Supporting note for the Copernicus for ecosystem accounting database

# Introduction

Ecosystem accounting is predicated on the measurement of the extent of different ecosystems and a set of condition characteristics (stock) and the ecosystem services they deliver (flow) at different points in time. These accounting items are, respectively, recorded in ecosystem extent, condition and ecosystem service supply and use accounts. Outside of these core bio-physical accounts, ecosystem accounting may support organising information on particularly policy themes for ecosystem management (specifically biodiversity, water, land and carbon). This note is intended to support the design and use of a database to link the data needs of ecosystem accounting producers in Europe to key data derived via the European Union’s Copernicus programme for Earth Observation (EO) and monitoring.

# Need for Copernicus data foundation

At the core of Copernicus is the Sentinel satellite constellation of the European Commission (EC), launched and run by the European Space Agency (ESA), on behalf of the EC. The Copernicus programme consists of the Sentinels, downstream services to use the Sentinel data and derived products (collectively referred to as EO herein) as well as supporting *in-situ* data*. In-situ* data are all non-satellite based data sources. Consequently, all ground-based, air-borne, and ship/buoy-based observations and measurements that are needed to implement and operate the Copernicus services are part of the *in-situ* component (it should be noted that such data may, elsewhere, also be referred to as EO).

The Copernicus services serve six thematic areas: land monitoring, marine monitoring, atmosphere monitoring, climate change, emergency management response and security. Most of the services and products provided under these themes are already operational and have been enabled by the Copernicus Sentinel satellites, as well as a number of contribution missions from other operators. The continuity and quality of observations is key for the future of the European Copernicus Space Component (CSC), but it is also recognized that the capabilities of the CSC could be broadened to address more and potentially new needs. Aside from traditional area such as fisheries management and agricultural monitoring, there are potentially many new applications for the CSC such as biodiversity monitoring and ecosystem accounting.

What sets the Copernicus programme apart from other EO programmes is that it is service-oriented and not experimental or focused on research and development, as are the ESA Earth Explorer missions, for example. A service implies a specific customer with needs to be met, dependent on delivery on time and on budget. Therefore Copernicus is founded on the core principle of continuity of observation and free and open access for a set of core users in key thematic domains. The services provided consist of spatially continuous data products and the spatial data infrastructure to access them as well as supporting documentation to use them. The spatial data products are routinely produced and come with well documented and, in some cases, peer-reviewed methodologies and validation protocols. Being an operational service, product validation is key to ensure product reliability and performance in real world applications.

Although focused on the needs of the European Commission and its agencies, Copernicus represents the [EU](https://en.wikipedia.org/wiki/European_Union)’s contribution to the Group on Earth Observations (GEO) and so has a global component. The accessibility and ability of Copernicus products and services to monitor ecosystem characteristics over space and time make them well-suited for supporting ecosystem accounting. In particular, the land services theme of the Copernicus programme provides a strong data foundation for the terrestrial context. Across the EU, there are both pan-European as well as local components. The following is a summary of the suite of Copernicus Land Services across the different components:

* Global (biophysical variables which describe the state and the evolution of the continental vegetation and soils, the energy budget at the surface, the cryosphere and the water cycle).
* Pan-European (land cover (CORINE Land Cover Map), biophysical variables (High Resolution Layers), reference data (digital elevation model, EU-DEM and river network, EU-Hydro).
* Local (land cover (Urban Atlas, Riparian Zones)).
* Reference Data (In-situ, Land Use and Coverage Area frame Survey, LUCAS).

These land monitoring products and services have considerable potential to support terrestrial ecosystem accounting at sub-national, Member State and EU scales. As outlined above, they provide robust, quality assured regular and repeatable coverage of spatial data that is not only consistent over both space and time but also at the resolution required to support ecosystem accounting. Furthermore, the thematic breadth of the land service products is likely to yield spatial data highly applicable to all the core ecosystem extent, condition and services accounts of the SEEA EEA handbook, as well as accounting themes of specific policy concern, comprising biodiversity, carbon, water, and land.

# Using Copernicus for Ecosystem Accounting

With respect to accounting for the extent of ecosystems over time, remotely sensed observation of land cover and land cover change have been employed in a pragmatic approach to compiling ecosystem extent accounts. Indeed, the Mapping and Assessment of Ecosystems and their Services (MAES) initiative of the EU is grounded in a typology of ecosystems based on aggregations of the Corine Land Cover Level 3 Classes. Integrating these data with maps of natural vegetation of data on species habitat preferences has also proved useful in understanding the implications of land cover change on these aspects of biodiversity. Nonetheless, it would be useful to move towards more ecologically representative descriptions of ecosystem extent.

The limitations of the Copernicus EO products for ecosystem accounting lie in the physical principles on which the products are generated, i.e. the measurement of reflected solar radiation from the Earth’s surface. Therefore, only visible surface features can be accurately mapped – vegetation, bare soil, urban areas, ice and surface water being the most obvious, as well as aspects of the Earth’s energy budget from which the transfer of atmospheric carbon to terrestrial and marine carbon sinks can be quantified. This is clearly reflected in the types of condition parameters reported in the literature using EO, such as vegetation measures (e.g., leaf surface index, NDVI and NPP), geomorphological measures (e.g., slope and elevation), damage impacts (e.g., fire) and water quality measures (e.g., chlorophyll a concentrations and NDWI). This data has also supported modelling of wider condition parameters, such as soil loss or flooding susceptibility and evapotranspiration and soil surface moisture). However, there remain significant challenges to condition assessment using EO. In particular, other direct condition aspects, such as biodiversity status, in terms of species and genetic diversity, require supplementary in-situ or other reference data to describe spatially and temporally.

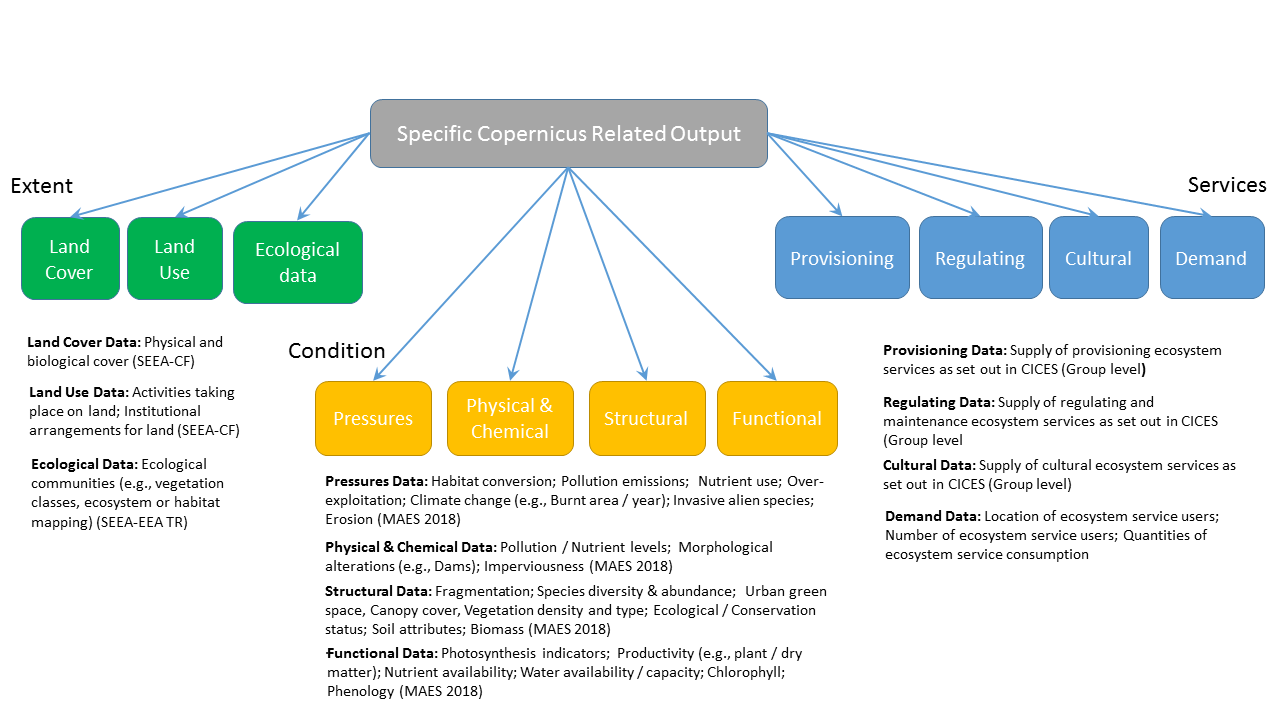
Accounting for ecosystem services is largely achieved using biophysical models, where ecosystem extent (often land cover) and condition measures are used to explanatory parameters for the supply or spatial disaggregation of ecosystem services use data. As described above, EO can clearly support such exercises and this is evidenced by a number of experimental ecosystem accounting and ecosystem assessment studies. However, while ecosystem service supply may often be mapped using information on ecosystem extent, and condition, challenges emerge when linking potential supply to actual use where beneficiaries vary across space.

# Methodology for evaluating Copernicus products for ecosystem accounting

This section explains the methodology employed to evaluate the potential of Copernicus product for calculating ecosystem accounts, identifying key metadata requirements and constructing a database to support practitioners to identify appropriate Copernicus products for different accounting purposes. For account producers, the thematic accuracy of the Copernicus product will be a key concern (i.e., the degree to which the product or services relates to the accounting item of interest, specifically ecosystem extent, condition, services). A conceptual model was constructed to aid matching Copernicus products into different accounting themes in the database. This is presented in Figure 1.

As shown in Figure 1, a Copernicus product was considered to be primarily relevant to ecosystem extent if it provided data on: Land Cover (i.e., physical and biological cover, following the SEEA CF description); Land Use (i.e., activities taking place on land or institutional arrangements for land, also following the SEEA CF description); or, Ecological (i.e., mapping of vegetation classes, ecosystem classes or habitat mapping, SEEA EEA TR description).

While ecosystem extent is a reasonably well represented parameter by EO, condition is more challenging to evaluate. Table 2.2 in the 5th MAES (2018) Report for mapping and assessment of ecosystem condition[[1]](#footnote-1) was employed to provide a set of high level criteria for matching Copernicus products to condition. This is based on the indicator providing data on ecosystem pressures; physical or chemical environmental quality, ecosystem structure; or, ecosystem function. The specific indicators proposed by ecosystem type presented in MAES (2018) were then reviewed to make these high level criteria more tangible and facilitate matching them and the Copernicus products (as shown in Figure 1). For ecosystem services, the CICES Group Level classification for data relating to provisioning, regulating and services was employed. In addition, data on ecosystem service demand (e.g., population estimates) was also included as a high level criteria for matching Copernicus products, as this can help move beyond modelling ecosystem service potential supply to actual use (see Figure 1).



**Figure 1: Conceptual model for matching Copernicus product to ecosystem accounting themes**

Whilst some Copernicus products could be used in the compilation of more than one type of ecosystem account, it was decided that each product should only matched to one theme of either ecosystem extent, condition or services. This was to minimise the potential for the same dataset to enter the accounting framework via multiple points. Accordingly, the following binary match criteria are employed in the database:

* No match – implies no significant association of a Copernicus product with an accounting theme, or that the product has a more appropriate (primary) ecosystem accounting purpose.[[2]](#footnote-2)
* Match – implies the Copernicus product provides data that is directly associated with an accounting theme and with reasonable confidence. For example, using land cover data to represent ecosystem extent.

There will also be key metadata requirements that Copernicus products and services will have to meet in order to support different analytical uses. As parameters chosen for inclusion in the accounts should be underpinned by datasets that allow a reliable quantitative analysis of trends at suitable spatial and temporal scale, the following metadata will be a key concern for account producers and is captured in the database:

* Ecosystem specificity, i.e. the degree to which the EO product can be used across all MAES ecosystem types, just a few, e.g. land, or specific to one ecosystem type e.g. grasslands.
* Status, i.e. if the Copernicus product is ‘operational’, ‘pre-operational’, ‘demonstration’ or ‘in development’
* Temporal coverage (i.e., is the product for one time point or time series)
* Spatial coverage and resolution (i.e. does the maximum spatial resolution achieve the 1km target for ecosystem accounting across the EU?)

All of the 72 different individual products available from the Copernicus land services website[[3]](#footnote-3) at the end of April 2018 were captured in the database. Where an individual product contained a main product and an additional product that was relevant to different ecosystem accounting themes these were captured as two distinct entries in the database. As an example, the Grassland 2015 HRL product contains information on grassland extent as the main product, plus an additional expert product on ploughing intensity (considered an ecosystem condition pressure indicator). Where there were multiple products that reflected different years of observation these are captured as a single entry in the database and the multiple editions communicated as a discrete set of temporal coverages. For example Corine Land Cover products only enter the database once but there are individual products available for 1990, 2000, 2006 and 2012 (plus associated land cover change products) available from the Copernicus land services website. This resulted in a database of 45 main and additional products.

Once the database was populated with Copernicus products, they were classified according to their primary ecosystem accounting theme of relevance. An assessment of the potential use, limitations and options for development could then be undertaken for each product. Initial thoughts in these regards are captured in the database. It is anticipated through future experimentations these can be updated and refined.

# Initial Database Results

A simple tool was built into the database to help users identify which Copernicus products have the best potential for supporting ecosystem accounting. Using the tool, the user can specify the ecosystem account theme they are interested in and associated criteria within that theme (e.g., the user can identify the Copernicus products with a ‘Match’ for ecosystem condition accounting and representative of data on ecosystem function only). Using this tool, it was possible to rapidly evaluate the possibilities for existing Copernicus EO products and services to inform the following ecosystem accounts in the EU:

* Extent
* Condition
* Services

Figure 2, provides a breakdown of 45 Copernicus main and addition products matches to different ecosystem accounts in the database. As Figure 2 reveals, Copernicus products are best suited to describing ecosystem extent (14 matches out of 45 products) and condition (25 out of 45). This is not surprising, given the limitations of EO data to estimate ecosystem services identified in Section 3. Figure 3 provides a breakdown of the ecosystem specificity of the 45 Copernicus products in the database. 22 of the products are considered cross-cutting for terrestrial ecosystems.[[4]](#footnote-4) Of these 8 are relevant for River and lake ecosystems. Urban (6 products); Rivers and Lakes (6 products) and Grasslands (4 products) have the highest number of ecosystem specific products. Forests and woodland (2 products) and Inland wetlands (1 product) also benefit from ecosystem specific products.



**Figure 2: Number of matches between Copernicus products and**



**Figure 3: Number of matches between Copernicus products and MAES ecosystem types**

## Results for Ecosystem Extent

Figure 2 identifies 14 Copernicus outputs that were relevant to informing on ecosystem extent (or at least land cover as a pragmatic approximation). The distribution of these products with respect to their match to land cover, land use or ecological data is provided in Figure 4. Figure 4 identifies that a majority of matched outputs relate to land cover products (11 out of 14). Corine Land Cover (CLC) is the land cover product currently used to define MAES ecosystem extent (with editions for 1990; 2000; 2006; 2012 available). CLC also provides the potential to undertake more detailed ecosystem accounting using the 44 CLC Level 3 classes it contains, which are aggregated to for the MAES ecosystem typology. The EEA have developed ecosystem extent accounts using both of these approaches under KIP-INCA.

Additional, ecosystem specific, land cover products are also available. These could support accounting for specific individual ecosystem types (e.g., Grassland) or experimenting with integration possibilities with CLC. For instance, the Forest Type 2012 product could be of interest for integration with CLC and deriving more detailed forest based accounts (although similar possibilities also exist via CLC 3 classes). Possibilities also exist for integrating the data on river type (transitional; river; canal) provided via the EU-Hydro River Network 2006-2012 product) with more aggregated River and lake extent and the extent of Riparian Zone land cover (via the Riparian Zones Land Use Land Cover product) with the extent of CLC classes located near rivers and in floodplains.

It is noted that the 3 of the ecosystem specific land cover products have now been discontinued (Natural Grasslands 2012; Wetlands 2012; Permanent water bodies 2012) and replaced with new products with a 2015 reference year. These comprise Grasslands 2015; Wetness and water 2015; Water bodies. The discontinued and current products should not be considered comparable and suitable for time-series analysis. The final land cover product is a Corine equivalent for Africa.

The two products relating to land use are LUCAS and the Urban Atlas. The only product considered to provide a more ecologically meaningful representation of ecosystems / habitats than land cover (or use) is the ‘Delineation of Riparian Zones’, as it incorporates wider data on riparian features beyond land cover observations.



**Figure 4: Number of matches between Copernicus products and ecosystem extent criteria**

## Results for Ecosystem Condition

As shown in Figure 2, the database contains 25 Copernicus products that were a match for ecosystem condition accounting. These were dominated by functional (9 out of 25) and Structural (9 out of 25) condition indicators.

The functional condition products were mainly comprised of products related to vegetation indices (FAPAR, Leaf Area Index, NDVI, VCI) or related primary productivity indices (Dry Matter Productivity, and VPI). In addition, 3 functional indicators related to water availability were identified (Snow water equivalent, Water level and the Wetness and water probability index).

A range of structural condition products were also identified in the database. These included 3 products relevant to tree cover (Fcover related to canopy cover but is can be considered similar to vegetation indices; Tree cover density and the Urban Atlas: Street tree Layer). Overall 4 products were considered relevant to landscape elements, these included Small woody features; Riparian Zones Green Linear Elements, in addition to which Natura 2000 and ESM (due to its urban green space data in urban areas only), which are included in the database on this basis following MAES 2018. There were 2 products related to soil attributes (Soil water index; LUCAS soil samples).

Of the 4 pressure condition products, 3 were relevant for indicators of climate change (Burnt area; Lake ice extent, snow cover extent). The other pressure condition product was the ploughing indicator in the Grasslands 2015 product, which was considered an indicator high intensity land-use (i.e., over-exploitation).

For the 3 Physical and Chemical environmental quality products, 2 were considered relevant to urban ecosystems specifically (Imperviousness and Land surface temperature). The third product was the EU-Hydro River Network 2006-2012, which provide data on Strahler stream order (a possible proxy for physical flow volume) and river barriers (dams and culverts). The latter could be developed to provide some indication of fragmentation in rivers.

Overall, the database reveals that the Copernicus products are suited to providing data on some simple structural and functional characteristics of ecosystems. This is not surprising given the Copernicus products are generally based on optical observations from space, which will be best suited to identifying these type of characteristics (as discussed in Section 3). It is also noted that no products have a clear match for biodiversity measurement, although some a quite relevant to the potential for higher levels of biodiversity (e.g., Natura 2000, Riparian Zones Green Linear Elements).



**Figure 5: Number of matches between Copernicus products and ecosystem condition criteria**

## Results for Ecosystem Services

Only 2 products were identified with a primary match was to ecosystem service accounting. This included the EU Digital Elevation Model (DEM), reflecting that DEMs have been used as an input to modelling a wide range of regulating ecosystem services supply (e.g., soil stabilisation, flood attenuation, etc.). The second product was the urban population estimates by polygon, provided in the Urban Atlas. These data are considered to be useful in modelling ecosystem service flow as they provide numbers of potential beneficiaries from ecosystem services and support estimating ecosystem service demand.

The two products identified above are considered relevant to ecosystem services as they are of little relevance to extent or condition (although population pressure could be a condition measure). It should be appreciated that many of the Copernicus products captured in the database will also be useful for various ecosystem service modelling approaches. For example the Urban Atlas Street Tree Layer can be linked to urban ecosystem services such as removal of particulate matter and aesthetic enjoyment. In addition, the JRC are developing air quality regulation models where Leaf Area Index is a model input.

# Key Messages

The analysis of the database revealed where Copernicus land monitoring services can provide long-term support to ecosystem accounting. This can, in turn, help establish the key opportunities for the development of further Copernicus products to meet the needs of the ecosystem accounting and assessment community in Europe. Based on the analysis, the following broad insights with respect to the potential for Copernicus outputs to inform Ecosystem Accounting in the EU are identified:

* As is well known there are a sufficient time-series of land cover observations for land cover accounting.
* Possibilities for integrating land cover data on Forest Type, Riparian Zones and River type (via the EU-Hydro River Network 2006-2012) with Corine land cover are identified.
* Copernicus products were identified for the measuring the extent of grassland, forest and wetlands. Experimentation is required to establish if these can deliver more ecologically robust ecosystem extent accounts. However, these products will not provide an exclusive coverage of ecosystem accounting areas and, currently, have a limited time-series.
* The Copernicus products considered most suitable for measuring ecosystem condition related to functional condition indices (grounded in vegetation indices) and structural indices (grounded in tree cover and landscape elements).
* Limited opportunities for experimenting with pressure based, soil attribute and physical & chemical environmental quality indicators condition indicators were identified. For the latter, the most relevant opportunities are for Urban ecosystems.
* There are no opportunities for directly using any Copernicus products for compiling ecosystem service accounts. However, it is noted that there are multiple data that will be useful for ecosystem service modelling.
* Initial observations on the limitations and possibilities for development of individual Copernicus products are also captured in the database.

It should be noted that the key messages above are based on a rapid subjective assessment of the Copernicus products listed on the land services database at the end of April 2018. They should not be considered as an exhaustive assessment of the possibilities of all products to support ecosystem accounting but rather as providing an overview that identifies the main opportunities and gaps and in products from this perspective. This can guide users in identifying where supplementary information will be required for accounting for key ecosystem features and themes of interest, as well as where additional Copernicus products could be developed to meet ecosystem accounting needs.

The structure of the database also allows for the identification of metadata limitations. This could be further be evaluated in the context of ecosystem accounting in extended analyses or on a case by case basis for specific accounting applications. Finally, experimentation is required to establish the full possibilities for using Copernicus products for an accounting context. Some of this is already underway via KIP-INCA. As such this database should be considered a live document that should be updated through the course of such experimentations.

# Appendix A: Database (Excel)

1. <http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/5th%20MAES%20report.pdf> [↑](#footnote-ref-1)
2. Where a product contained a main product and a distinct additional product with different primary accounting purposes these were may enter the database as distinct entries. The rationale for this is described latter in this section. [↑](#footnote-ref-2)
3. <https://land.copernicus.eu/> [↑](#footnote-ref-3)
4. Based on the sum of Terrestrial (exc. Freshwater), Terrestrial (Inc. Freshwater) and All ecosystems [↑](#footnote-ref-4)