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Directorate E: Sectoral and regional statistics

Unit E-2: Environmental statistics and accounts; sustainable development

MAPPING HETEROGENEOUS ECOSYSTEMS WITH HIGH RESOLUTION DATA – TECHNICAL RECOMMENDATIONS FOR THE REPORTING FOR ANNEX IX OF REGULATION (EU) 691/2011

Technical note supporting the Ecosystem accounts handbook

Version December 2025

1. INTRODUCTION

The purpose of this document is to present guidance on how to deal with ecosystem heterogeneity in an efficient and coordinated manner, for regular production of ecosystem accounts. It explores the use of national and EU-wide data of high spatial resolution for producing the ecosystem extent dataset. It identifies the data-integration challenges inherent in producing the accounts from input datasets with different levels of geo-spatial detail, and the adjustments required in these datasets to meet the reporting obligations under Annex IX of Regulation 691/2011. The document is based on insights gained during the review of the ecosystem classification workflows provided by countries as metadata in their voluntary reporting on ecosystem extent accounts and the relevant internal experience at the EEA.

Some key recommendations from this document will be included in the future Handbook on Ecosystem accounts, to be published by the end of 2025, and serve as reference methodological document for the legal reporting.

2. CONTEXT AND BACKGROUND

The newly introduced ecosystem accounting module in Regulation 691/2011 requires that countries report the area and change in area for each ecosystem type within their national territory. The related Guidance note on ecosystem extent accounts, explicitly specifies the reporting to be based on geographically explicit data. This implies that countries compile a national wall-to-wall geospatial product reflecting the extent of each individual ecosystem asset, according to a predefined ecosystem typology and prescribed level of spatial detail. The level of detail of spatial representation (whether vector or raster based) can be ecosystem type-specific, since ecosystem types vary in size, compositions, behaviours, and can be location specific. Such product could be created through dedicated mapping or compiled from different spatial data sources, the latter being a frequent approach used by national compilers of ecosystem accounts under the new EU module.

The results from the voluntary reporting on extent accounts show that, depending on the level of investment in spatial data infrastructure, countries rely on different national or EU-wide datasets (or their combination), as input. Each of these datasets reflects features and components of the ecosystems, which in combination are expected to provide the spatial dimension of the ecosystem assets. Consequently, compilers need to address technical questions regarding the type of spatial data to use, the appropriate level of spatial and thematic detail to set, as well as the conventions to apply when integrating datasets with different specifications and intended purpose. Please see the box below for a definition of some key technical terms.

Data needs at national level vary substantially between administrative domains and thematic topics. In addition, information is often collected by different national registers, such as cadastres, territorial planning, or the administrative systems managing agricultural payments. Technological advances allow the collection and handling of geospatial data of unprecedented spatial detail (individual tree or house) and temporal frequency (several observations per week). Although this offers enormous opportunities for far more granular and insightful analysis, it comes also with certain challenges of extracting and handling the required information from this “data deluge”.

This document aims to discuss three challenges in mapping heterogeneous ecosystem types:

- a) What are the key features that characterize the heterogeneity of ecosystem types?
- b) How the characteristics of different data sets used for ecosystem mapping support or hinder identification of particularly heterogeneous ecosystem types?
- c) How to avoid erroneous recording of the area of heterogeneous ecosystem types due to technical or methodological errors in the data processing approach?

An underlying key conceptual question is how far one should go in spatial detail before one begins mapping the individual components of an ecosystem, rather than the ecosystem itself?

The following technical sections aim to support countries in selecting among the datasets developed in different contexts those that address the information needs of ecosystem accounting and combine them in an effective and efficient manner to produce the ecosystem extent dataset.

Box 1: Defining some key technical terms:

SEEA EA defines **ecosystem assets** as individual spatial areas occupied by a single ecosystem type. They are the primary spatial units for ecosystem accounting.

Ecosystem types are thematically clearly defined so that they can be distinguished from all other ecosystem types due to their inherent characteristics (e.g. vegetation structure and type, species composition, hydrology, soil characteristics or topography).

The sum of the spatial size of all the different **ecosystem assets** belonging to the same **ecosystem type** produces the **ecosystem extent** of the given ecosystem type per country (or other reporting area).

Ecosystem accounting area is the area for which the ecosystem account is compiled. For reporting under Annex IX of Regulation 691/2011 this is defined as the entire territory of any given country. However, it is conceptually possible to define different ecosystem accounting areas, e.g. a NUTS2 region, a national park or a large forest area.

The term ‘*spatial unit*’ describes any geographic area that is recognised as a separate unit in spatial analysis. It can be defined by geographic boundaries (a river etc.), administrative boundaries (a municipality), distinct features that allows its identification (e.g. vegetation or land cover) or the data structure used in spatial analysis (e.g. raster cells or polygons).

Figure 1 illustrates how individual spatial units of ecosystem assets can be distributed across a geographic area that comprises several different ecosystem types.

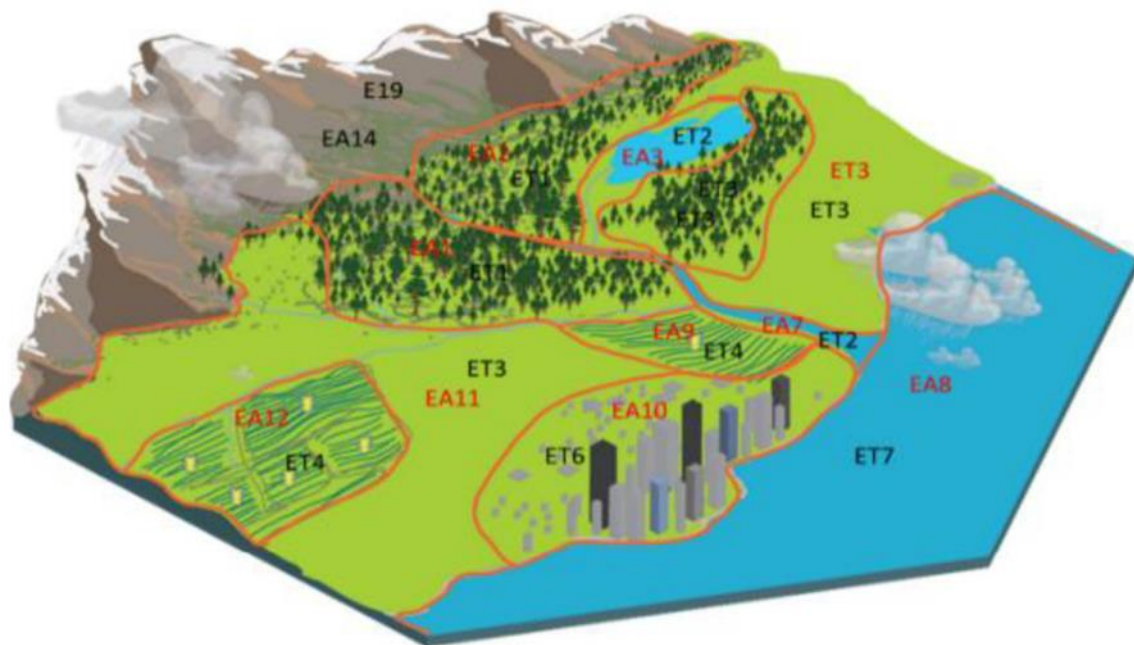


Figure 1. Spatial units of ecosystem assets (in orange contour and labelled in red font) that represent different ecosystem types (labelled in black font). Source: <https://seea.un.org/Introduction-to-Ecosystem-Accounting>

3. WHAT MAKES ECOSYSTEMS HETEROGENOUS?

Europe has a very heterogenous and often spatially intricate distribution of ecosystem types, due to its geography, climate and land use history. Furthermore, many of its ecosystem types are heterogenous in themselves. The question here is what makes an ecosystem heterogenous and how to map such ecosystem types?

Some ecosystem types are characterised by certain parameters that make them very mappable. The water surface of lakes or the open sea are examples of that; even many forests or uniform modern arable farming landscapes can be defined by individual features¹. However, differentiating individual ecosystem types in coastal areas or within areas of mixed farming interspersed with settlements, for example, is already more complex. Then there are ecosystem types that are heterogeneous in themselves. This means that they are defined by a combination of different features that can be mapped individually but that only together create the characteristics of a specific ecosystem type. A typical example is agro-forestry where the combination of herbaceous and tree components defines the ecosystem type in a stable “intrinsic mix”. Urban settlement areas are another example as they are comprised of a mix of buildings as defining feature interspersed with roads, urban green and other features that together define an urban settlement area. See Figure 2 for an illustration of the above.

¹ Homogeneous ecosystems could still have condition parameters that vary spatially across the asset (for example, a homogeneous forest patch can still have non-uniform distribution of the deadwood within)



ET9.2: Artificial reservoir with dam infrastructure, Cyprus.

Homogeneous: uniform distribution of the determinant water component



ET2.4: Agro-forestry area near Madrid. Pasture or arable land with scattered broadleaved trees.

Heterogeneous: non-uniform (scattered) distribution of the woody component.



ET2.5: Mixed farmland. In this case an area principally occupied by agriculture interspersed with significant natural areas (forests); near Oslo, Norway.

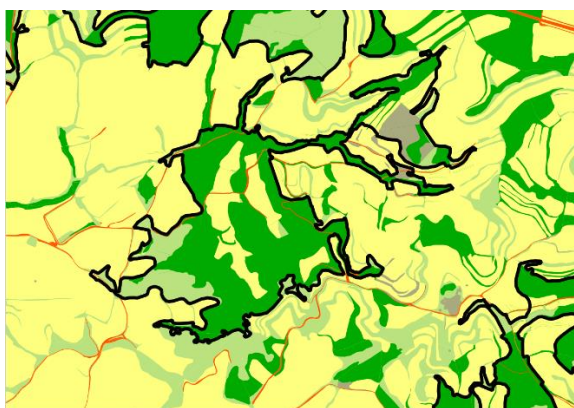
Heterogeneous: non-uniform (clustered) distribution of the woody component.

Figure 2. Examples of homogeneous and heterogeneous ecosystem types. Source of photos: Updated CLC illustrated nomenclature guidelines, 2017.

While homogenous ecosystem types can be (fairly) easily identified, heterogenous types often represent a considerable mapping challenge. This is not only due to their more complex characteristics but also due to the fact their identification requires a combination of feature types, some of which may be defining characteristics of other ecosystem types. To use the above example, agro-forestry areas comprise both oak trees and arable or pasture area. All these components are found in separate L2 ecosystem types (ET2.1 Annual cropland, ET3.2 Natural and semi-natural grasslands, ET4.3 Broadleaved evergreen forest, respectively), but the combination of them, when they are in an ecological relationship, defines agro-forestry areas (ET2.4 Agro-forestry areas).

The total extent of a given ecosystem type in a country is defined by the sum of the area of all the individual ecosystem assets that represent this ecosystem type. These can be large or quite small themselves, which can make separating them out from other ecosystem types a considerable challenge.

The **heterogeneity within the spatial unit** of a geospatial product could be related both to the intrinsic heterogeneity of the ecosystem type but also to the cartographic scale. The latter means that within the spatial unit, there can be several ecosystem assets that are too small to be mapped individually in the respective geospatial product; thus, represented as single entity (see Figure 3).



Ecosystem extent map derived from LPIS in Spain (2021), MMU of 0.1 ha



Ecosystem extent map of the same area derived from CLC (2018), MMU of 25 ha

Figure 3. Example of cartographic heterogeneity. The spatial unit in black outline contains ecosystem assets other than forest, which are below the MMU of 25 ha.

A range of ecosystems include distinct geographic features, which could be considered as separate ecosystem types, defined at lower level of the EU typology. At higher level of ecosystem typology, these individual components are considered an integral part of the ecosystem asset of a given ecosystem type and incorporated into the spatial unit. However, at lower level, they could be theoretically considered individual ecosystem assets and mapped separately (Figure 4).



Wooded hedges within vineyard plots



Incorporated into single spatial unit of ET2 Cropland and ET2.3 Permanent crops



Separate ET2.39 Semi-natural elements (see arrows) associated with agricultural land use in permanent crops

Figure 4. Same area, occupied by an agricultural ecosystem, mapped differently at the L1/L2 and L3 of the EU ecosystem typology.

In summary, heterogeneous ecosystem types are defined by an intrinsic mix of different biotic and abiotic components, mainly different vegetation types and structures (such as in agro-forestry) or a fine-scale mix of land use types (such as in mosaic farmland). Together they define the ecosystem type, e.g. agro-forestry by the combination of trees with a canopy cover of 10 – 30% and crop- or grassland cover. As shown in Figure 4, these features can be mapped separately as individual components. However, such a mapping procedure needs to provide the possibility that when certain combination of features relates a defined heterogeneous ecosystem type, these are represented as single spatial entity. Where permanent crops, arable crops and

small settlement areas are mapped on their own due to the availability of a detailed spatial resolution, for example, this would not recognise their intrinsic functional relation that creates a specific ecological environment for bird and animal species. This would falsely classify the individual small spatial components as belonging to related ecosystem type that is more homogenous (large-scale arable cropland, areas dominated by permanent crops etc).

Given the risk described above, **it is recommended that, within a given level of ecosystem typology, heterogenous ecosystems are mapped as a single entity, regardless the applied cartographic scale, even if the input data allows separate spatial representation of the individual components.** Their identification as a separate mixed ecosystem type is aided by the description of the ecosystem types in the given level of the EU ecosystem typology.

4. HOW TO IDENTIFY HETEROGENEOUS ECOSYSTEMS BASED ON DIFFERENT DATA INPUT

4.1 BUILDING ON THE EU ECOSYSTEM TYPOLOGY

The EU ecosystem typology is central to EU ecosystem accounting as it does not only provide the nomenclature, but it gives also the basis for the structure of the ecosystem extent data model.

The EU ecosystem typology accommodates different levels of information — starting with structured broad-level types — which allow further systematic subdivision into more detailed subclasses. At the higher levels of the classification, few diagnostic criteria are used, whereas at lower levels, the number of diagnostic criteria increases.

Box 2: Diagnostic criteria in hierarchical classification systems:

The ISO19114-1 standard describes the general principles to be followed for the design of classification systems used for geographical information. Based on these principles, diagnostic criteria (classifiers) are defined to ensure mutual exclusiveness and exhaustiveness of the ecosystem types at a specific level typology. Furthermore, the diagnostic criteria (classifiers) at each level are different and they are not repeated at another level (e.g. criteria used to define an ecosystem type at a lower level shall not be duplicated to a higher level of the hierarchy). At lower level of typology, heterogeneous ecosystems could be “broken down” into other individual ecosystem types, as it is the case of ET2.39 (ET2.39 Semi-natural elements associated with agricultural land use in permanent crops) separated from ET2.3 (Permanent crops), because there are different diagnostic rules applied at this lower level (Table 1).

Table 1 Illustration of the classification logic.

Level 2	E2.3 Permanent crops	✓ Dominant land use ✓ Dominant vegetation structure	Semi-natural features are NOT diagnostically relevant at this level
Level 3	ET2.39 Semi-natural elements associated with agricultural land use in permanent crops	✓ Non-cultivated vegetation ✓ Ecological function (habitat, connectivity, regulation) ✓ Structural distinction from crop area	New diagnostic criteria (not used in the above level)

Heterogeneous ecosystems can be further decomposed at lower typology levels where new diagnostic criteria are introduced, ensuring that ecosystem types remain mutually exclusive and exhaustive at each level while avoiding duplication of classification rules across the hierarchy.

To ensure compliance with the principle of mutual exclusivity and collective exhaustiveness (MECE), the EU typology, being a hierarchical classification, “directs” the assignment of an area to only one ecosystem type, at given hierarchical level. It does this by applying the set of diagnostic criteria extracted from the EU typology that are unique for each ecosystem type. The boundary outline of the related spatial unit should ensure that it encloses exhaustively the ecosystem asset. A presence of distinct components/features associated with another ecosystem type within the spatial unit is allowed only if they are smaller than the adopted cartographic scale and MMU; thus, considered insignificant in areas terms.

Consequently, at a given level of ecosystem typology and according to the diagnostic criteria applied, the spatial unit for each ecosystem asset should be designed in a way to enclose ecosystem assets of a certain ecosystem type, and allow for the presence of “contaminations” only if they are below the MMU, thus, considered too small to be accounted and mapped (Figure 5).

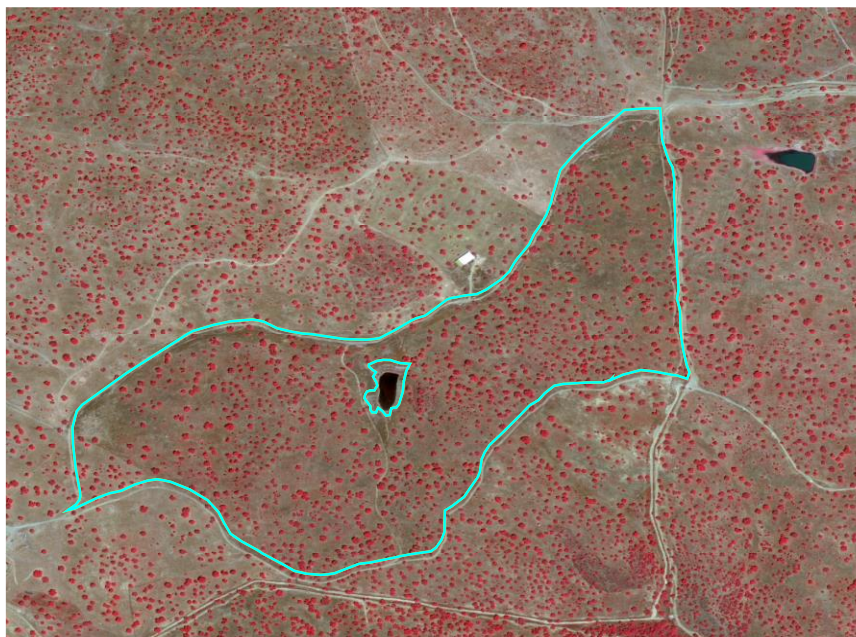


Figure 5 Spatial unit from the Portuguese LPIS2 of a typical grassland with (holm) oak trees, forming an agro-forestry ecosystem (Montado). A small pond within the grassland is mapped out separately as it is bigger than the prescribed MMU of 0.1 ha. Any other features, such as narrow road or patch of bare area are not mapped separately as smaller than the MMU. Source: Orthophoto, 2015, Direção-Geral do Território, Portugal

There are some additional principles that are useful when mapping heterogeneous ecosystems:

1. When several input datasets with different specifications are available, priority should be given to those with spatial units closer to the spatial representation of the heterogeneous ecosystem, as functional unit (see Figure 5 to Figure 8).
2. Mapping procedures must account for the spatial context, proximity and combination of at least the key components of heterogeneous ecosystem types to provide a meaningful spatial representation.
3. The MMU is not a diagnostic criterion in the EU typology, but a parameter related to spatial granularity, at a given level of ecosystem typology.

² Land Parcel Identification System

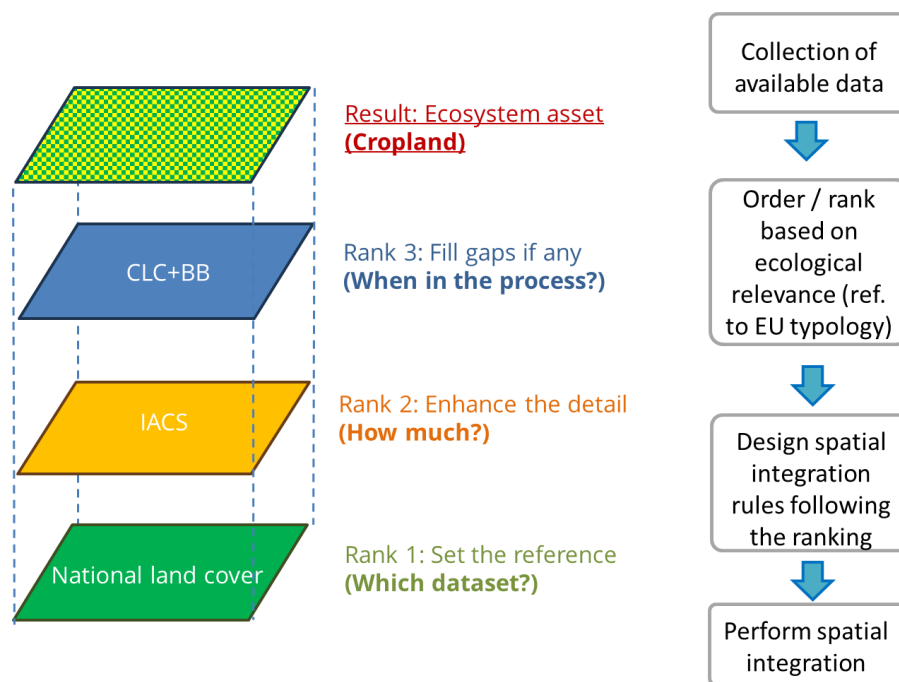


Figure 6 Schematic illustration of a possible spatial data integration process towards a generation of the outline of an ecosystem asset (Cropland). Left side of the figure shows the prioritization of the input dataset through ranking. The dataset with the highest rank is the one that represents the ecosystem in its whole as functional unit. The right side of the figure outlines the main processing steps.

The following section illustrates the practical approach on a few typical cases when the use of national data to derive heterogeneous ecosystems assets is challenging. While these issues do not significantly impact the ecosystem extent account, they can create an incomplete representation of the ecosystems, potentially creating confusion or uncertainty for users.

4.2 A MAPPING EXAMPLE: ET2.5 ‘MIXED FARMLAND’

When input datasets with high spatial detail are used, each of the plots within the intrinsic mosaic – arable or permanent crops, grassland fields, and semi-natural elements - can be identified and classified, as an individual ecosystem asset. Consequently, the small cropland ecosystem assets could be categorised as ‘2.1 Annual cropland’ and ‘2.3 Permanent cropland’ and the small grassland ecosystem assets as ‘3.1 Sown pastures’. In doing this, ‘Mixed farmland’ could be incorrectly subdivided and reclassified; thus, losing information on the ecological connectivity and specific mix of ecological features present in an identifiable spatial area.

Approach: The name of ET 2.5 (Mixed farmland) could erroneously give the impression that it is just a “container” for compilation of different agricultural ecosystem types, which are not represented separately in the extent dataset, because they are below the MMU. ET2.5 Mixed farmland is a distinct ecosystem type related to an intrinsic mix of different juxtaposed agricultural land uses, in combination with associated landscape features or natural elements creating a specific type of mosaic (Figure 7). Individual components of this ecosystem types are much smaller than the components of the surrounding ecosystem, and create a specific “texture”. The agricultural fields within that mosaic relate to different types of land use (annual

crops, permanent crops, grassland), with none of the uses being clearly predominant within the ecosystem asset. As part of ET 2.5 (Mixed farmland), this ecosystem asset can be always represented as a single spatial unit, irrespective of the cartographic scale and the adopted MMU.



Figure 7. Intrinsic mix of interconnected small-size agricultural fields (family gardens) with their associated landscape features. Even if the adopted MMU is smaller than the individual agricultural plots, there is no need to map each of the plots separately. Example of CLC class [2.4.2 Complex cultivation patterns](#) from Bulgaria. Source of background imagery: "© Microsoft Bing Maps"

The description in the EU ecosystem typology provides an insight into the combination of features that define ET 2.5.1 Mosaic farmland (comprising cropland, grassland and (semi-) natural components):

Mosaic of small, cultivated land parcels with different cultivation types -annual crops, pasture and/or permanent crops-, eventually with scattered houses or gardens. Mosaic landscapes have no single dominant land cover that covers more than 50% of the MMU. Includes tree lines, hedgerows and other semi-natural elements in mixed farmland.

ET 2.5 was created to recognise the diverse mixes of agricultural land uses with other components in European landscapes, which create their own specific ecological environments. The mapping of such land cover types was pioneered via the establishment of the Corine Land Cover survey (CLC). The mapping manual for CLC classes provides helpful descriptive detail for identifying heterogeneous agricultural classes. As these have inspired the definition of ET 2.5, links to the class description for related CLC classes are given here: [2.4.2 Complex cultivation patterns](#)

[2.4.1 Annual crops associated with permanent crops](#)

[2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation](#)

4.3 MAPPING ECOSYSTEM EXTENT WITH NATIONAL DATA

As evidenced from the voluntary reporting on extent accounts, countries could have numerous datasets at hand for deriving the extent of ecosystems. For some ecosystem types there can be one dataset that provides the extent, while for others (for example, the heterogeneous ones), there can be a number of candidate datasets available, some of them being very detailed.

The use of high-resolution datasets is always appealing, as they offer the most spatially detailed representation of the individual areas and geographic features. However, there is an implied risk to start representing the individual ecosystem components, rather than individual ecosystem assets. Moreover, this option implies excessive data processing and complex rules for spatial overlay, which can produce artifacts.

The key question is then how to know whether the resulted ecosystem asset is sufficiently adequate to reflect the given ecosystem as functional unit, without going into further detail, which could be irrelevant for accounting purposes. For urban ecosystems, it will be the functional zones defined by the urban management plans (Figure 8), for forest ecosystems, the forest units in the forest management plans, for agricultural ecosystems, the production blocks defined in the systems managing the agricultural payments.

Figure 8 shows a section of the urban centre of the city of Sofia, represented by three different national datasets (cadastre, topographic map and the urban management plan) and the Urban Atlas (a dataset from the Copernicus Land Monitoring Service - CLMS). As visible from the illustrations, the cadastre and topographic map are datasets focussed on depicting the individual land tenure parcels and individual buildings, respectively. Consequently, they are too detailed to represent directly the urban ecosystem types as defined by the EU Typology, since they are mapping the individual ecosystem components (buildings, open spaces, green areas) of the urban ecosystems.

Contrary, the spatial units of the urban management plan enclose larger urban entities (called functional zones), according to their function, which is much closer to the principles and logic of the EU typology. The similarities with the spatial units from Urban Atlas – a dataset compliant with the EU typology – confirms this observation. Functional zones provide the required information of the individual components and their distribution within the ecosystem as information in the class definition, without the need to represent the components spatially. Therefore, the urban management plan is a better candidate as reference dataset to derive the outline of the urban ecosystems at all three typology levels, comparing to the cadastre and topographic maps. Some urban management plans have also the advantage to set the allowed percentage of build-up surface within each functional zone. This would allow a better differentiation between ET 1.1 Continuous settlement area and ET1.2 Discontinuous settlement area.

Cadastre



Large-scale topographic map



Functional zones (Urban Management Plan)



Land cover (Urban Atlas)



Figure 8. Different options for spatial representation of the urban ecosystem and its components for the city centre of Sofia, Bulgaria. The land cover from Urban Atlas and the functional zones are the spatial units that are closest to the notion of ecosystem assets. The data from cadastre and topographic maps is too detailed. It outlines the individual ecosystem components and should not be used directly for the data collection, unless aggregated and generalized, which is not trivial. Source: Municipal Enterprise Sofproject OGP, Bulgaria; European Union's Copernicus Land Monitoring Service information.

5. HOW TO AVOID DATA PROCESSING ERRORS IN MAPPING HETEROGENEOUS ECOSYSTEM TYPES

This chapter discusses potential methodological and data processing errors that could lead to under- or over-reporting of heterogeneous ecosystem types. It uses case studies to illustrate mapping solutions in different situations.

In section 5.2 it discusses general methodological issues in processing geo-spatial data. This includes principles for the use of metadata and data processing rules relating to an adopted minimum mapping unit (MMU).

5.1 A REVIEW OF SPECIFIC MAPPING CHALLENGES

This sub-section uses case studies to illustrate mapping solutions for different spatial features or a fine-scale mix of different land cover classes.

Case 1: Linear features in forests

When using several high-resolution data sources for the classification of coniferous, deciduous and mixed forests, small, detailed polygons arise that do not precisely overlap, for example, at the place of small forest roads or walking paths. When reclassifying these remaining polygons based on the largest overlap, there can be resulting slivers not reflecting the actual vegetation type or data gaps.

Approach: This issue could be resolved by reconsidering the role of all input datasets in the data integration and keeping only those that are sufficient to provide the outline of the ecosystem asset at the given level of typology. If all datasets are required, a buffering could be applied to the higher-ranking dataset and slivers can be reclassified based on the forest type associated with the buffered polygons. Gaps in data could be filled in with information from CLMS datasets, such as CLCplus Backbone.

Case 2: Multiple land use types within an urban cell

In heterogeneous urban environments, with a great variety of residential and non-residential buildings, categorising urban streets is also challenging. Smaller streets are categorised as ‘Streets in settlement areas’, whereas major roads and motorways are designated as ‘Infrastructure’. However, this subdivision could result in issues in the ecosystem extent dataset where minor streets and major infrastructure overlap, creating minor inconsistencies.

Approach: As in Case 1, this issue could be resolved by relying on datasets that are sufficient to provide the outline of the ecosystem asset at the given level of typology.

Alternatively, such issues could be resolved, possibly, by incorporating contextual factors such as the surrounding land use, road type and urban density. Such an approach would allow for a more accurate and context-sensitive classification, enhancing the reliability of spatial analyses and decision-making processes. Furthermore, ideally, small roads and streets would be dissolved into the associated sub-ecosystem type of

the settlement areas using a buffering approach. However, such an approach is not straightforward and requires specific context related solutions (see Case 3).

Case 3: Characterising mixed land use (ET2.5) based on high resolution crop type data

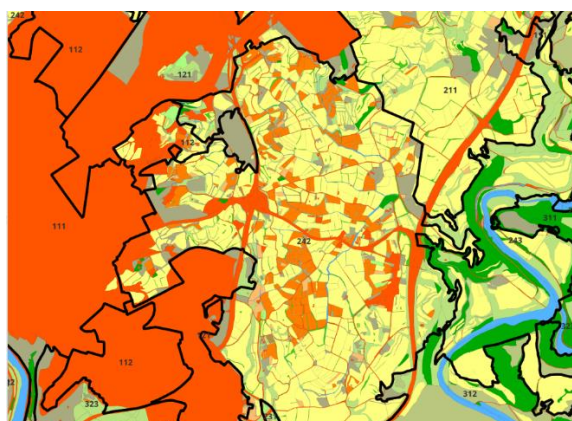
There could be cases where the most reliable dataset to use is the spatial dataset on land and agricultural parcels for management of CAP subsidies, as part of the Integrated Administration and Control System (IACS, also called Integrated System). These datasets are of very high resolution, subject to robust methodologies and annual quality checks. They could map land cover and land use types beyond agriculture; thus, providing a wall-to-wall spatial data over the given country. Due to the administrative purpose of this data, the spatial and thematic granularity is such that every individual cropped or managed parcels and every single landscape features can be explicitly mapped. Consequently, the heterogeneous ecosystem types, related to the agricultural mosaic are not represented as a whole but through individual mapped components (see Figure 9).

Approach: There is no trivial and straightforward method to combine and aggregate such spatial data in larger spatial entities representing the relevant heterogeneous ecosystems. Specific diversity indices could be applied to qualify and quantify the richness and evenness of the different types of land cover and crop types within larger spatial aggregates. However, such patterns are often local-specific and the test performed by some countries on IACS data have not yielded promising results yet (see Box 3). Consequently, when IACS data, or equivalent data, is used for ecosystem extent data, the related heterogeneous ecosystems will be represented by their individual components, assigned to the correspondent level 2 and level 3 ecosystem types.

Area classified in CLC as 2.4.2 Complex cultivation patterns (black contour)



An ecosystem dataset of the same area generated by IACS data



Area classified in CLC as 2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation (black contour)

An ecosystem dataset of the same areas generated by IACS data

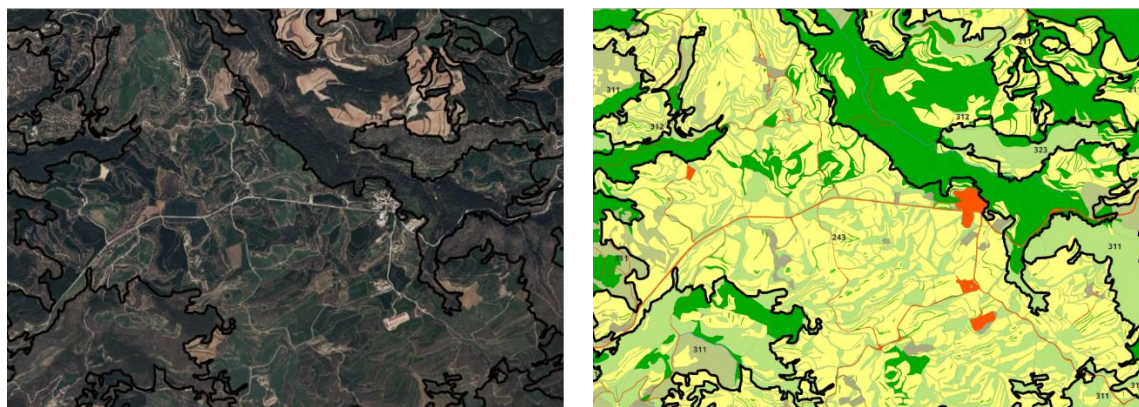


Figure 9 Use of IACS data for mapping heterogeneous agricultural ecosystems, using IACS. Example from Catalonia, Spain (SIGPAC). Each cropped parcel and landscape feature is a separate spatial unit. Source of background imagery: "© Microsoft Bing Maps"

Box 3: Detection of mixed farmland within the spatial units of the Land Parcel Identification System

The Integrated Administration and Control System contains two spatial datasets - the Geospatial Application (GSA) and the Land Parcel Identification System (LPIS). These datasets are complementary components developed primarily to support the implementation and control of the EU Common Agricultural Policy (CAP) of the European Union, but they serve distinct purposes. **GSA** is an application used by farmers to declare, geolocate, and submit claims for agricultural aid, allowing them to digitize crop areas and management practices directly on maps for a given year. In contrast, **LPIS** is a reference geospatial database maintained by public authorities that delineates and stores the official, stable boundaries and attributes of agricultural land parcels, or their aggregates, used to verify and control aid applications. While GSA is farmer-driven, annual, and dynamic, reflecting declared land use and crops, LPIS is authority-driven, relatively stable, and structural, providing the authoritative spatial framework against which GSA declarations are checked for eligibility, accuracy, and compliance.

EU countries use different types of spatial units to outline the stable boundaries of their “land parcels” in LPIS, depending on the land management, land fragmentation and dynamics in land use and tenure. While some countries have their LPIS reference parcels matching the annual agricultural parcels, others use higher spatial aggregates such as farmer blocks (multiple parcels managed by one farmer), and even physical blocks (multiple parcels managed by different farmers). Consequently, some of the farmer or physical blocks could contain a mosaic of cropped parcels and network of landscape features, qualifying these parcels as representing mixed farmland related to any of ET 2.4.2, ET2.4.1 or ET2.4 (see Figure 10).

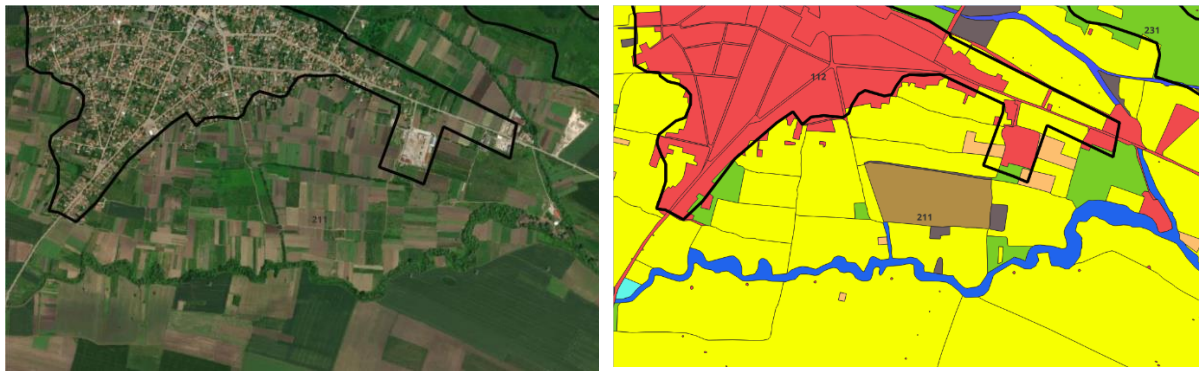


Figure 10 Mapping of the parcel mosaics in the Bulgarian LPIS. Left Image shows an area enclosed by a village from the north and a creek from the south, occupied by a mosaic of small parcels with different land use. The black contour is the boundary between the CLC classes CLC 112 (discontinuous urban fabric) and CLC211 (non-irrigated arable land). Right image shows the same area mapped as set of larger spatial units in the Bulgarian LPIS. Colours correspond to different land cover/land use classes in the LPIS. The big brown polygon in the center of the area has a class “Mixed land use”. Source of background imagery: "© Microsoft Bing Maps". Source of LPIS data: Bulgarian Ministry of Agriculture and Food (shape.mzh.government.bg)

A possible practical approach (as the one developed and tested by the Central Statistics Office of Ireland) to assess whether the LPIS parcels represent heterogeneous agricultural ecosystems could be based on the following steps:

1. Select all land parcels in the Land Parcel Identification System (LPIS) which could relate to mixed farmland (for example those corresponding to the Cropland ecosystem type).
2. Overlay the CLMS product ‘HRL Crop Type’ (Figure 11).
3. Fill gaps with CLCplus Backbone land cover (excluding class 1 ‘sealed’).
4. Calculate heterogeneity (Shannon’ Diversity Index) within each LPIS parcel
5. Select parcels with Shannon’ Diversity Index higher than certain quantile value (for example, the 99.9th quantile).
6. Classify such parcels as Mixed Farmland.

Despite its sound logic and its efficiency, the approach suffers from the potential bias introduced by the design of the LPIS parcels. When farmer blocks are used as LPIS reference parcels, they can either contain multiple fields (all owned by one farmer) or can correspond to single fields. This biases the classification of Mixed Farmland towards areas of land owned by larger farm owners. This means that, at landscape level, two identically heterogeneous areas of land may be characterised differently depending on how many separate farmers use the land. This issue is less prominent when physical blocks are used as LPIS reference parcels; however, much of the LPIS implementation in the EU countries is based on farmer blocks or agricultural parcels.

Therefore, the main challenge would be the definition of the common spatial unit (or mowing window) to measure heterogeneity in equal and comparable manner across countries. This topic is already subject of numerous JRC projects and research studies (Heidi et al, 2024)

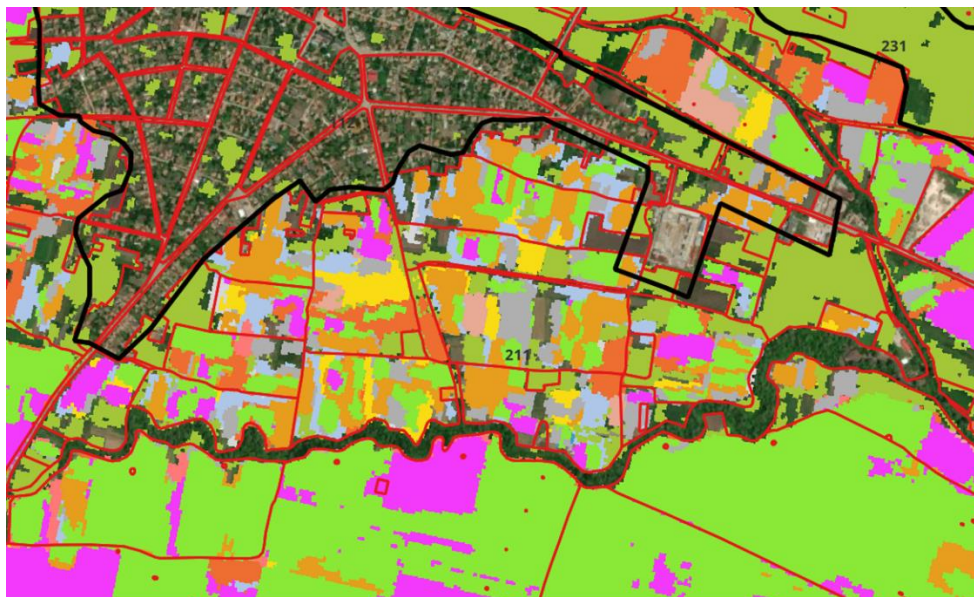


Figure 11 The same area as shown in Figure 10, where the 2024 LPIS reference (in red contour) is overlaid with the 2023 HRL CropType product (different crops/uses are in different colours). Source of background imagery: "© Microsoft Bing Maps". European Union's Copernicus Land Monitoring Service information.

5.2 GENERAL DATA PROCESSING RULES TO CONSIDER IN MAPPING APPROACH

To assure the required level of accuracy for all data, explicit datasets and maps resulting from modelling or image classification should be harmonized. Harmonization does not necessarily imply that all data must have the same accuracy level but ensures that the combined and resulting information meets the minimum requirement of its classification level. The representation of a real feature in different map scales may look different due to shape generalization. Nonetheless, consistency between the datasets should be ensured. The semantic relationship between the thematic information stored in the spatial dataset (i.e. wetland map, protected areas, and national land cover information), needs to be assessed prior to any integration.

The following good practices should be adhered to when combining different data types and sources (based on IPCC, 2019) to ensure results of required quality:

- The metadata of the data sources, and especially the spatial scales, creation dates and the minimal mapping unit should be documented; particular attention should be paid to distinguishing between thematic datasets (class label based on interpreted information, such as CLC) and measurement datasets (gridded data on measurable surface characteristic, such as vegetation index).
- The conformity of the spatial datasets to national mapping standards should be checked. Any notable deviation, especially with reference to the legacy/historical data, should be documented.
- A hierarchy among various data sources should be established before the process (higher quality data prevail where an inconsistency with other data appears).
- Any uncertainties in the data integration should be documented.

Most of the spatial datasets of administrative character (cadastre, LPIS), indicate their spatial granularity by specifying the cartographic scale (1:5 000 in the case of LPIS). There is a relation between the cartographic scale and the MMU and MMW, which can differ depending on the nature of the dataset and features represented. The MMU always refers to the **smallest size of a geographic feature that is consistently mapped and represented in a spatial dataset** (and not happens to occur in the dataset just by chance). In raster-based cartography (such as satellite imagery or land cover classification maps), the MMU refers to the **smallest group of contiguous pixels** that is recognized as a distinct mappable feature.

Nowadays, high-resolution satellite imagery or drone data may detect and store features below the MMU. However, not everything that can be mapped, needs to be mapped. It depends on the relevance and purpose of the geospatial dataset, as well as the resources available. In such cases, the **MMU acts as a reporting threshold**, not a detection limit. Therefore, it is advisable to interpret the MMU as reporting threshold setting the size of the ecosystems that should always be mapped but allowing the flexibility for smaller ecosystems to be mapped as well, when deemed appropriate.

6. CONCLUDING CHAPTER THAT ALSO PROPOSES CONCRETE GUIDANCE

6.1 GENERAL CONSIDERATIONS

This note has aimed to develop guidance on how to deal with ecosystem heterogeneity in the regular production of ecosystem accounts. It explored the use of national and EU-wide data of high spatial resolution for producing the ecosystem extent dataset. It reviews data-integration challenges inherent in producing the accounts from input datasets with different levels of geo-spatial detail.

Previous sections have discussed the conceptual and methodological approach for defining and mapping heterogeneous ecosystem types. Case studies have illustrated different types of mapping challenges and technical sections reviewed individual methodological issues in processing geo-spatial data.

This chapter concludes with a description of a step-by-step approach that could guide national compilers in mapping heterogeneous systems in section 6.2.

6.2 ADOPTING A PRACTICAL APPROACH

A processing workflow to deal with heterogeneous ecosystems in a practical manner could comprise the following steps (see also Figure 6 and Figure 12):

1. Extract the diagnostic criteria for the heterogeneous ecosystem type at the given level of typology
For example, for ET2.5 Mixed Farmland, such criteria will be: (1) mosaics of small parcels with diverse agriculture use; non-dominance of any land use; (3) interspersing with significant natural areas; etc.
2. Collect national datasets that are candidates to provide spatial data
3. Order them in terms of:
 - a. Relevance of spatial representation:
 - i. ecosystem functional unit (higher rank),
 - ii. ecosystem components (middle rank),
 - iii. bio-physical measurements (lower rank)
 - b. Timeliness: Newer to older
 - c. Release calendar: regular, irregular, one-off
 - d. Coverage: wall-to-wall to area-specific
 - e. Other data quality criteria, such as accuracy, temporal consistency, etc.
4. Exclude from the data integration datasets that:
 - a. Do not relate to the diagnostic criteria at the given typology level
 - b. Are related to ecosystem components already reflected by other higher-ranking datasets
 - c. Represent features smaller than the adopted MMU for the given ecosystem type

Note: These datasets could still be used to provide some extra information or be used to increase the confidence of the ecosystem classification.

5. Design the rules of spatial integration considering the ranking order of the input datasets.

Note: The rules should respect the principles of the priority ordering between ecosystem levels. For example, once a bog forest is classified as such, the same area cannot become a montane forest later in the classification process, even if it is located at high altitude.

6. Perform the data integration
7. Check and validate the outcomes

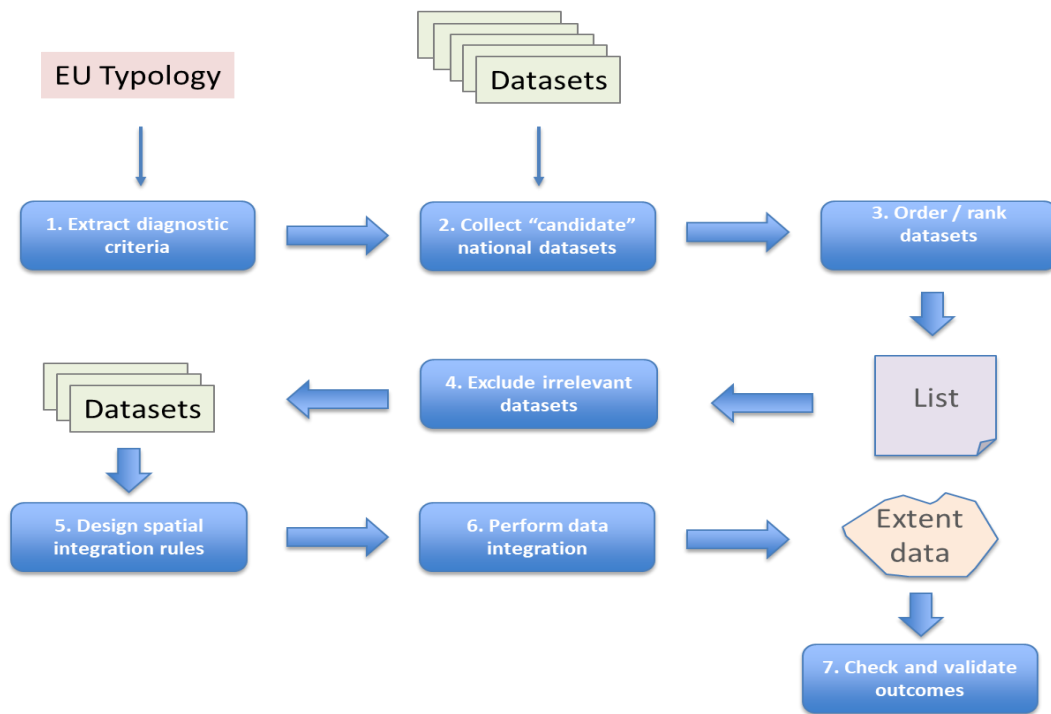


Figure 12. Ecosystem data integration workflow