woody LFs, some other Copernicus HRL products may convey additional information about the other feature types. Nevertheless, it is important to keep in mind that these HRL products were not designed with LF mapping in mind so their actual specifications (class definitions, geometric resolution, mapping rules, etc.) may limit their usefulness in identifying LFs in agricultural land.

One relevant Copernicus product is the **Grassland HRL** layer[22]. It displays information on grassland and non-grassland vegetation for the reference years 2015 and 2018 in the resolution of 10m and 100m, whereby the minimum mapping unit is a cluster of 3 pixels. Unfortunately, this geometric resolution is too coarse for most of the grassy landscape features, however the layer can be of interest to assess some of the grassy LFs (the ‘patchy’ ones that are large enough) in the agricultural context.

A third HRL of interest is the **Water & wetness HRL** product[23] displaying water and wetness classes based on 2012-2018 imagery for the reference year 2018 in 10m spatial resolution. Again, the spatial resolution can be considered too coarse for the assessment of smaller linear water elements, whereas it can be a source of information for more patchy water surfaces (minimum mapping unit is 10 X 10 m), provided the concept of agricultural land is taken into account.

Furthermore, the Copernicus Land Monitoring Service is exploring the possibilities to expand the currently mapped objects for instance by mapping also ditches, stone walls, ponds to achieve a more complete coverage of LF types with their mapping products. It is proposed that a limited set of eXtreme High Resolution (XHR) imagery (sub-meter resolution) would be used to train a convolutional neural network, yielding an artificial intelligence classification algorithm, which then can be deployed on the full VHR image coverage.[24] However, a full EU coverage and classification layer based on XHR data still seems to be challenging, and technical issues

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[22] https://land.copernicus.eu/user-corner/technical-library/grassland-2018-user-manual.pdf

[23] https://land.copernicus.eu/user-corner/technical-library/water-wetness-2018-user-manual.pdf

[24] https://enrd.ec.europa.eu/evaluation/publications/rural-evaluation-news-issue-number-17_en, p. 14.

are still to be resolved. While these methodological and technological improvements are foreseen, it would also be necessary to assess the quality and accuracy of these new products independently.

2.2 Statistically representative field surveys

The EU has a major tool to get reliable unbiased area estimates of various land use and land cover types of European policy interest: the LUCAS surveys (Gallego & Delincé, 2010; d'Andrimont et al., 2021). LUCAS, which stands for the Land Use and Coverage Area frame Survey[25], is a harmonized in situ land cover and land use data collection exercise that extends over the whole EU territory based on field observations which are then used for statistical calculations. It is based on a standardized survey methodology in terms of a sampling plan, classifications, data collection processes and statistical estimators that are used to obtain harmonized and unbiased area estimates for land use and land cover. A panel approach ensures that a certain percentage of the points are surveyed in successive LUCAS campaigns. To avoid bias due to inaccessible points (e.g., in the mountains, far from road network, etc…), a complementary sample is photo-interpreted in the office. The sample design is taken into account for the computation of the final estimates by calculating appropriate weights for each surveyed point.

LUCAS was launched by Eurostat in 2006 in response to the increased need for reliable area estimations, and it has been carried out every 3 years ever since. The latest published LUCAS survey dates from 2018. It provides observations at more than 330 000 points surveyed in the EU Member States. The next LUCAS core survey is planned for 2022. Throughout the years the surveys were extended to cover several policy areas of EU interest in a modular design. From the perspective of LF assessments the two most relevant modules are the discontinued LUCAS transect module, and the planned new LUCAS LF module.

2.2.1 The LUCAS transect module

The LUCAS transect module was implemented in the campaigns of 2009, 2012, and 2015, and it is thus perhaps the most **important source of data on landscape features** in this period. This module was performed in a **transect sampling**, characterized by a walk departing from the main LUCAS sampling point. The exercise was, however, excluded from LUCAS 2018 campaign and will also not be continued in the forthcoming mapping campaigns.

In the transect module, the surveyors were expected to "walk a transect" of 200m departing from the main sampling point, and record all land cover/use types that were "crossed" during this walk. Luckily, the rules to walk the transect and to collect data have remained the same for the three campaigns. In this sampling, 'linear features' (such as walls, hedges, roads, railways, or irrigation channels, etc.) were recognized, which is a slightly broader category than landscape features, also including several artificial constructions. Linear features had to be wider than 1 m (with some exceptions including walls, ditches, electric lines and other aerial cables and fences) but not exceeding 3 m, and at least 20 m long. A linear feature wider than 3 m was classified as a 'normal' land cover category with the corresponding land cover code (exceptions were made for tracks, roads and railways). The linear features must also have been continuous except for negligible gaps (for example a hedge with a small interruption). There were special rules for the case if the surveyor crossed a feature in a gap (if this gap was larger than 20 m, then the feature was not classified as linear). The multiple characteristics of linear feature collected in the LUCAS transects module are best documented in the "Instruction to the surveyors".[26]

2.2.2 LUCAS LF module

The next LUCAS survey is planned for 2022 and for the first time will be complemented by a Landscape Feature module to retrieve landscape features information that are located in agricultural land through complementing the existing LUCAS core module point survey (given that the LUCAS transect module will not be carried-out in the LUCAS 2022). The total LUCAS core sample to be visited in the field will comprise approximately 150,000 sampling units (LUCAS points).

The LUCAS LF module is a point survey nested into the main LUCAS survey, which aims to get a consistent, homogeneous, and statistically representative quantification of the area of all functional LF types at the EU and MS levels. To achieve this, the LUCAS Landscape Features (LF) module will be made of a sub-sample

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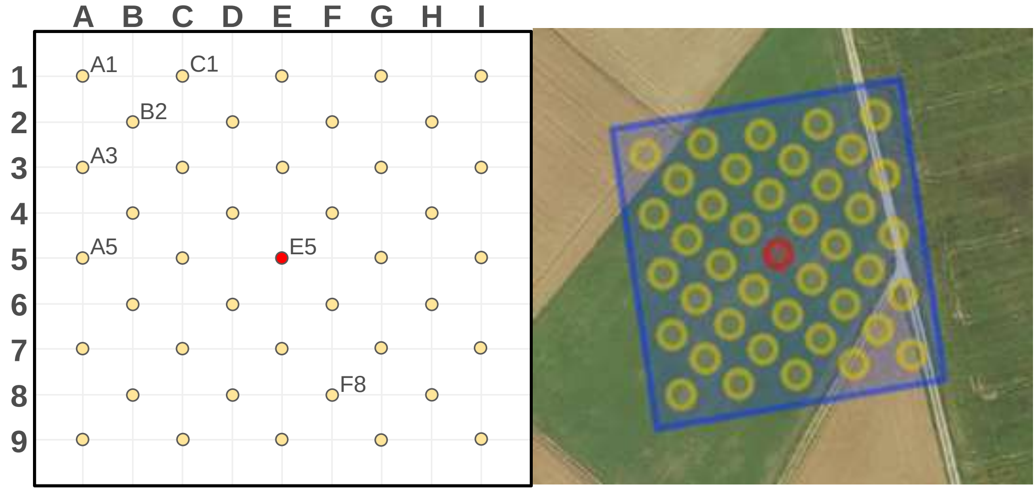
[25] https://ec.europa.eu/eurostat/web/lucas

[26] https://ec.europa.eu/eurostat/documents/205002/6786255/LUCAS2015-C1-Instructions-20150227.pdf

(93,000 sampling units) of the LUCAS core sample selected for in-situ visit, all of which will be within a predominantly agricultural landscape.

Figure 4. The layout of the 41 subpoints in a 100×100 m quadrat of the LUCAS LF module (left), and an example quadrat with the sub-points overlaid on an aerial orthophoto centred on a LUCAS point (right). The central subpoint (E5, in red) corresponds to the main LUCAS point.



Source: LUCAS 2022 C1 Instructions document (yet unpublished)

As LF cover a relatively low fraction of the agricultural landscapes, the LUCAS LF module employs a second level of sampling points to “catch” them. Accordingly, each sampling unit will consist of a regular grid of 41 sub-points, placed in a 100×100 m quadrat around the original LUCAS sampling point (Fig. 4). Each of these subpoints will be classified either as “not LF” or one of 7 simple LF types (see Section 3.3). It will also be possible to register two LF types in case of overlapping landscape features (e.g., a tree over a ditch).

The evaluation of the sub-points is carried-out in 2 phases:

- Phase 1 is an office-based photo-interpretation where the sub points are evaluated on very high resolution (≈20 cm) ortho-photos for the presence of LFs;
- Phase 2 is the LUCAS field-survey of the same sampling units, where the LFs identified during Phase 1 will have to be confirmed or corrected in-situ.

2.2.3 European Monitoring of Biodiversity in Agricultural Landscape (EMBAL)

EMBAL is in preparation through DG Environment since 2018 in order to develop a sound methodology to assess (i) agricultural landscape structure, and (ii) the state of farmland biodiversity.[27] Landscape features (which are called “**landscape elements**” in the EMBAL parlance) are one of the main focusses of the EMBAL survey.

Currently a pilot study is conducted to prepare the ground for a potential wider application of the methodology, which is planned to start in 2022-23. The result of this work — robust methodology and tools for biodiversity data collection — will support better evaluation of the impacts of EU policies on biodiversity and their contribution towards halting its loss.[28]

Similarly to the LUCAS LF module, EMBAL is also planned to be performed on a systematic subsample of the LUCAS sampling sites. For each site 500×500 m quadrats (plots) are selected, which need to contain at least 10% agricultural land (ensured by an overlay with CLC). The main mapping approach consists of three spatial levels of sampling units:

- *Plots*: The first level of recording units are the 500×500 m plots (25 ha) with the LUCAS point in the middle.
- *Parcels* and *landscape elements*: Each plot will be digitally mapped based on orthophotos before the fieldwork, delineating patches of parcels and landscape elements and assigning them to one of the types. Then the fieldwork focusses on the agricultural parcels and the landscape elements: each of these need to

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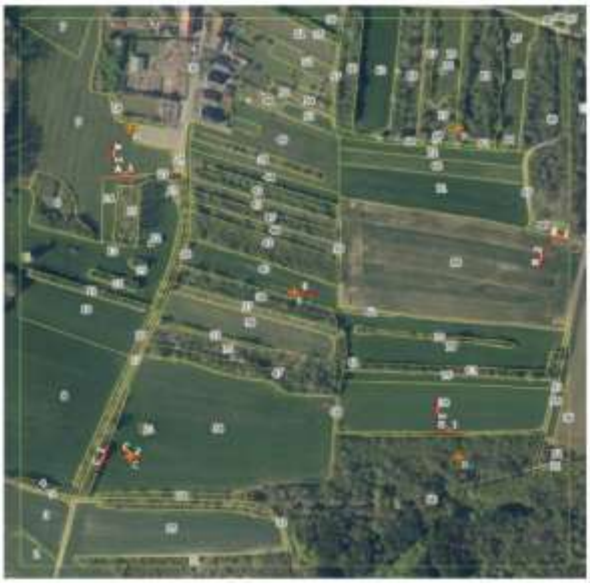
[27] https://ec.europa.eu/environment/nature/knowledge/pdf/embal_report.pdf

[28] https://ted.europa.eu/udl?uri=TED:NOTICE:585414-2019:TEXT:EN:HTML

be verified, and described by recording a basic set of parameters, including an overall score of their ecological condition (“nature value”).

- *Vegetation transects*: In addition, each plot also contains up to 9 vegetation transects, which are only observed in either grassland or cropland, adapting methodology from the LUCAS Grassland module. (As these transects avoid the Landscape elements, they are less relevant in the context of LFs but complementary to LUCAS for information on herbaceous species).

Figure 5. Example plot with parcels/landscape elements, location of 5 transect identification points (A-E) and related transects. A_1 – D_1: field border transects; A_2 – D_2: inner field transects; E: from E-point (EMBAL centre) 20m straight to the east (only in grassland, comparable with LUCAS grassland survey)



Source: 2nd EMBAL workshop, 06.05.2021.

Currently the EMBAL survey is the only EU-level harmonized data collection initiative that will be able to collect information about the quality (condition) of the landscape features. In general, EMBAL data will offer a high potential to provide qualitative information on biodiversity merging information for both herbaceous and landscape feature elements as well as Europe-wide ground truth data for remote sensing products, such as Copernicus High Resolution Layers (HRL) and the future LUCAS LF module.

2.3 CAP administrative and geographic data

Resulting from the CAP obligations there are currently two potential information sources at MS level: GAEC and EFA-related information. Member States have a high degree of freedom in implementing the CAP instruments and their related administrative and control mechanisms, which results in a diversity of approaches in collecting and processing data about LFs. While this info cannot be directly used for monitoring purposes at the EU-level, it can still be very useful for case studies, and methodological developments, and in principle, it is a good idea to maintain as much synergy between EU-level and national approaches (typologies, geometric limits, etc) as possible. To ensure the synergy between EU and MS level information, it is also very important that information on the CAP context (e.g. indicator I.21) and implementation (output and result indicators, see chapter 1.1.1) should be expressed in a harmonised way. More details about national approaches, datasets and the challenges identified by the MS will be available in a next JRC report.

2.3.1 GAEC related information (period 2014-2020)

The most general obligation related to the retention of LF in agricultural land was established in GAEC 7, which also defined a non-exhaustive list of landscape features to be retained (*hedges, ponds, ditches, trees in line, in group or isolated, field margins and terraces;* Regulation (EU) No 1306/2013, Annex II).[29] Nevertheless, **it was**

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[29] Buffer strips, which are often also considered as a relevant type of LF are established under GAEC 1 in the same regulation (1306/2013)

left to the Member States to define which landscape features shall be considered as part of the requirement. This way Member States could focus their efforts only on the landscape features that they considered to be at risk of being removed.

In order to check that landscape features protected under GAEC 7 are not removed, some Member States started developing a Land Parcel Identification System (LPIS) geographic layer with the landscape features to be retained. This digital layer was not compulsory, as other means such as a past reference aerial photographs could also be used to compare the actual situation at the moment of the check with the past whether LF's had been removed.

As a conclusion, the creation of a landscape features layer in the LPIS for GAEC 7 was not an obligation. Some Member States created it in their LPIS, but:

- Landscape features in GAEC are only a subset of all existing landscape features, only those retained specifically by each MS are subject to mapping.
- The MS could use their own specifications (definition, geometric limit, etc…) to identify and register the selected LF types. Furthermore, not all elements represented in the selected LF types had to be retained (i.e., a Member State can have defined "single trees" as a landscape feature type protected under GAEC but with only the trees that fit certain characteristics being forbidden to be removed, such as monumental trees)
- Landscape features in GAEC could be registered in the LPIS in multiple ways: as a geographical object (as point, line, or polygon), as well as alphanumeric attribute associated to a reference parcel.

2.3.2 Ecological Focus Area layer

Within the Greening scheme of the current CAP programming period, landscape features could also be used as Ecological Focus Area (EFA). The regulation established that for holdings with more than 15 hectares of arable land, EFA should cover at least 5% of the farm arable land. Commission Delegated Regulation (EU) No 639/2014 prescribed the LF types to be used for EFAs (hedges, wooded strips, trees in line, isolated trees, field copses, ponds, ditches, traditional stones walls, buffer strips, field margin and other features protected under GAEC7, SMR2 and SMR3).

To facilitate the implementation and control of the EFAs, **MS were requested to create a specific EFA layer within their LPIS** in Article 5(2)(c) of the Delegated regulation No 640/2014. Since the EFA layer is a reference layer to perform administrative cross-checks, all potential types of EFAs which are to be considered as stable in time were expected to be included in it. However, an evaluation of the Greening measures implementation indicates that: a) MSs were timorous in selecting landscape features in the possible EFAs types to be activated by farmers (green cover, catch crops, fallow were the preferred options); and b) in the creation of the EFA layers Member States had the obligation to include as a minimum only the EFAs that were declared by the beneficiaries (farmers' choice went similarly more for cover crops and fallow than for hedges rows). Indeed, the uptake of landscape features as EFAs has been very low – less than 2% of the total EFA area at EU level (with relevant differences at MS level).[30] Consequently, landscape features available in the EFA layer are only a limited subset of all existing landscape features.

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[30] https://www.eca.europa.eu/Lists/ECADocuments/SR17_21/SR_GREENING_EN.pdf

3 Landscape feature typologies and their geometric specifications

Types and definitions are critically important elements in an EU-level harmonized assessment of LFs. In this chapter we focus on the details of the various approaches taken by the key EU-level data sources in this respect. We also use the simple 'functional typology' presented in Table 1 to create a 'common denominator' across the approaches. This information enables a meaningful comparison between the different sources, which can help to best tailor future LF survey / data collection initiatives to be aligned with data from the past, thus also allowing to derive information of possible changes. We conclude the chapter with a summary of the key differences and commonalities between the approaches, and a proposal for a simple set of four functional LF types as a meaningful 'common denominator' of the various approaches.

3.1 COPERNICUS SWF

As its name suggests, the Copernicus SWF product exclusively focuses on woody features. It distinguishes **linear** (such as hedgerows, shrubs or tree rows along field boundaries, riparian, and roadside woody vegetation) and **patchy woody features** (Table 2). Small woody features are essentially defined as the union of these two 'subtypes'.

Table 2. The geometric specifications of the subtypes recognized by the Copernicus HRL 2015 SWF product linked to the functional LF classes (FLF, Table 1)

	Width	Length	Compactness	Area	Link to Functional LF*
Linear SWF	≤ 30 m	≥ 50 m**	≤ 0.75***		Woody
Patchy SWF	≥ 10 m		> 0.75***	200 m² ≤ area ≤ 5000 m²	Woody
Additional woody features (AWF)				1500 m² ≤ area (≤ 50,000 m²)	Woody****

* Only based on the dominant vegetation / land cover of the features, geometric specifications are not taken into account.

** this value has been revised to 30m in the 2018 SWF product

*** this value has been revised to 0.785 in the 2018 SWF product

**** AWF are typically too large to be meaningfully considered as a landscape feature.

source: https://land.copernicus.eu/user-corner/technical-library/hrl_lot5_d5-1_product-specification-document_i3-4_public-1.pdf, materials presented at an AGRI-EEA-JRC workshop, 21.06.2021.

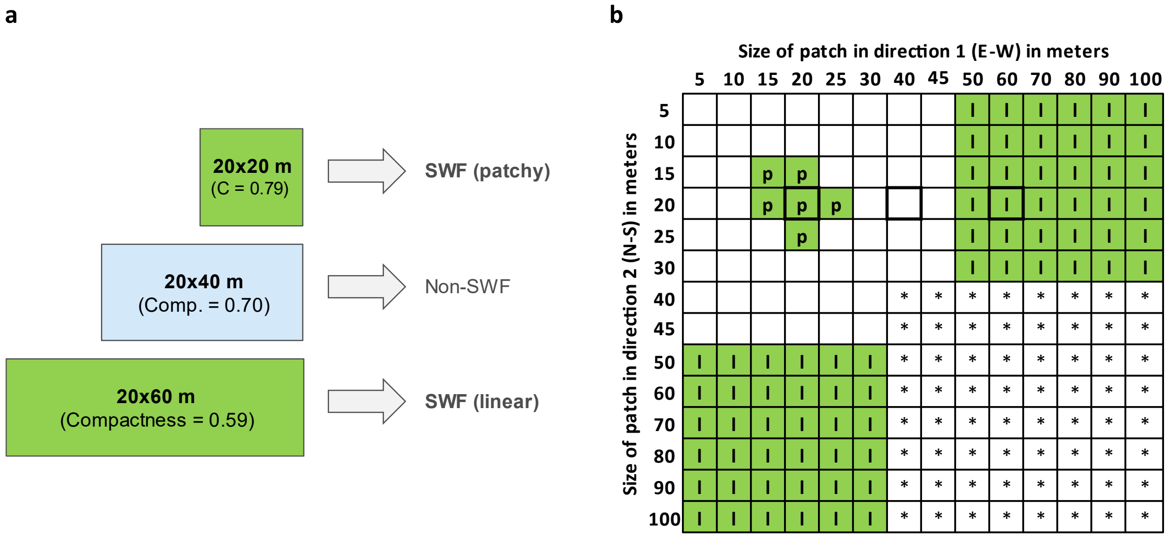
The application of the geometric specifications (Table 2) is associated with additional mapping rules, such as:

- Linear structures may contain feature parts wider than 30 m if connecting 2 features of less than 30 m width, each longer than 50m, over a distance of less than 50 m – otherwise this would result in rather artificial cuts in linear structures;
- Patchy structures may have a width of less than 30 m over a distance below 50 m. A cut is not applied in order to keep the overall, natural characteristic of the identified patch.
- Trees are considered as green linear structure when the gaps between the trees are smaller than 5m. Linear and patchy features within open forest are excluded from the SWF product.

The production workflow applies different strategies to exclude various 'non-target' woody objects from the final product: while permanent crops (e.g., orchards, vineyards) are in theory excluded by the classification algorithms, the exclusion of forest is carried out by masking with a forest layer based on the Tree Cover Density Copernicus product. but the final product still contains elements which are clearly out of scope from the perspective of agricultural LF (e.g., pieces of forests,). Due to the scale-dependence of the compactness index applied the distinction between patchy and linear elements is also somewhat arbitrary, and a significant fraction of real-life woody features does not meet the specifications for either SWF subtypes. This creates an 'inconsistency' in the product: for example while a woody patch of 20×20 m is considered an SWF (a 'patchy' one) just like a similar one of 20×60 m ('linear'), a third one in between (of 20×40 m) would just be filtered out by the specifications (Figure 6), because it is too short to be linear and too 'incompact' for the patchy class. This kind of inconsistency is difficult to justify from an ecological or an agricultural policy perspective.[31]

During production it became obvious that the geometric specifications were too restrictive, so an additional class of features was implemented (called AWF Additional Woody Features in the 2015 product). **Additional woody features** (AWF) were defined as "*woody features that are neither linear nor patchy SWF, but which are connected to linear or patchy SWF and isolated woody features that are not linear nor patchy SWF, but which present an area above 1500 m^2*" and below 5 ha including "*linear features wider than 30 m, and out-of-specifications patches*"[32]. The purpose of this AWF class was to re-inject meaningful features detected by pre-classification and removed by post-processing due to the applications of SWF geometric rules. However, AWFs, as defined in the HRL SWF 2015 specifications, do not seem to be able to completely resolve the geometric inconsistencies of the SWF product (Figure 6). Most importantly, they either need to be connected to existing SWFs, or they are restricted to be quite large (above 1500 m^2), so they still do not contain the small features that are neither patchy nor linear. On the other hand, the AWF layer of the 2015 SWF product includes several 'almost forest' objects, left out by the relatively restrictive thresholds used in the forest mask. Based on the lessons from the 2015 product, the approach (including the geometric rules, the forest mask) are changed for the 2018 production, which integrates additional woody features as an integral part of the product. The SWF 2018 product will also directly expose the tree cover mask to the end users, which makes it possible to apply any set of geometric rules, therefore allowing users to apply their own LF specifications.

Figure 6. Geometric inconsistencies of the Copernicus HRL 2015 SWF product specifications illustrated with type assignments rectangular woody patches of various sizes. a: three hypothetical wooded patches inconsistently classified as SWF and non-SWF; b: a table showing the assignments outcomes for further of 'simulated' rectangular woody patches (l: the patch is considered a linear SWF, p: a 'patchy' SWF; *: a possible AWF; <blank>: the patch is discarded according to the specifications; the three cases illustrated in the left part of this figure are highlighted with thicker cell borders).



Size of patch in direction 1 (E-W) in meters

Size of patch in direction 2 (N-S) in meters

	5	10	15	20	25	30	40	45	50	60	70	80	90	100
5									l	l	l	l	l	l
10									l	l	l	l	l	l
15			p	p					l	l	l	l	l	l
20			p	p	p				l	l	l	l	l	l
25				p					l	l	l	l	l	l
30									l	l	l	l	l	l
40							*	*	*	*	*	*	*	*
45							*	*	*	*	*	*	*	*
50	l	l	l	l	l	l	*	*	*	*	*	*	*	*
60	l	l	l	l	l	l	*	*	*	*	*	*	*	*
70	l	l	l	l	l	l	*	*	*	*	*	*	*	*
80	l	l	l	l	l	l	*	*	*	*	*	*	*	*
90	l	l	l	l	l	l	*	*	*	*	*	*	*	*
100	l	l	l	l	l	l	*	*	*	*	*	*	*	*

3.2 LUCAS transect data

The LUCAS transect module placed the emphasis on '**linear features'**, which were recognized and recorded as the surveyor crossed them during their transect walk of 200 m. The definition of linear features also includes several artificial objects (e.g. fences, power lines) in addition to the 'linear' versions of the landscape features in the focus of this report. Table 3 documents the classes and codes used by surveyors to identify linear features along the transect walked during LUCAS survey 2015 that are relevant LFs or are closely linked to it. The land

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[31] While the HRL 2018 SWF will still be affected with this issue, it will also include a raw tree cover mask to which any geometric rules can be applied post hoc, thus offering a way to eliminate this inconsistency, and making it possible to emulate the LUCAS / EMBAL geometric specifications for the quantification of agricultural LF.

[32] https://land.copernicus.eu/user-corner/technical-library/hrl_lot5_d5-1_product-specification-document_i3-4_public-1.pdf

cover types crossed during the transect walk were only recorded as a sequence of codes, and no other parameters (e.g., their width, or the length of the 'walk' within them) were noted. To distinguish the linear features, from their 'regular' (patchy) counterparts the following geometric rules were applied:

- Linear features were taken into account if they were wider than 1 m and at least 20 m long (with the exception of stone walls (21), ditches (31), and several artificial feature types (e.g., power lines), which were always coded, even when they were < 1 m wide).
- In case a feature width was larger than 3 m, it should not be classified as linear any more, but were to be coded with the respective 'regular' LUCAS land cover code.

This simple data structure nevertheless still makes it possible to estimate the area of the linear landscape features, which will be demonstrated in Chapter 4.

Table 3. Names and definitions of the most relevant linear feature types distinguished in the LUCAS transect module (2009-2015), cross-walked to the functional LF classes (FLF, Table 1). Features in bold have been used for the quantification exercise (see Chapter 4.1)

Code & name	**Definition / instructions (if provided)**	**Link to FLF***
01 Grass margins	Strip of mainly uncultivated (not agriculturally used) vegetation, dominated by grasses, grass-like plants or herbs. Often located at the edge of fields, between cropped areas (beetle banks) or bordering roads and tracks (roadside verge) as well as associated with water courses.	Grassy
02 Heath/Shrub, tall herb fringes		Woody
10 Singles bushes/trees		Woody
11 Avenue trees or other lines of trees	Refers to one line of trees, not clustered trees. Two lines of trees (avenue trees) are normally separated by a road	Woody
12 Conifer hedges		Woody
13 Managed bush or tree hedges or coppices	They should be visibly managed (e.g. pollarded). Generally they are < 5 m height	Woody
14 Not managed bush or tree hedges	They can have single trees or shrubs, deriving from abandonment. Shrub or wood margins are found as field boundaries within agricultural land or alongside roads or water courses.	Woody
15 Grove/Woodland margins (if no hedgerow)		Woody
21 Dry stone walls	Also includes stone heaps which were collected by the farmer on the field even though not in a linear form.	Stony
31 Ditches and channels	Artificial drainage or irrigation line, usually straight, temporarily or permanently wet. Ditches are frequently found in agricultural land for lower the water table or drainage. They are often associated with roadside verges used to drain the runoff from the associated road. Ditches are to be recorded independently from their width and inside artificial areas (A). Edges or banks along the small water body are to be recorded separately as grass, shrub or wood margin.	Wet
32 Rivers and streams	A linear body of water, often flowing in its naturally shaped bed through the land into a body of water such another stream, a lake or the ocean. Banks or edges (riverside vegetation) have to be recorded separately as grass, shrub or wood margin. Rivers and streams are collected even if within artificial areas	Wet
41 Ponds and wetlands		Wet
51 Rock outcrops with some natural vegetation		Stony

* Only based on the dominant vegetation / land cover of the features, geometric specifications are not taken into account

Source: Eurostat, 2015ab

3.3 LUCAS LF module

The new LUCAS LF module defines landscape features as "*elements of natural or semi-natural vegetation present in an agricultural context which provide ecosystem services and support for biodiversity*". This functional definition implicitly includes all elements which are lying

- within an agricultural field (i.e., typically within arable land, grassland or permanent crops);
- between agricultural fields;
- between an agricultural field and linear infrastructure (farm track, road, or railway);
- between an agricultural land and detached buildings (individual farmyards; agricultural buildings); and
- between an agricultural field and water bodies (rivers, lakes, reservoirs…).

On the other hand, this definition excludes all features that are not in an agricultural context, or which are above the size limits (which are generally set at a maximum width of 20 m or a maximum size of 0.5 ha, interpreted flexibly by the surveyors). Similarly, it also excludes objects which do not have an "added value" in terms of ecosystem services (e.g. a row of shrubs next to a forest), which is clarified through examples.

The quantity of LFs in agricultural land is estimated using a set of 41 'sub-points'. Seven LF types will be distinguished (Table 4), and the presence & type of the LFs will only be determined in the sub-points, based on a series of decisions:

- does the sub-point fall in an 'agricultural context' (see above);
- if yes, does it fall on a landscape feature (a non-productive element);
- and if yes, what is the type of the vegetation (or physical surface) at the location of the sub-point?

This approach is adapted to a swift point survey, i.e. there is no need to determine a single LF type for a "polygon" with heterogeneous land cover, if it the whole polygon meets the LF definition anyway. It also ensures that "no one is left behind" i.e., all elements that are small, semi-natural, and are embedded in an agricultural context will end up in one of the classes (if there is a sub-point falling on them). Each sub-point can contain up to two landscape feature types (e.g., a hedgerow above a stone wall), with 'LUCAS-style' rules restricting the list of eligible combinations to the most meaningful & plausible cases.

Table 4. Names and definitions of the landscape feature types distinguished in the LUCAS LF module (2022-), cross-walked to the functional LF classes (FLF, **Table 1**)

Code & name	**Definition / instructions**	**Link to FLF**
W: Woody vegetation LF	This type includes isolated trees, trees in line, hedgerows, riparian woody vegetation (along water course), or any narrow strips (<20 m) of land covered by trees and shrubs within an agricultural context. This type can also include small groups of trees, field copses, or any small groups of woody semi-natural vegetation in an agricultural context. In case there is a grass (herb) layer under the woody vegetation, the woody feature is considered to incorporate the underlying grass layer too. (…) The maximum area for a woody LF is 0.5 ha.	Woody
G: Permanent grass / herbaceous LF	This type consists of permanent semi-natural herbaceous vegetation (typically grass and/or perennial herbs) which are in the agricultural context, and which are not directly used for grazing, or fodder production (…). This may include field margins, buffer strips (along ditches or ponds), or any other small pieces of semi-natural herbaceous vegetation (…) as long as they are between arable or permanent crops fields. The minimum width of this type is 1m (for ensuring persistency). Nevertheless, this type of LF excludes parcels of actively managed grasslands (used for grazing or fodder production), and large patches of (semi-)natural grasslands (wider than 20 m). Furthermore, farm tracks with grass, and grass strips between the rows of vineyards/orchards are also excluded from the LUCAS LF module scope, and "grassy margins" that are next to grassland patches should NOT be registered, either. Permanent grass/herbs landscape features do not include the grass layer under a woody feature, nor wet marsh vegetation (which are registered either with code D or P).	Grassy
T: Temporary herbaceous LF	This type consists of narrow strips of cropland planted with non-productive crops or flower-rich fallow (weed) vegetation inside arable land or permanent crops (typically along field margins), deliberately sown by the farmers to support biodiversity (…). The maximum width of this subtype is 20 m, and wider strips of flowers or fallows should not be considered in the LUCAS LF module. The minimum width of this feature type is 1m. Exclusions: Weedy spots resulting from the failure of arable crops. If a grassland strip shows the characteristics of both a temporary (T) and a permanent (G) grassland strip, then G should be chosen.	--*
D: Ditches and streams	This type includes small water courses (G20) within an agricultural context, including the open water surface of streams, ditches, and small channels and the adjacent marsh vegetation (…) up to a maximum width of 20 m. Ditches that are dry at the moment of observation can also be registered as D if the vegetation reveals a regular presence of water. Exclusions: Artificial constructions (channels with walls of concrete and subterranean constructions) are excluded. If a sub-point falls on edges or banks along small water bodies, it shall be recorded separately as e.g. grass (G), or woody LF (W) (according to their nature), if they satisfy the relevant criteria.	Wet
P: Small ponds and small wetlands	This type includes small patchy landscape features characterized by wetlands (…) and water bodies (G10) in an agricultural context up to a maximum size of 0.5 ha. The type also includes accumulations of still water formed naturally (e.g. wetlands, lakes, natural lagoons, seepage areas) or artificially (e.g. pits and waterholes). Small ponds can contain a core of open water and an adjacent wetland, characterized by marsh vegetation (e.g. reed or sedge beds) adapted to and dependent on the regular presence of surface water and high water levels. Exclusions: reservoirs lined with concrete or plastic and depressions used as landfills. If a sub-point falls on edges or banks along small ponds, it shall be recorded separately as grass (G), or woody LF (W) (according to their nature), if it satisfies the relevant criteria.	Wet
S: Stone walls, cairns, and terraces	This type includes piles of rock or stone (…) in an agricultural context, and terraced agricultural landscapes. Such features may be natural (e.g. secular stones) or man-made, often historical, objects (e.g. dry stone walls, clearance cairns, terraces). Terraced hillsides are anthropogenic structures created to reduce the risk of erosion, consisting of one or more "steps" (steep sections covered permanent woody or grassy vegetation or stone walls) and "land blocks" (flat sections that are used for agricultural production, separated by the steps). If trees and shrubs (liana) cover the stone walls, both features shall be registered. Herbaceous vegetation, on the other hand, is considered to be an integral part of S. If a sub-point falls on the flat part (land block) of a terraced hillside, it shall still be recorded as S.	Stony
C: Cultural features	Cultural features are local elements of cultural heritage that provide ecosystem services. This type includes historical mounds (round or elongated masses of earth protruding above a flat agricultural landscape, typically of (pre)historic origin and covered in semi-natural vegetation: e.g. burial mounds, prehistoric tells, Cumanian mounds, and historical earth banks). Historic mounds are covered either by permanent grass (G) or scrub/trees (W), which shall be registered as the primary LF, and the LF code C should thus only be used as secondary LF type.	--**

* Temporary herbaceous features (T) are parts of the arable/cultivated parcels, thus they do not follow the general LF definition. However, as they have a high policy relevance (possibly financed by the CAP and managed by farmers), and they are relatively easy to survey, the decision was taken to include them (cf. the EMBAL type eE71).

** Cultural features (C) do not follow the general functional logic of the LF definition, nevertheless they are important for the MS and often included in GAEC 7 protected features, so the decision was taken to register the presence of the most 'field-recognizable' cultural features as a secondary LF type (along with the ecologically functional LF type as the primary type).

Source: LUCAS 2022 C1 Instructions document (yet unpublished)

3.4 EMBAL

Landscape elements are a key focal areas for EMBAL, so the survey methodology distinguishes a high number of types, including several types of (seminatural) landscape features, as well as artificial constructions that are related to agricultural land use or frequently occurring in agricultural landscapes (Table 5). The EMBAL typology is still in a development phase, so further changes are still possible. The type definitions also include a scale for assessing the "nature value" (quality, condition) of the landscape elements, which is also estimated by the surveyors.

Table 5. Names and definitions of the landscape element types distinguished in the EMBAL programme (2022-), cross-walked to the functional LF classes (FLF, **Table 1**)

Category	Code	Specification	Extent	Link to FLF
Woody elements	**eE11**	Isolated trees with a crown radius of minimum 3 meters or a height of minimum 4 m or small groups of trees. If the tree canopy cover makes up >5% of the surrounding parcel area, this code can be used as LC2. If ≥4 trees are in an obvious line, see eE12.	≥4 m height or ≥3 m radius	Woody
	eE12	Tree lines and avenues. Trees with minimum height of 4 m in a line of at least 4 trees, space between trees maximum 20 m (if not see eE11). This code can only be used as LC2.	≥4 trees	Woody
	eE13	Hedges, woody strips, field coppices and riverine scrub (including trees and bushes). If the woody canopy covers a distinct area of ≤ 0.50 ha with >70%, eE13 should be entered as LC1. If the woody canopy is scattered on a parcel covering > 5 %, eE13 should be entered as LC2, with the appropriate ground cover land use as LC1. If the woody canopy covers a distinct area of >0.50 ha with >70% and there are no signs of agricultural use, the parcel should be coded as non-agricultural (LC1 = eN10). In extraordinary cases of very long hedges covering an area of > 0.50 ha (e.g. 500 m length and 15 m width = 0.75 ha) they shall also be mapped as eE13 (applies only for hedges < 20 m width).	> 25 m^2 ≤ 0.5 ha	Woody
Grass-herb elements	**eE21**	Grassy strips, including field margins, embankments and buffer strips around linear elements such as watercourses or hedges. Width of strips is 1 to 20 m. Wider areas should be classified as eC (e.g. eC31). Grassy strips >1 m wide along tracks and roads do not belong to the road but should be mapped separately under this code. Trees and bushes up to 70% coverage are allowed (>70% see eE13). Strips <1 m in width are integrated into the adjacent parcel. Areas >20 m wide see eC codes.	1-20 m	Grassy
	eE22	Small grassy patches with permanent grass-herb cover, wider than 20 m, smaller than 0.5 ha in size and without regular recent agricultural use (with recent agricultural use this would be eC31). If >0.5 ha then eN20	25 m^2 ≤0.5 ha	Grassy
Water elements and reed or sedge beds*	**eE31**	Rivers and streams, including their riverbanks (define the vegetation in LC2), up to 20 m in width. Larger areas of open water see eN30.	1-20 m	Wet
	eE32	Ditches with flowing or standing water, or dry. Ditches are man-made structures for drainage or irrigation, running usually in straight lines.	1-20 m	Wet
	eE33	Standing small water bodies such as natural or man-made ponds or oxbow lakes, including their banks, up to 0.5 ha in area. Larger areas of open water see eN30.	>25m^2 ≤0.5 ha	Wet
	eE34	Reed or sedge beds up to 1 ha in size without regular agricultural use. If >0.5 ha then eN20	>25m^2 ≤0.5 ha	Wet
Stone, rock, raw soil and terrace elements	**eE41**	Terrace elements, dry stone and natural stone walls, at least 1 m wide including the adjacent vegetation. Also brick and cement walls can be included here, but should be assigned a nature value of 1-2. If at a high density of ≥ 1 wall /20 m of slope mixed with other land cover, eE41 should be entered as LC2, with the appropriate ground cover land use as LC1 (or in case of presence of woody structures as LC2 (e.g. vineyards) the small terraces then need to be split into new parcels and coded as eE41.	≥1 m width as LC1 Up to 1 per 20 m, or ≥ 1 /100 m^2 for stones as LC2	Stony
	eE42	Field stone heaps and cairns.		Stony
	eE43	Isolated rock outcrops larger than 1 m diameter. If at a high density of ≥ 1 /100 m^2 mixed with other land cover, eE44 should be entered as LC2, with the appr. ground cover land use as LC1.		Stony
	eE44	Sand, clay and loess escarpments. Not formed through human activities, but e.g. glacier or alluvial processes.		--
	eE45	Raw soil sites (stone, sand, dirt surfaces with little or no veg.) larger than 1 m diameter. If obviously anthropogenic (gravel extraction site, open cast mine, building site) then see eN50.		--
Roads and tracks	**eE51-eE53**	Three categories of artificial features (dirt / grass track, gravel track, paved farm tracks; public roads and highways whose main purpose is not agricultural traffic are excluded)	≥1 m width	--
Man-made structures	**eE61-eE66**	Six categories of artificial features (field barn, machinery/animal shed, woodpiles, solar panels, antenna/electric pylon/wind turbine, other)	≥1 m width	--

* Including banks and riparian vegetation up to 5 m on either side - for linear elements up to a total width of 20 m

Source: EMBAL Survey Manual (version 26.11.2021)

The EMBAL quadrats may also include significant portions of non-agricultural (urban, forest, wetland, etc) areas. Landscape elements which do not form part of the agricultural landscape are partly excluded (e.g. urban green surfaces, private gardens) by the pre-classification methodology and the type definitions.

3.5 GAEC and EFA information

GAEC and EFA list a high number of LF types that can be protected (GAEC) or activated (EFA) by the MS in the programming period 2014-2020. This list includes *hedges, ponds, ditches, trees in line, group of trees, isolated trees, field margins, terraces, traditional stone walls*, and *others*. The types are not defined, and dimension limits are only prescribed for LFs to be declared as EFAs, but for GAEC no dimensional characteristics are established by the legislation. However, a limited number of MS introduced dimensions limits also for LFs in GAECs. A summary of hedges, ponds and ditches characteristics is provided below based on information in the GAEC database and compared with the limits established by the legislation for LF in EFA (Table 6).

Only a very limited number of MSs consider field margins in GAEC. Wallonia and Malta set a minimum width of 1 m, Malta and Slovakia defined a 20 m maximum width. Some MS protected terraces in GAEC, some also defined a minimum height for terraces from 0,5 to 3 m. Portugal defined a minimum height of 12 m. For the traditional stones walls only two MSs defined dimensions (height and width): EE (minimum height 0,3 m, maximum height 1,7 m; minimum width 0,5 m, maximum width 2,8 m), and IT (minimum height 0,3 m, maximum height 5 m; minimum width 0,5 m, maximum width 5 m).

This overview, however, only scratches the surface of the wealth of complex information in the approaches (definitions & geometric specifications) chosen by the MS in their own CAP implementations. More detailed information, including an overview of commonalities and recommendations for meaningful simplifications can be found in recent and upcoming EEA and JRC reports (e.g. Kleeschulte et al. 2021).

Table 6. Different definitions of landscape features (hedges, ponds and ditches) in GAEC and EFA: an analysis on EU countries choices

	Only protected in GAEC – National criteria	**Protected both in GAEC and EFA – National criteria**	**Eligible to be declared as EFA – art. 45 EU 639/2014**
Hedges	Length (=> 25 m)	Length (=> 10 m) minimum area = 0.01 ha	Width <= 10m
	Width <2m, =<20m	Width (>= 15 m, <20m)	
	difficult to see through and pass through	Presence of gaps (< 2m, <5m, “gappy hedgerows” with 20% hedgerows species)	
	Height after cutting >= 0.8 m	Minimum area = 0.01 ha	
Ponds	Dimension max (=< 0.5 ha)	Dimension max (=< 0.1ha, but also 0.2 ha)	Area <= 0.1 ha, strip of riparian vegetation up to 10m wide
	Function: rearing fish	Dimension min (=> 0.01ha)	
		Riparian vegetation included	
	Perimeter definition: operating level	Location: surrounded by arable area	
	Presence of water (continuously surface water or moist ground)	Presence of water (water at least on 25 m2 from 1 Nov to 31 May)	
Ditches	Max width (8m, 6m water mirror?)	Max width (2m,10m,12m)	Width <= 6m, no walls of concrete
	Min width (0.5m from the edge of slope)	Min width (2m at the base, bed width)	
	Min depth average (0.3m)	Catchment area (=<10 km2)	
	Riparian vegetation and slopes included	Riparian vegetation included	
	Adjacent: ditch centreline average >= 5m from arable land block	Function: irrigation and/or drainage	
	Presence of water: dry ditches included	Presence of water: permanently or only following flash flooding	

Source: Angileri, 2015

3.6 Towards a European consensus typology of landscape features

In general, the typologies applied in the information sources studied share several commonalities, however, differences do exist when looking at the detailed specifications. In particular, for the two upcoming EU-level statistical survey programs (LUCAS LF and EMBAL) a harmonisation process has taken place to ensure alignment as much as possible at the EU level. Accordingly, the high-level typologies of these two surveys show the same pattern, following the four 'functional LF classes' presented in Table 1. These functional LF classes can be seen as a prospective 'common denominator' for future European projects working with agricultural landscape features. In Tables 3-6 we linked these functional classes to the datasets studied, and a reverse crosswalk is presented with a proposal for unified geometric delimitations in Table 7.

The geometric criteria used in the various typologies shows less alignment. The administrative datasets (GAEC 7, EFA) show a particular diversity, but the EMBAL and LUCAS LF specifications are more consistent. From an ecological perspective there is little rationale in prescribing different geometric specifications to the various types of woody and grassy features, and most of these harmonised specifications could also be meaningfully applied to the wet and the stony features. In Table 7 we also provide a tentative proposal for a harmonized set of geometric limits for the four functional LF classes introduced in Table 1. This simple and harmonized approach towards geometric limits also creates an opportunity for efficient workflows simplifying the pre-processing and post-processing of the surveys, thus relieving the field surveyors from taking a large amount of (possibly subjective) geometric decisions, and helping them in focussing about the task for which human observers are most indispensable (type identification based on ecological/management characteristics).[33]

Table 7. The proposed functional landscape feature classes with geometric specifications and a tentative crosswalk to the LF types (codes) identified in the major EU-level LF data sources

Functional LF class	Proposed geometric specifications	LUCAS Transect	LUCAS LF	EMBAL
Woody features	width >= 1 m AND (width <= 20 m OR area <= 0.5 ha)	02, 10, 11, 12, 13, 14, 15	W	eE11, eE12, eE13
Grassy features	width >= 1 m AND (width <= 20 m OR area <= 0.5 ha)	01	G	eE21, eE22
Wet features	width >= 1 m AND (width <= 20 m OR area <= 0.5 ha)	31, 32, 41	D, P	eE31, eE32, eE33, eE34
Stony features	(width OR height) >= 1m AND (width <= 20 m OR area <= 0.5 ha)	21, 51	S	eE41, eE42, eE43

In the medium term it is important that the LUCAS LF definition for woody features is in line with the Copernicus SWF products, and indeed both apply the same upper size limit, as we envisage that these will be major information sources for the quantification and comparability needs to be assured. Further geometric rules can be used to extract the corresponding woody features from the 5m resolution 'woody vegetation mask' raster layer of the SWF2018 product that will include all woody features identified without any geometric thresholds. The lower size limits are constrained by the resolution of SWF.

We conclude this summary with four 'infographics' which illustrate the main communalities and differences in the studied data sources. Figures 7–10 give a concise summary of the key messages of Chapters 2 & 3, taking into account the applied typologies as well as the nature of the information generation.

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[33] For example, a harmonized set of simple geometric rules makes it possible to use a simple GIS workflow to create an "agricultural context" mask at the local scale containing <u>all</u> LF that are "eligible" in terms of size and adjacency criteria: (1) start out from a polygon map of the agricultural fields in the study area → (2) add a buffer with the harmonized "max LF width" (e.g. 20 m in Table 7) → (3) subtract the same buffer → (4) fill in the holes that are smaller than the harmonized "max LF area" (e.g. 0.5 ha in Table 7). This "agricultural context" mask can, for example, be very useful in the context of a field survey, where it can substantially speed up the work of the surveyors, and reduce the risk for misaligned subjective decisions at the same time.

Figure 7. EU-wide data sources for woody landscape features within agricultural context

EU wide data sources for woody landscape features within agricultural context

LUCAS LF

Code W - woody landscape features

Isolated trees, trees in line, hedgerows, riparian woody vegetation (along water course), or any narrow strips (<20 m) of land covered by trees and shrubs, small groups of trees, field copses, or any small groups of woody semi-natural vegetation

Minimum width: 1 m
Maximum width: 20 m
Maximum area: 0.5 ha

STATISTICAL FIELD SURVEY
Subset LUCAS Core data set
Agricultural land only
Reference year: 2022
Coverage: EU-27, 93 000 samples

LUCAS TRANSECT

Codes 10, 11, 12, 13, 14, 15

Singles bushes/trees (10), Avenue trees or other lines of trees (11), Conifer hedges (12), Managed bush or tree hedges or coppices (13), Not managed bush or tree hedges (14), Grove/Woodland margins(15)

Minimum width: 1 m
Maximum width: 3 m
Minimum length: 20 m

STATISTICAL FIELD SURVEY
Subset LUCAS Core data set
Can be filtered for agricultural land, but dubious cases
Reference years: 2012, 2015
Coverage: EU-28, ~120 000 samples (transects) fall in agricultural area

EMBAL

Codes eE11, eE12, eE13 - woody elements

Isolated trees >4 m height (eE11), Tree lines and avenues ≥4 trees (eE12), Hedges, woody strips, field coppices and riverine scrub (eE13)

Minimum area: 25 m^2
Maximum area: 0.5 ha

STATISTICAL FIELD SURVEY
Includes an assessment of condition/quality (**nature value** scores)
Subset LUCAS Core data set
Agricultural land only
Reference year: 2022-23
Coverage: EU-27, 3000 samples/year

EFA

Isolated trees, hedges, wooded strips, trees in line, field copses

Maximum width for area to be qualified as EFA (excl. isolated trees): 10 m
Maximum size for area to be qualified as EFA for copses: 0.3 ha
Sketchy geospatial data

GAEC

Hedges, trees in line, in group, or isolated

Only few MS defined dimensional limits.
Sketchy geospatial data

COPERNICUS HRL SWF

two woody classes

Linear structures of trees, hedges, bushes and scrub > 50 m long
Patchy structures of trees, hedges, bushes and scrub, area >= 200 m^2

Minimum width: 3 m
Maximum width: 30 m
Maximum area: 0.5 ha

MAPPING / EARTH OBSERVATION
Can be filtered for agricultural land
Reference years: 2015, 2018 (not yet published)
Coverage: EEA-39, wall to wall mapping

Abbreviations:

- *LUCAS LF: Land use / cover area frame survey, landscape feature module*
- *LUCAS transect: Land use / cover area frame survey, Transect module*
- *EMBAL: European Monitoring of Biodiversity in Agricultural Landscape*
- *COPERNICUS SWF: COPERNICUS Small Woody Feature layer*
- *EFA: Ecological Focus Area*
- *GAEC: Good Agricultural and Environmental Condition*
- *EEA: European Economic Area / EU: European Union*

Sources:

- *LUCAS LF module 2022, instructions for surveyors*
- *LUCAS 2015, Technical reference document C1 Instructions for Surveyors. Eurostat*
- *EMBAL Survey Manual (version 22.09.2021)*
- *High Resolution Layer Small Woody Features 2015, Product Specifications & User Guidelines*
- *JRC-GAEC database*
- *Member States' choices on elements qualifying for Ecological Focus Area (EFA) Ref. Ares(2019)664707*

Figure 8. EU-wide data sources for grassy landscape features within agricultural context

EU wide data sources for grassy landscape features* within agricultural context

LUCAS LF

Code G – permanent grass / herbaceous LF

Permanent semi-natural herbaceous not directly used for grazing, or fodder production. May include field margins, buffer strips (along ditches or ponds), or any other small pieces of semi-natural herbaceous vegetation as long as they are between arable or permanent crops fields.

Minimum width: 1 m
Maximum width: 20 m

STATISTICAL FIELD SURVEY
Subset LUCAS Core data set
Agricultural land only
Reference year: 2022
Coverage: EU-27, 93 000 samples

LUCAS TRANSECT

Codes 01, 02

Grass margins (01): Strip of mainly uncultivated (not agriculturally used) vegetation, dominated by grasses, grass-like plants or herbs. Often located at the edge of fields, between cropped areas (beetle banks) or bordering roads and tracks (roadside verge) as well as associated with water courses. Heath/shrub, tall herb fringes (02)

Minimum width: 1 m
Maximum width: 3 m
Minimum length: 20 m

STATISTICAL FIELD SURVEY
Subset LUCAS Core data set
Can be filtered for agricultural land, but dubious cases
Reference years: 2012, 2015
Coverage: EU-28, ~120 000 samples (transects) fall in agricultural area

EMBAL

Code eE21 – Grassy strips

Grassy strips, including field margins, embankments and buffer strips around linear elements such as watercourses or hedges. Width of strips is 1 to 20 m. Grassy strips >1 m wide along tracks and roads do not belong to the road but should be mapped separately under this code. Trees and bushes up to 70% coverage are allowed. Strips <1 m in width are integrated into the adjacent parcel.

Minimum width: 1 m
Maximum width: 20 m

STATISTICAL FIELD SURVEY
Includes an assessment of condition/quality (**nature value** scores)
Subset LUCAS Core data set
Agricultural land only
Reference year: 2022-23
Coverage: EU-27, 3000 samples/year

EFA

Strips of eligible hectares along forest edges, buffer strips, field margins

Minimum width: 1m (MSs may set it higher)
Maximum width to calculate area to be qualified as EFA: 20 m (10 m for strips of eligible hectares with agricultural production)
Sketchy geospatial data

GAEC

Field margins

Few MS consider field margins in GAEC (e.g. BE-Wa & MT set a minimum width of 1 m, MT & SK defined a maximum width of 20 m)
Sketchy geospatial data

COPERNICUS HRL Grassland

Grassland and derived indicators

natural, semi-natural and managed grasslands, not tailored to linear elements

Minimum width: 10 m
Minimum size: 0.3 ha

MAPPING / EARTH OBSERVATION
Can be filtered for agricultural land
Reference years: 2015, 2018
Coverage: EEA-39, wall to wall mapping

Abbreviation:

- *LUCAS LF: Land use / cover area frame survey, landscape feature module*
- *LUCAS transect: Land use / cover area frame survey, Transect module*
- *EMBAL: European Monitoring of Biodiversity in Agricultural Landscape*
- *COPERNICUS HRL Grassland: COPERNICUS High Resolution Layer Grassland*
- *EFA: Ecological Focus Area*
- *GAEC: Good Agricultural and Environmental Condition*
- *EEA: European Economic Area / EU: European Union*

Sources:

- *LUCAS LF module 2022, instruction for surveyors*
- *LUCAS 2015, Technical reference document C1 Instructions for Surveyors. Eurostat*
- *EMBAL Survey Manual (version 22.09.2021)*
- *High Resolution Layer Grassland layer 2018, User manual*
- *JRC-GAEC database*
- *Member States' choices on elements qualifying for Ecological Focus Area (EFA) Ref. Ares(2019)664707*

*LUCAF LF and EMBAL also assess "**temporary" herbaceous features**, like flower strips, that are sown by the farmers on arable land for biodiversity. Technically these are not LF, but it makes sense to assess them in the context of an LF survey. (Codes: TS (LUCAS LF) & eE71 (EMBAL))

Figure 9. EU-wide data sources for wet landscape features within agricultural context

EU wide data sources for wet landscape features within agricultural context

LUCAS LF

Codes D, P – Ditches, Ponds

Ditches and streams (D): small water courses including the open water surface of streams, ditches, and small channels and the adjacent marsh vegetation. No concrete walls

Small ponds and small wetlands (P): small patchy landscape features characterized by wetlands and water bodies of still water formed naturally or artificially

Maximum width: 5 m
Maximum area: 0.5 ha

STATISTICAL FIELD SURVEY
Subset LUCAS Core data set
Agricultural land only
Reference year: 2022
Coverage: EU-27, 93 000 samples

LUCAS TRANSECT

Codes 31, 32

Ditches and Channels (31) & Rivers and streams (32): Vegetation not included, 31 and 32 can also be recorded in an artificial context

Minimum width: 1 m (except for ditches)
Maximum width: 3 m
Minimum length: 20 m

STATISTICAL FIELD SURVEY
Subset LUCAS Core data set
Can be filtered for agricultural land, but dubious cases
Reference years: 2012, 2015
Coverage: EU-28, ~120 000 samples (transects) fall in agricultural area

EMBAL

Codes eE31, eE32, eE33 – Water elements including adjacent vegetation
Code eE22 – Reed-sedge beds

Inland channels of fresh water (eE31), standing small water bodies (eE32), and ditches (eE33): including banks and riparian vegetation up to 5 m on either side; Reed-sedge beds (eE22): reed or sedge beds without regular agricultural use

Minimum width: 1 m
Maximum width: 20 m
Maximum area: 0.5 ha

STATISTICAL FIELD SURVEY
Includes an assessment of condition/quality (**nature value** scores)
Subset LUCAS Core data set
Agricultural land only
Reference year: 2022-23
Coverage: EU-27, 3000 samples/year

EFA

Ditches (no concrete walls), ponds
Minimum size for ponds may be set by MS
Maximum width to calculate area to be qualified as EFA for ditches: 10 m
Maximum size for area to be qualified as EFA for ponds: 0.3 ha
Sketchy geospatial data

GAEC

Ditches, ponds
Maximum width for ditches: 2 - 12 m
Minimum area for ponds: 25 m^2 - 0,1 ha (1000 m^2)
Maximum area for ponds: 0,1 ha - 0,5 ha
Sketchy geospatial data

COPERNICUS HRL
Water & Wetness

Different classes of water surface and wet surfaces, but the layer does not have sufficient spatial detail

Minimum mapping unit 10 x 10 m.

MAPPING / EARTH OBSERVATION
Can be filtered for agricultural land
Reference years: 2015, 2018
Coverage: EEA-39, wall to wall mapping

Abbreviations:
- *LUCAS LF: Land use / cover area frame survey, landscape feature module*
- *LUCAS transect: Land use / cover area frame survey, Transect module*
- *EMBAL: European Monitoring of Biodiversity in Agricultural Landscape*
- *COPERNICUS HRL: COPERNICUS High Resolution Layer*
- *EFA: Ecological Focus Area*
- *GAEC: Good Agricultural and Environmental Condition*
- *EEA: European Economic Area / EU: European Union*

Sources:
- *LUCAS LF module 2022, instructions for surveyors*
- *LUCAS 2015, Technical reference document C1 Instructions for Surveyors. Eurostat*
- *EMBAL Survey Manual (version 22.09.2021)*
- *High Resolution land cover characteristics, Water & Wetness user manual 2018*
- *JRC-GAEC database*
- *Member States' choices on elements qualifying for Ecological Focus Area (EFA) Ref. Ares(2019)664707*

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Figure 10. EU-wide data sources for stony landscape features within agricultural context

EU wide data sources for stony landscape features within agricultural context

LUCAS LF
Code S - Stone walls, cairns, and terraces

Piles of rock or stone in an agricultural context and terraced agricultural landscapes. Such features may be natural (e.g. secular stones) or man-made, often historical, objects (e.g. dry stone walls, clearance cairns, terraces).

No area requirements

STATISTICAL FIELD SURVEY
Subset LUCAS Core data set
Agricultural land only
Reference year: 2022
Coverage: EU-27, 93 000 samples

LUCAS TRANSECT
Codes 21, 51

Dry stone walls (21): also includes stone heaps which were collected by the farmer on the field even though not in a linear form; Rock outcrops with some natural vegetation (51)

Minimum width: 1 m (except for stone walls)
Maximum width: 3 m
Minimum length: 20 m

STATISTICAL FIELD SURVEY
Subset LUCAS Core data set
Can be filtered for agricultural land, but dubious cases
Reference years: 2012, 2015
Coverage: EU-28, ~120 000 samples (transects) fall in agricultural area

EMBAL
Codes eE41, eE42, eE44 - Stone, rock, and terrace elements

Dry stone and natural stone walls or terraces (eE41): stone surface + adjacent vegetation; field stone heaps & cairns (eE42); Isolated rock outcrops (eE44)

Minimum width: 1 m (eE41 can be narrower if at least 1m high)
Maximum width: 20 m

STATISTICAL FIELD SURVEY
Includes an assessment of condition/quality (**nature value** scores)
Subset LUCAS Core data set
Agricultural land only
Reference year: 2022-23
Coverage: EU-27, 3000 samples/year

EFA & GAEC
Terraces and traditional stone walls

Dimension limits may be set by MS in the context of GAEC 7 and EFA

Sketchy geospatial data

No corresponding information in COPERNICUS products

Abbreviations:

- *LUCAS LF: Land use / cover area frame survey, landscape feature module*
- *LUCAS transect: Land use / cover area frame survey, Transect module*
- *EMBAL: European Monitoring of Biodiversity in Agricultural Landscape*
- *EFA: Ecological Focus Area*
- *GAEC: Good Agricultural and Environmental Condition*

Sources:

- *LUCAS LF module 2022, instructions for surveyors*
- *LUCAS 2015, Technical reference document C1 Instructions for Surveyors. Eurostat*
- *EMBAL Survey Manual (version 22.09.2021)*
- *JRC-GAEC database*
- *Member States' choices on elements qualifying for Ecological Focus Area (EFA) Ref. Ares(2019)664707*

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4 Quantification of Landscape Features based on the LUCAS transect data

This chapter documents the use of an important data source for the quantification of LF at the European scale based on the LUCAS transect data. This is the first EU-level data source (going back to 2006) that consistently covers the whole EU and can thus add a reliable historical perspective to the amount of some LF in Europe. In this chapter we show a prototype calculation based on this data source with data from 2015 (the last LUCAS survey with transect data), but theoretically the same calculations can also be performed for all of the earlier LUCAS survey years. The calculations presented here were covered in the CAP impact assessment of 2018.[34]

4.1 Relevant observations in the 2015 LUCAS survey data

In 2015 altogether 267,900 LUCAS points were included in the field survey, all of which were also surveyed with the transect methodology (see sections 2.2.1 & 3.2). The objective of this study is to give a statistical estimation of the extent (total *length* and *area*) of the LF types ("landscape elements") covered by this dataset in the agricultural land s of the EU.

As described in Section 3.2, for each of the selected LUCAS points, the surveyors were expected to walk a transect of 250m, oriented W-E from the starting point. The observation is an array of codes of land cover (simplified legend) and linear elements crossed. Only the types of the linear elements crossed were recorded during the walk, using the normal LUCAS land cover type codes (Eurostat, 2015ab; d'Andrimont et al., 2021), extended with additional codes for linear features (Table 3). A LUCAS transect observation can be for example: C10, 1, 31, 1, 62, 1, 31, 1, BB2, 21, B11, meaning that it starts in a broadleaved forest (C10), goes through a road (62) with associated ditches (31) and grass margins (1) on both sides, goes through a vineyard (BB2), then straddles a stone wall (21) and finishes in a field of wheat (B11). Features that are wider than 3 m are not reported as linear elements in the LUCAS transect observations (but are reported in the LUCAS core module, see section 4.4).

This analysis presented below (section 4.5) is focused on a subset of the 'linear feature' elements recorded by the surveyors, excluding all of the artificial elements that cannot be considered as LFs (e.g., roads, fences, power lines). Furthermore, LF types, which are normally not directly managed by farmers were also excluded. Accordingly, the following types of linear elements were considered in this analysis: LUCAS code 1, 2, 10, 11, 12, 13, 14, 15, 21, 31 (see also Table 3).

Even though the primary focus of the LUCAS transect module is the linear elements, the LUCAS core survey also offers a way to get some information about "patchy" LF types (wider than 3 m). LUCAS points are part of the main LUCAS "Core" observations scheme, which makes it possible to complement the area estimations for linear LFs, with another simple area estimation for 'small woody patches'.[35] This will necessarily be a coarse estimation, nevertheless it can be used to get an EU level estimate, and this additional analysis complements the more detailed results from the transect module.

4.2 Determining the agricultural context

LUCAS transect observations do not record if a specific linear element is part of the agricultural area or not. Fortunately, the adjacent land-use/cover is registered, which makes it possible to select only those which are in agricultural fields or adjacent to them. However, discriminating in the LUCAS transects linear elements in agricultural area or not in agricultural area is not as straightforward as it seems because the transect observations report only the land cover, not the land-use (and land use cannot always be derived from the land cover). While it is easy for crops (i.e., if the land cover is wheat, then land use is agriculture), it can be more difficult for grassland and fallow. Indeed, grassland (the land use code is not reported in the transect observation), can be used either for permanent pasture, or for recreation (e.g., sport field, parks). In this analysis, it was assumed that area classes B (cropland), E (grassland) and F40 (includes ploughed land and agricultural

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[34] One purpose of this chapter is to documents the calculations presented in Annex 5.4 of the CAP Impact Assessment (SWD(301)2018, page 101 (https://eur-lex.europa.eu/resource.html?uri=cellar:c1206abb-65a0-11e8-ab9c-01aa75ed71a1.0001.02/DOC_3), as well as to provide a "corrigendum" to the results presented there, which contain several mistakes.

[35] Linear LF types are not recorded in LUCAS core (they are actively avoided using point shifting rules), and for other patchy LU/LC types it is difficult to filter for compliance with the functional LF defintion presented in the introduction.

fallow, but also other bare land categories) are agricultural areas. It is acknowledged that it is a simplification which may introduce some bias.

As a first approximation, only linear elements with agricultural land on both sides of the transect were selected. Nevertheless, this simple approach seemed to underestimate the total length, so in a next step more detailed inclusion rules were determined. The construction of these inclusion rules was partly inspired by the EFA regulations, and practical feasibility considerations (e.g., a combination of contiguous hedge, ditch, and field margin). Based on the contextual information in the LUCAS transects on adjacency, the following Linear Feature Elements (LFE) have been included:

- LFEs between two agricultural elements (B, E, and F40 in the LUCAS land cover legend), with E including permanent grassland; F40 including fallow and ploughed land.
- LFEs between agricultural area and a fence, a stone-wall, a ditch, or a track.
- If there are two or more adjacent LFEs between two agricultural patches they are all counted.

Similarly, specific Linear Feature Elements (LFEs) were excluded from the estimates:

- LFEs between two non-agricultural areas (A, C, D, F1, F2, F3, G, H).
- If there are two or more adjacent LFEs between two non-agricultural patches they are all excluded.
- LFEs between a non-agricultural area and a transportation line (railway, road, or track) or between two transportation lines.
- Hedges or lines of trees adjacent to artificial land.
- Ditches adjacent to roads, railways or tracks even if separate by a grass margin (likely to be road drains).
- LFEs between (fence or stone wall) and (non-agricultural or track or ditch.
- Grass margins adjacent to paved roads or railways.

The main potential source of bias is to attribute LUCAS reported LFs to the agricultural area or not. An initial set of rules to attribute observations to the agricultural domain roughly classifies around 15% as *dubious cases*. This includes a number of infrequent combinations of linear elements and patches. Furthermore, when the transect is photo-interpreted (in case it is not physically accessible), some land cover classes cannot be identified, which is reported using a special code (“Z”). These cases lead to additional observations classified as dubious.

4.3 Estimation of length and area

As this analysis aimed to estimate the area of linear features, it was necessary to apply conversion factors to go from length to area. It was agreed to use the same conversion factors as those for the Ecological Focus Area (EFA) of the CAP 2013-2020 policy framework (annex II of the Commission Delegated Regulation 639/2014 as amended by the Commission Delegated Regulation 1155/2017). For single trees or bushes found in LUCAS transects, a simplification was applied: the length of a hypothetical line that would result from putting all of them in a row with a distance of 4 m between them was used (Table 8).

Total length of linear features from a sample of transects by counting the number of intersections between the sampled transects and the linear features can be estimated with an unbiased estimator such as the classical Buffon’s needle (Wood and Robertson, 1998, Gallego, 2017). This was achieved using the method described in (Gallego, 2017), based on the pre-selected landscape elements (the ones of the selected types which confirmed to the adjacency rules). The area was then computed from the length multiplied by the conversion coefficients (Table 8).

Table 8. Landscape features elements and conversion factor (m to m^2)

Code	Linear element type	Conversion factor (Commission Delegated Regulation 2017/1155) (m to m^2)
01	Grass margins	6
02	Shrub margins	6
10	Single trees and shrub	20 (m^2/tree)
11	Lines of trees	5
12	Conifer hedges (managed or not)	5
13	Managed hedges (exc. conifer)	5
14	Abandoned hedges (exc. conifer)	5
15	Grove/woodland margins	6
21	Stone walls	1
31	Ditches, channels	5

Source: Commission Delegated Regulation 2017/1155

4.4 Estimations for small woody patches using LUCAS core

To complement the estimations for the area of the linear elements, we also performed a secondary analysis to get an area estimation for the 'small woody patches' (trees or shrub) that are wider than 3 m. To identify small woody patches, we searched for LUCAS points with LC codes CXX (patches covered by trees) and DXX (covered by shrubs) that were smaller than 0.5 ha (the main size limit of the Copernicus SWF and LUCAS LF definitions). In 2015 ~17,000 LUCAS Core points were found which were in such woody patches. However, these small woody patches can still include various (e.g., urban, or alpine) 'tree/shrub islands', which are not managed by farmers, nor located in a farmland context.

To filter the points for an agricultural context, we used additional information from the CORINE Land Cover (CLC) datasets. We selected the subset of these points that fall in one of the CLC agricultural classes or in "complex agricultural landscapes". This type of filtering is a rather coarse approach but has the advantage to be quickly available. For a more accurate estimation, a more refined methodology would be needed. This resulted in a subset of 3370 LUCAS points that conformed to all criteria.

4.5 Results

Table 9 and Table 10 below report the estimation of the total area of linear elements based on data from the LUCAS transect module.[36] The results shown are based on two different assumptions: excluding and including the dubious cases for completeness. In policy documents such as the CAP Impact Assessment (SWD(301)2018), the assumption excluding dubious cases was the one always used to express this estimation.

The estimated share of landscape features within the utilized agricultural area of the Member States is also shown in Fig. 11. The figures and maps presented here only include those *linear* LF types that were covered by the LUCAS 2015 Transect module.

Table 11 shows the results of complementary analysis based on LUCAS Core, presenting an EU-level estimate for the area of 'small woody *patches*' in agricultural land. Due to the low number of available samples, in this case it was only possible to calculate a single EU-level estimate. This result was calculated with a size limit of 0.5 ha (a threshold of 'small' that is consistent with the Copernicus SWF and LUCAS LF definitions, as well as the FAO definition of forests – FAO, 2012).

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[36] These calculations were made available to DG AGRI in the course of the 2018 CAP impact assessment. It shall be noted that the results presented here do not correspond to the ones provided in Annex 5.4 of the CAP Impact Assessment (SWD(301)2018, page 101, where a reference is made to JRC calculations). Table 5.4 there gives a figure of 860,000 ha for EU Landscape elements (excluding dubious cases), while our calculations here point to a total area of 6,050,800 ha (also excluding dubious cases).

Table 9. The estimated area of some linear LF types and their estimated share in agricultural land based on LUCAS transect data from 2015 (excluding dubious cases)

	LF area (1000 ha, excluding dubious)								UAA***	Share in UAA	
	Grass margins	**Shrub margins**	**Single tree bushes**	**Lines of trees**	**Hedges**	**Ditches**	**Woody LF**	**All LF***		**Woody LF**	**All LF***
AT	44.6	1.6	4.2	2.3	4.9	6.0	12.9	63.6	2653.8	**0.49%**	**2.39%**
BE	30.5	0.1	2.5	5.5	9.3	9.6	17.3	57.4	1356.1	**1.28%**	**4.23%**
BG	67.3	2.9	7.4	2.2	10.9	9.1	23.4	99.7	5030.3	**0.46%**	**1.98%**
CY	3.8	0.2	1.7	0.8	1.7	0.3	4.3	8.4	132.4	**3.28%**	**6.32%**
CZ	24.1	1.3	3.7	6.8	2.0	4.8	13.7	42.6	3523.2	**0.39%**	**1.21%**
DE	260.4	43.7	18.4	30.7	31.5	90.2	124.1	474.7	16645.1	**0.75%**	**2.85%**
DK	32.0	11.5	3.2	2.4	9.0	8.6	26.0	66.5	2632.5	**0.99%**	**2.53%**
EE	5.3	1.0	1.7	1.3	9.7	6.3	13.7	25.3	984.7	**1.39%**	**2.56%**
EL	60.4	20.5	6.9	0.9	31.1	9.8	59.3	129.5	5288.1	**1.12%**	**2.45%**
ES	581.3	140.6	38.9	12.3	52.6	36.7	244.3	862.3	24201.9	**1.01%**	**3.56%**
FI	125.9	44.2	2.9	5.7	21.5	120.0	74.2	320.2	2271.9	**3.27%**	**14.09%**
FR	356.0	20.5	53.1	108.2	324.6	97.2	506.4	959.6	29020.2	**1.74%**	**3.31%**
HR	14.3	4.6	5.2	1.8	7.5	6.7	19.1	40.0	1485.7	**1.28%**	**2.69%**
HU	69.5	6.1	2.3	6.7	9.7	15.6	24.7	109.8	5343.8	**0.46%**	**2.05%**
IE	8.0	5.3	5.1	7.1	126.3	40.7	143.7	192.4	4516.0	**3.18%**	**4.26%**
IT	248.9	14.5	29.6	26.3	122.4	178.4	192.8	620.1	12908.8	**1.49%**	**4.80%**
LT	25.4	8.2	4.0	3.2	9.1	11.3	24.5	61.1	2947.2	**0.83%**	**2.07%**
LU	1.0	0.1	0.3	0.4	0.9	0.4	1.6	3.0	131.6	**1.22%**	**2.26%**
LV	8.0	10.4	5.1	2.3	15.7	10.4	33.5	51.8	1937.9	**1.73%**	**2.67%**
MT	0.4	0.1	0.2	0.2	0.1	0.1	0.4	0.9	11.6	**3.54%**	**7.60%**
NL	12.5	9.2	2.0	5.3	4.8	58.2	21.2	91.9	1822.4	**1.16%**	**5.04%**
PL	459.3	2.9	24.4	46.6	45.1	79.4	118.9	657.6	14539.6	**0.82%**	**4.52%**
PT	24.5	19.7	16.4	4.2	20.1	7.8	60.3	92.7	3591.4	**1.68%**	**2.58%**
RO	138.9	21.2	22.8	34.7	71.9	43.6	150.5	333.0	13413.7	**1.12%**	**2.48%**
SE	39.9	9.7	5.2	1.4	14.0	50.3	30.1	120.3	3000.4	**1.00%**	**4.01%**
SI	12.1	0.7	1.8	0.2	4.0	2.6	6.5	21.2	477.9	**1.36%**	**4.44%**
SK	9.4	2.3	3.0	1.6	2.2	3.3	9.0	21.7	1919.5	**0.47%**	**1.13%**
UK	187.5	12.8	28.5	19.2	224.5	51.4	284.9	523.7	17357.0	**1.64%**	**3.02%**
EU27	**2664**	**403**	**271**	**320**	**962**	**907**	**1957**	**5527**	**161788**	1.21%	3.42%
EU28	**2851**	**416**	**300**	**340**	**1186**	**958**	**2241**	**6051**	**179145**	1.25%	3.38%

* Woody LF entails the following types from the LUCAS 2015 transect survey: Shrub margins, Single tree bushes, Lines of tress, Hedges

** only includes the linear feature types covered by LUCAS Transect (see Tables 3 & 8)

*** Utilized Agricultural Area in 2018 (https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1/default/table, accessed on 27.07.2021

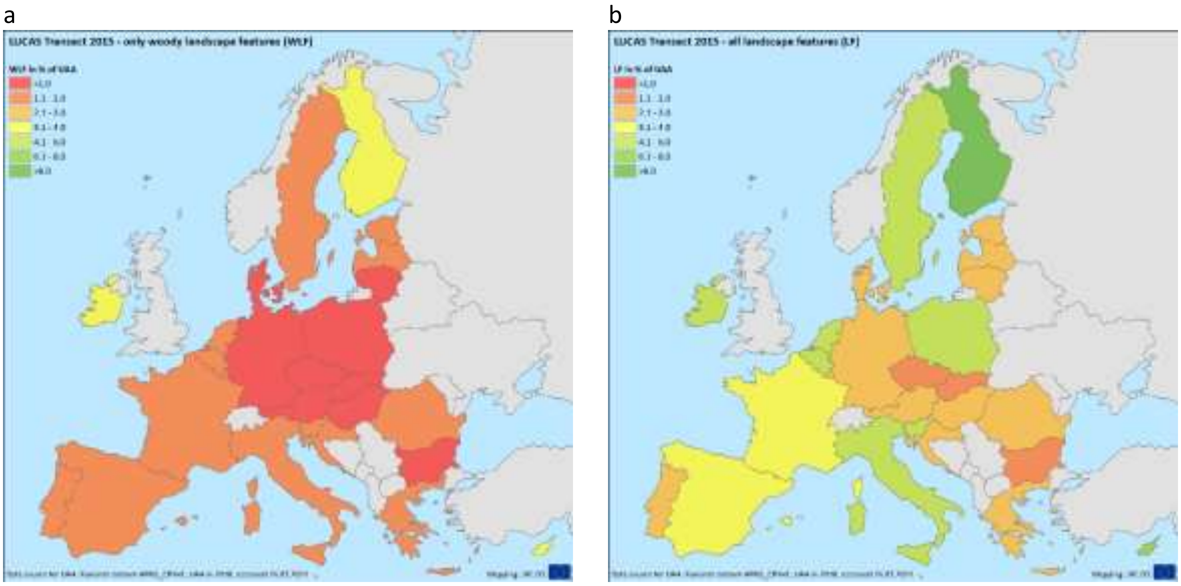
Source: JRC calculations

Table 10. The estimated area of some linear LF types and their estimated share in agricultural land based on LUCAS transect data from 2015 (including dubious cases)

	LF area (1000 ha, including dubious)								UAA***	Share in UAA	
	Grass margins	**Shrub margins**	**Single tree bushes**	**Lines of trees**	**Hedges**	**Ditches**	**Woody LF***	**All LF****		**Woody LF***	**All LF****
AT	56.8	3.4	5.2	3.8	8.0	8.4	20.3	85.5	2653.8	0.77%	3.22%
BE	41.2	0.2	3.2	11.7	13.6	14.6	28.7	84.4	1356.1	2.12%	6.22%
BG	84.9	5.3	9.3	6.3	14.1	11.9	34.9	131.7	5030.3	0.69%	2.62%
CY	4.5	0.4	1.8	1.2	2.6	0.3	5.9	10.7	132.4	4.42%	8.05%
CZ	34.0	3.4	5.1	12.4	2.9	8.4	23.7	66.1	3523.2	0.67%	1.88%
DE	329.3	85.4	25.2	68.6	49.4	128.4	228.6	686.3	16645.1	1.37%	4.12%
DK	44.0	16.2	4.3	3.4	10.8	12.0	34.7	90.7	2632.5	1.32%	3.45%
EE	9.4	2.7	2.0	1.8	13.2	20.8	19.7	49.8	984.7	2.00%	5.06%
EL	69.7	32.8	8.1	1.7	42.8	12.8	85.3	167.7	5288.1	1.61%	3.17%
ES	660.7	184.4	47.2	18.9	74.5	45.7	324.9	1031.3	24201.9	1.34%	4.26%
FI	159.4	99.3	4.2	11.2	52.3	284.3	166.9	610.5	2271.9	7.35%	26.87%
FR	494.3	35.1	62.7	156.0	420.6	139.6	674.4	1308.2	29020.2	2.32%	4.51%
HR	18.8	6.1	5.6	2.3	11.0	11.7	24.9	55.4	1485.7	1.67%	3.73%
HU	93.3	8.5	3.1	12.3	15.3	20.1	39.1	152.5	5343.8	0.73%	2.85%
IE	20.2	12.7	6.1	9.7	168.5	57.7	196.9	274.8	4516.0	4.36%	6.09%
IT	302.0	22.3	34.9	37.8	165.2	199.6	260.1	761.8	12908.8	2.02%	5.90%
LT	30.5	14.9	4.7	4.0	13.0	17.6	36.5	84.6	2947.2	1.24%	2.87%
LU	1.5	0.2	0.3	0.6	1.2	0.6	2.2	4.3	131.6	1.70%	3.25%
LV	11.3	19.4	5.9	3.3	21.9	26.1	50.4	87.8	1937.9	2.60%	4.53%
MT	0.4	0.1	0.2	0.3	0.1	0.1	0.6	1.0	11.6	4.84%	8.89%
NL	22.7	18.7	2.9	18.0	7.1	70.5	46.6	139.8	1822.4	2.56%	7.67%
PL	493.8	4.1	28.6	72.5	55.4	100.7	160.6	755.1	14539.6	1.10%	5.19%
PT	41.2	38.4	19.9	6.2	30.0	11.2	94.4	146.8	3591.4	2.63%	4.09%
RO	155.5	29.6	24.6	42.7	90.0	49.1	186.8	391.4	13413.7	1.39%	2.92%
SE	60.7	25.4	6.6	2.6	23.0	102.7	57.6	221.0	3000.4	1.92%	7.36%
SI	16.1	1.4	1.9	0.3	6.6	3.3	10.2	29.6	477.9	2.14%	6.19%
SK	14.9	5.2	3.2	2.6	2.8	5.2	13.8	33.8	1919.5	0.72%	1.76%
UK	256.3	24.6	40.4	31.6	339.7	65.6	436.2	758.1	17357.0	2.51%	4.37%
EU27	**3271**	**676**	**326**	**511**	**1315**	**1363**	**2829**	**7462**	**161788**	**1.75%**	**4.61%**
EU28	**3527**	**700**	**367**	**543**	**1655**	**1428**	**3265**	**8221**	**179145**	**1.82%**	**4.59%**

* Woody LF entails the following types from the LUCAS 2015 transect survey: Shrub margins, Single tree bushes, Lines of tress, Hedges
** only includes the linear feature types covered by LUCAS Transect (see Tables 3 & 8)
*** Utilized Agricultural Area in 2018 (https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1/default/table, accessed on 27.07.2021
Source: JRC calculations

Figure 11. The estimated share of several LF types in agricultural land in the EU Member States
(a: woody linear landscape features; b: all linear LF types covered by the LUCAS 2015 transect module)



Source: JRC calculations (based on LUCAS Transect data from 2015, excluding dubious cases, see Table 9)

Table 11. The estimated area of ‘small woody patches’ (width > 3 m, size <0.5 ha, LUCAS LC code CXX or DXX) in CLC agricultural areas

	Number of LUCAS points	Estimated area for EU28 (1000 ha)
Small patches of trees	2219	2936
Small patches of shrubs	1151	1523
Total (EU-28)		**4459**

Source: JRC calculations

According to the results in 2015 there used to be 5.5/7.5 million hectares of linear landscape features in the EU (EU27, excluding / including dubious cases respectively). This area corresponds to 3.4-4.6% of the UAA in EU27 countries. Additionally, according to LUCAS Core there were further 4.5 million hectares covered with small woody *patches* in 2015 in Europe. Therefore, LUCAS Transects + Core area estimations for LF range between 10-12 million ha (depending on dubious cases), which corresponds to 6.2-7.4% of the UAA in the EU27.

This estimation is laden with uncertainties, and it does not consistently cover all types of LF that meet the functional definition of LF provided in Chapter 1. In particular, the identification of features “belonging” to the agricultural land was not clear and straightforward (causing the issue with the dubious cases). All this has contributed to the decision to discontinue the LUCAS LF module in its original form, and to redesign the methodology into a point survey combining photo-interpretation of aerial ortho-photo and field survey for the LUCAS 2022 landscape feature module (see Section 2.2.2). In the case of the two upcoming statistical surveys (LUCAS LF, EMBAL), a focus on agricultural area will be established already by the stratification and selection of surveyed points from the main LUCAS sampling frame. Then the selected samples will be checked by photo-interpretation and the field survey, which can also filter out observation (sub) points falling out of the agricultural context.

5 Conclusions

In this report, we provided an overview on the main data sources on agricultural landscape features (LF) available at the European level. There is a considerable diversity of definitions, and typologies underlying these data sources, mainly due to the different methodologies and purposes behind, which we also documented. The first challenge in creating a comprehensive, consistent and reliable EU-level quantification of LF is to bring these approaches to a common framework, by establishing a common semantics (definitions, typology) of LF types, supported by detailed definitions and geometric specifications which can be clearly linked to the previous approaches (e.g. via cross-reference tables) and can provide a solid foundation for the future work. The definition of the agricultural area should be as much as possible harmonised, taking in account the different methodological approaches between a field survey and remote sensing estimations. These standardized definitions also need to be closely linked to the original ecological and policy roots of the LF concept (i.e. they should cover all features with significant contributions in biodiversity and Ecosystem Services to the surrounding agricultural landscapes; but they should not cover any features which lack these contributions or provide them out of an agricultural context). The overall functional definition of LF proposed in Chapter 1, as well as the simplified functional typology and geometric specifications proposed in Tables 1 and 7 can be seen as first steps on this road, proposed for EU-wide discussion.

In theory, quantification of LFs could be derived on the basis of remote sensing data (high resolution data) and ortho-photos (comparable to the approach followed for the COPERNICUS Small Woody Feature product) or from a statistical field survey (comparable to LUCAS core, LUCAS transect). For what concerns the ecological value of LFs, field visits are indispensable. Moreover, there are some administrative and geographical data linked to the CAP implementation, based on farmers' declarations requirements.

However, as we pointed out, the existing data sources come with serious issues, which need to be addressed for an efficient and reliable EU-level quantification. From the two existing EU-level data sources, the LUCAS Transect module was critically assessed for its capabilities for capturing all LF types, and based on the lessons it has been redesigned into a point survey combining photo-interpretation and field survey for the LUCAS 2022 landscape feature module (see Section 2.2.2). Similarly, Copernicus products (including the existing and upcoming Small Woody Features (SWF) and Small Landscape Feature (SLF) products) also need to be assessed by an entity independent from the Copernicus consortium for their fitness to answer the CAP needs. These assessments will also need to explore the options to detect and to monitor area changes in time for the CAP PMEF.

There are several robust statistical methods that can be used to combine data from wall-to-wall maps and statistical surveys in a meaningful way, leading to an unbiased estimation for any region of interest (Card, 1982; GEOSS, 2009; Olofsson et al., 2014). These unbiased estimations also come with mathematically quantifiable statistical properties (accuracy, error rates), which outperform those of the individual data sources (maps, surveys) taken alone (e.g. Czaplewski & Catts, 1992; Gallego, 2004; Olofsson et al., 2014). With a careful attention to the underlying semantic inconsistencies, Copernicus SWF and LUCAS LF could be tested for the computation of such an estimator. EMBAL can also provide further important details to enrich this picture, because it is the only data source that will give information on the quality of the surveyed features.

Given the diversity of information available, and the semantic, scientific, technical, and logistical complexities of this work, the implementation of the I.21 indicator should be prepared carefully. JRC is about to prepare a roadmap for this indicator development, highlighting the most important tasks and challenges, and which can then be used as a basis for discussion and more concrete planning for the EU institutions involved.

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List of abbreviations

AGRI	Directorate General Agriculture and Rural Development
AWF	additional woody features
CAP	Common Agricultural Policy
CLC	CORINE Land Cover
CMEF	Common Monitoring and Evaluation Framework
CORINE	Coordination of Information on the Environment
DG	Directorate General
EC	European Commission
EEA	European Environment Agency
EFA	ecological focus area
EMBAL	European Monitoring of Biodiversity in Agricultural Landscape
ESA	European Space Agency
EU	European Union
EUROSTAT	Statistical Office of the European Union
FADN	farm accountancy data network
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FLF	functional linear feature classes (own abbreviation)
GAEC	Good Agricultural and Environmental Conditions
HRL	high-resolution layer
JRC	Joint Research Centre
LC	land cover
LF	landscape feature
LFE	linear feature elements
LPIS	Land Parcel Identification System
LUCAS	Land Use and Coverage Area frame Survey
MS	Member States
PMEF	Performance and Monitoring Evaluation Framework
SAR	synthetic aperture radar
SMR	Statutory Management Requirements
SWF	small woody features
UAA	utilized agricultural area
VHR	very high resolution
XHR	extreme high resolution

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