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Research Article

Towards National Ecosystem Accounts: a first application of EU Regulation 2024/3024 in Italy

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Abstract

This paper presents a first national-scale application of Regulation (EU) 2024/3024 on ecosystem accounts, focusing on the physical quantification of seven ecosystem services in Italy. It describes the development of pilot accounts using the Eurostat guidelines and applying the INCA tool. Spatial data and official statistics are integrated to assess ecosystem contributions, enabling a disaggregation by ecosystem type and land cover. The results highlight both the methodological feasibility and the data limitations, particularly regarding spatial resolution and national specificity. The accounting approach reveals the distinct role of ecosystems in providing biophysical outputs, clarifying their contribution compared to human inputs. The analysis also confirms that accounting tables and maps can support policy integration, spatial planning and the assessment of sustainability trade-offs. The study contributes to the implementation of ecosystem accounting in Europe, offering insights for future improvements in data quality and institutional cooperation.

Keywords

ecosystem accounting, EU Regulation 2024/3024, ecosystem services, ecosystem models

Introduction

The growing need to integrate environmental sustainability into economic and policy decision-making has led to the development of comprehensive frameworks for environmental-economic accounting. In this context, Regulation (EU) 2024/3024, amending Regulation (EU) 691/2011, represents a significant step forward, introducing ecosystem accounting as a formal module within the European environmental economic accounts. This initiative is fully aligned with the System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA), adopted in 2021 by the United Nations as an international statistical standard and recently edited in 2024 (United Nations 2024) and responds to the increasing demand for reliable, harmonised data on ecosystems and their contributions to human societies. Ecosystem accounting provides a structured approach to monitor the extent and condition of ecosystems and to quantify the flows of ecosystem services that support economic activities and societal well-being. Under the new regulation, Member States are required to compile accounts for seven specific ecosystem services: wood provision, crop provision, crop pollination, global climate regulation, local climate regulation, air filtration and recreation-related ecosystem services. These services are to be documented using standardised supply and use tables in physical units, disaggregated by ecosystem types and sectors of use. The methodological framework outlined in the Regulation emphasises consistency with existing economic accounts and adherence to SEEA EA principles, ensuring that ecosystem-related data are fully compatible with broader environmental and economic datasets. Data integration involves a combination of Earth observation systems, environmental monitoring, administrative records and modelling techniques to quantify service flows across spatial and temporal scales. This paper presents the methodological approach elaborated within the Eurostat Task Force for Ecosystem Account and applies this framework for the estimation of the mandated ecosystem services and the compilation of the associated accounts for Italy. By documenting this process, the study contributes to the implementation of ecosystem accounting and it represents a first test before the official submission by the end of 2026. Future challenges will relate to data availability and the need for more accurate spatial resolution.

The integration of ecosystem services (ES) into environmental-economic accounting frameworks has become a central theme in recent international and European scientific and policy agendas. The SEEA EA offers the principal global standard for ecosystem accounting. It provides structured guidance on measuring extent, condition and service flows of ecosystems and establishes a comprehensive link between ecological assets and national economic systems. A growing body of scientific literature has addressed the conceptual and methodological underpinnings of ecosystem accounting. Significant contributions have focused on the integration of biophysical modelling, economic valuation and spatial analysis to estimate ES flows and link them to socio-economic uses (Bateman et al. 2011, Weber 2014, Bagstad et al. 2014, Obst et al. 2016, Hein et al. 2020). These studies emphasise the need for robust interdisciplinary frameworks to guide the implementation of the SEEA EA in policy-centric and spatially-explicit contexts. At the European level, the Joint Research Centre (JRC) of the European Commission has led the advancement of technical methodologies for ecosystem services accounting, notably through the INCA (Integrated system for Natural Capital Accounting) initiative. In particular, the JRC has developed methodologies and operational models to map and assess ecosystem services across Europe, contributing to initiatives, such as MAES (Mapping and Assessment of Ecosystems and their Services) and supporting Member States in the implementation of SEEA EA principles (La Notte et al. 2017, Maes et al. 2020, Paracchini et al. 2022, Babi Almenar et al. 2023). Through this work, the JRC has emphasised the importance of consistent spatial datasets, standardised indicators for ecosystem condition and sectoral attribution of ecosystem service flows. In this regard, the INCA project, by translating the SEEA EA into practical applications, has produced biophysical and monetary accounts for key ES, including crop provision, crop pollination, carbon sequestration, and nature-based recreation (Vallecillo et al. 2018, Vallecillo et al. 2019a, Vallecillo et al. 2019b, La Notte et al. 2021a, La Notte A et al. 2021b, Rokicki et al. 2024) while aligning with the SEEA EA framework. INCA has also produced general lessons and conceptual advances for ecosystem accounting, such as the clustering of ES by sustainability thresholds, the distinction between ecosystem potential and actual flow and the treatment of ES as either intermediate or final depending on the modelling context. These insights are critical for integrating ES accounts with the SEEA Central Framework and the System of National Accounts (La Notte A et al. 2019b, La Notte et al. 2019a, United Nations 2024). This scientific evolution is complemented by European policy frameworks such as the European Green Deal, the EU Biodiversity Strategy for 2030 and the 2024 Regulation on Environmental Economic Accounts which have anchored ecosystem accounts as instruments for monitoring progress towards climate, biodiversity and sustainability targets (Maes et al. 2020, Perez Soba et al. 2025. The 2025 JRC report on *Natural Capital and Regional Growth* (Giannakis et al. 2025) further demonstrates the link between natural capital and territorial cohesion, showing that investments in ecological assets foster regional development and economic resilience. Altogether, these developments and the emerging corpus of literature confirm the scientific maturity and institutional integration of ecosystem accounting in Europe (Vallecillo et al. 2019b). At national level, although significant progress has been made (Capriolo et al. 2020, Capriolo et al. 2022, Boschetto et al. 2023), the field of ecosystem accounting is improving especially on data quality, methodological transparency and awareness of the relevance of ecosystem accounts for environmental and economic governance; however, important gaps remain, particularly with respect to spatial resolution, data availability and coverage. This article partially contributes to closing these gaps by applying, for the first time, the harmonised methodology defined in Regulation (EU) 2024/3024 to the full set of ecosystem services in physical terms, thus offering technical insights for future official implementation.

Material and methods

The EU regulation 2024/3024 states that Member States will have to generate ecosystem accounts, including accounts of ecosystem services, at the national level and report them to EUROSTAT by the end of 2026, as a first release (European Commission 2024). In order to fulfil this new obligation, the Italian National Institute for Environmental Protection and Research (ISPRA) has started and completed the assessment of the ecosystem services provided by the Regulation on the basis of the EU guidance notes on ecosystem services*[1] and INCA-Tool*[2], both prepared as a part of a joint effort of the EU Task force on ecosystem accounting (2021 – 2025). To coordinate the implementation of the Regulation at national level, a dedicated inter-institutional task force on ecosystem accounting has been established under the leadership of ISTAT, the Italian National Statistical Office. The task force brings together key technical and scientific institutions, including ISPRA (Italian National Institute for Environmental Protection and Research), CREA (Council for Agricultural Research and Economics), AGEA (Agricultural Payments Agency), CNR (Research National Council) and national experts from academia, to support methodological development, ensure consistency with existing statistical frameworks and contribute sector-specific knowledge. Within this structure, ISPRA plays a central role in coordinating the environmental and spatial data components of the accounts, as well as in developing biophysical estimates through the INCA Tool. A simplified diagram of the current governance framework is presented in Fig. 1, to help readers contextualise Italy's approach.

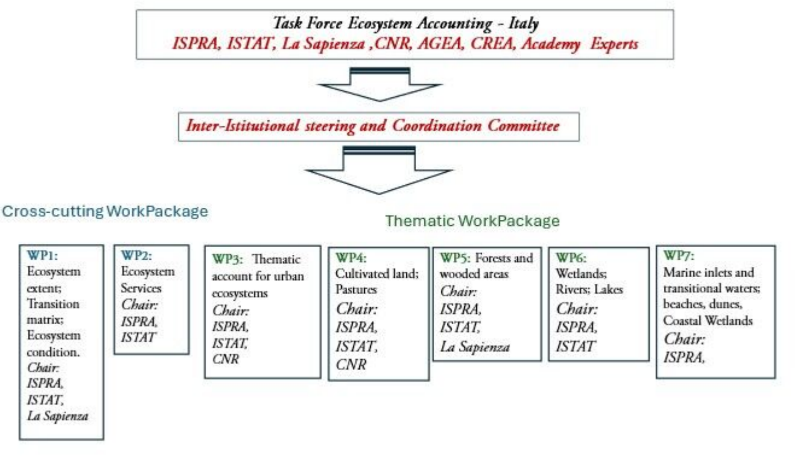

Figure 1.

Diagram of the current governance on ecosystem accounting in Italy.

This section outlines the procedures used to estimate the physical supply and use of seven selected ecosystem services: crop provision, crop pollination, wood provision, air filtration, global climate regulation, local climate regulation and recreation-related ecosystem services. Each service is assessed using tailored models and indicators that reflect both the ecological processes and the socio-economic context in which the service is generated and used. The INCA Tool operates as a hybrid system: for some ecosystem services, it provides standardised default datasets (e.g. European land-cover maps, default carbon stock tables, productivity proxies), while others allow or require users to upload custom national data inputs, such as forest inventories, agricultural production statistics or pollutant concentration maps. In our case, the outputs still rely on European defaults. Supply tables allocate the ecosystem contributions by ecosystem type, while use tables link these flows to economic sectors or population groups, depending on the nature of the service. Some services, such as crop and wood provision are measured using data from material flow or forest accounts, while others, such as pollination, local cooling and recreation require the integration of geospatial models with behavioural or ecological parameters. Services that address global benefits, such as carbon sequestration and air filtration, are treated as collective contributions. The following subsections describe, for each service, the conceptual basis, formulae applied, data sources and the structure of the supply and use tables.

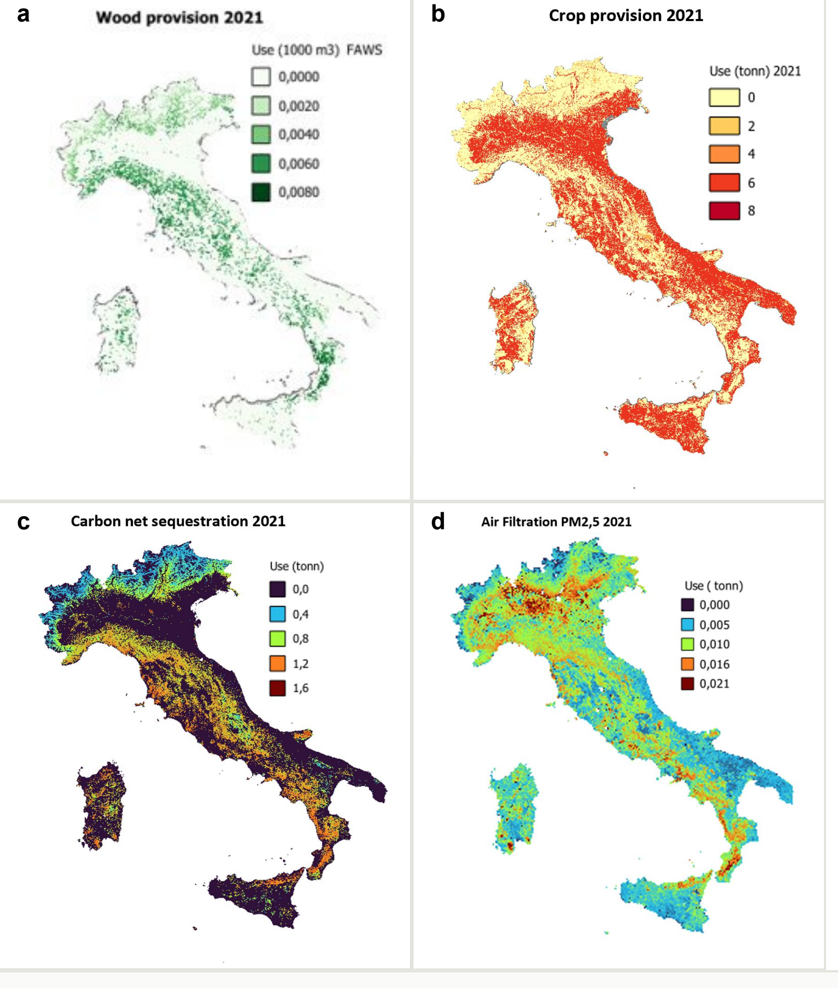

Figure 2.

Maps of ecosystem service uses: Wood Provision (1000 m^3), Crop provision (tonn), Global Climate regulation (tonn) and Air Filtration (tonn).

Wood Provision Ecosystem Service

The wood provision ecosystem service accounts for the ecosystem contribution to tree growth which is measured by the net increase in timber stocks or by removals in the case of uncultivated forests. This definition is in line with the Regulation (EU) 2024/3024 and with the SEEA EA and the forthcoming Forest Accounts module. In cultivated forests (forests available for wood supply, FAWS), wood provision is quantified by the net annual increment:

$$Net\ Annual\ Increment = Gross\ Growth - Natural\ Mortality$$
(eq. 1),

where gross growth and mortality are measured in cubic metres overbark with the reference year for this study being 2021. This indicator reflects the progressive ecosystem contribution to economic outputs. In non-cultivated forests (forests not available for wood supply, FNAWS), ecosystem service flow is approximated by timber removals, as growth occurs outside the production boundary. Removals from FNAWS are considered a voluntary reporting item. In other wooded land and tree cover, removals are used where forests are not formally classified. The *supply table* allocates wood provision to ecosystem types, based on forest inventory data, usually assigning the net increment from forests and woodlands. Minor flows from cropland, grassland or settlements are included where data are available. The *use table* assigns the ecosystem service primarily to intermediate consumption by industries (e.g. forestry, logging) and, in the case of removals by households (e.g. firewood collection), to households' final consumption. For cultivated forests, we have considered:

$Supply(m^3) = Net\ Increment(FAWS)$ (eq. 2).

In uncultivated forests:

$Supply(m^3) = Removals(FNAWS)$ (eq. 3).

Data Sources and Key Considerations

Primary data are derived from: Forest accounts, National Forest Inventories, Pan-European Questionnaire of UNECE/FAO, Agricultural statistics for tree cover outside forests. In Italy, almost all trees are to be considered 'cultivated' and available for wood supply. Exceptions are only integral reserves and inaccessible areas. As national data on net increment and removals by ecosystem type are unavailable, a mapping approach, based on land use classes (Copernicus productivity map), has been adopted as an alternative. This accounting approach ensures coherence with national accounts principles and also highlights the critical role of ecosystems in generating timber resource across varied land management contexts.

Regarding double counting with climate regulation services (e.g. carbon sequestration), no adjustments were applied in the physical accounts. This is consistent with the SEEA EA framework, which recommends treating biomass-related provisioning and regulating services separately in physical terms, while ensuring alignment at the integration stage of analysis.

We also note that greenhouse, orchard and urban trees are mentioned in the accounting guidelines as potential contributors to wood provisioning. However, in this study, they were not included in the final calculations due to the lack of harmonised, spatially explicit national data covering these tree stocks. Future updates may consider their inclusion if data availability improves.

Crop Provision Ecosystem Service

The crop provision ecosystem service accounts for the ecosystem contribution to plant growth, as estimated by the amount of harvested crops for food, fibre, fodder, energy and grazed biomass. In accordance with the Regulation (EU) 2024/3024, the measurement approach aligns with the Economy-Wide Material Flow Accounts (MFA), which use the 'harvest approach', to record domestic extraction at the point of harvest. According to this method, crop provision encompasses all marketed and non-marketed harvested crops, including losses on the farm and during transportation, but excluding in-field losses and residues left unharvested. Conceptually, crop provision combines the SEEA EA categories of 'crop provisioning' and 'grazed biomass provisioning' services. Livestock provisioning is excluded to avoid double-counting and only cultivated crops (MFA sections 1.1 and 1.2) are considered, excluding wild biomass. All forms of agriculture are included regardless of management intensity, acknowledging that even highly intensive farming relies on ecosystem functions such as photosynthesis. For items reported in hectares, mass is estimated using:

$$Harvested\ Mass(tonnes) = Area(ha) \times Yield(tonnes/ha)$$
(eq. 4).

The Crop provision supply table allocates the harvested biomass to cropland or grassland ecosystems. Harvested biomass was assigned to cropland by default, except in cases where the source data or the classification within the Material Flow Accounts (MFA) explicitly referred to grazed biomass, which was then allocated to grassland. Where possible, it distinguishes between production in urban areas (e.g. greenhouses) and elsewhere. If more than 5% of a crop's national output is produced in permanent greenhouses, this should be allocated to 'settlements and other artificial areas', separately. Otherwise, it may be pragmatically attributed to cropland. The *use table* primarily assigns the ecosystem service flow to intermediate consumption by industries, notably agricultural holdings that produce for the market or for their own intermediate consumption. Conceptually, exports of ecosystem services are excluded, as ecosystem service flows occur within the domestic economy only, in line with the SEEA EA accounting principles.

Data Sources and Key Considerations

The primary data sources are MFA datasets and Eurostat crop production statistics. In agreement with ISTAT, we decided to adopt MFA as main source for the operation of the INCA Crop Provision tool, as for Italy, it shows a more complete dataset with respect to agricultural statistics including floriculture, family garden production and crop residues. If national geospatial datasets or registries of agricultural parcels are available, a spatially explicit bottom-up approach may be considered for future improvements.

Crop Pollination Ecosystem Service

The crop pollination ecosystem service represents the contribution of wild pollinators to crop production, as defined in Regulation (EU) 2024/3024. This service is reported as the ecosystem-attributed portion of pollinator-dependent crop yields, measured in tonnes and disaggregated by crop type. Pollination account focuses exclusively on wild pollinators, excluding managed honeybees. The ecosystem contribution is modelled, based on habitat suitability for pollinators, landscape structure and crop type dependency on pollination. The estimation framework relies on a five-step geospatial model:

- **Habitat Attribution**:
  Habitat Attribution is performed by overlaying the CORINE Land Cover 2018 dataset with additional layers accounting for linear features (e.g. hedgerows, irrigation canals) and land management practices (e.g. organic farming, semi-natural elements). These factors should be integrated using expert rules derived from the EU MAES and INCA guidance.

- **Habitat Suitability Mapping**: The Expert-Based Suitability Index (EBSI) combines species occurrence data, floral resource availability and nesting site potential. Values for FA and NA were derived from literature-based scores per land-cover type, as specified in the INCA methodological documentation. The index ranges from 0 (unsuitable) to 1 (highly suitable) and serves as a proxy for wild pollinator habitat quality:

$$EBSI_{ij} = \frac{FA_{ij} + NA_{ij}}{2} \times c1_{ij}c2_{ij}$$
(eq. 5),

where FA = floral attractiveness, NA = nesting attractiveness, c1 and c2 are correction factors.

- **Pollinator Activity Adjustment** correcting EBSI based on forage activity, modelled via:

$FAI_{ij} = -39.3 + 4.01 \times T_{blackglobe}$ (eq. 6),

$T_{blackglobe} = -0.62 + 1.022 \times T + 0.006 \times R$ (eq. 7), where ij is the pixel for ecosystem types, T = ambient temperature (°C) and R = solar irradiance (Watt/m^2). The corrected habitat suitability becomes:

$$EBSI_{final} = \frac{EBSI_{ij} + FAI_{ij}}{100}$$
(eq. 8).

- **Pollinator Demand Mapping**: identifying the spatial distribution of pollinator-dependent crops and their specific dependency rates.
- **Supply and Use Estimation**: linking suitable habitats to crops through distance-based foraging constraints, assigning pollination contributions proportionally.

Pollination contributions are aggregated per ecosystem type and crop class using the Service Provision Area (SPA) model:

$$SPA_k = \omega_1 \times EBSI_k + \omega_2 \times SGSI_k$$
(eq. 9),

where ω are weights (default ω1 = ω2 = 0.5) and SGSI denotes species group suitability index.

The *supply table* attributes pollination services to ecosystem types hosting nesting habitats, while the *use table* records the service as intermediate consumption by the agricultural sector. No aggregation with the crop provision service should occur, avoiding double counting.

Data Sources and Key Considerations

Key inputs include geospatial land-cover maps, species occurrence data, crop-type maps and meteorological datasets. National datasets would be preferred for accuracy; however, for the time being, European defaults (e.g. Copernicus, Eurostat) are used given current data limitations at the national level. Crop types are not reported in spatial distribution and this lack of location information implies that the pollination model is imprecise both in spatial distribution and in the physical amount of pollination to be assigned.

Global Climate Regulation Ecosystem Service

The global climate regulation ecosystem service quantifies the role of ecosystems in the sequestration and storage of carbon, thus mitigating global climate change. Following Regulation (EU) 2024/3024, it focuses on the net exchange of greenhouse gases (GHGs), mainly carbon dioxide (CO_2), reported in tonnes of CO_2 equivalents (tCO_2eq) per year. Global climate regulation is split into two parts: annual carbon net sequestration and long-term carbon retention. For net sequestration, the INCA-tool requires LULUCF GHG inventories, which subtract carbon emissions (emitted by society) from the estimated uptake of carbon by ecosystems in order to calculate the net uptake. European or national GHG inventories can be used for this purpose. Optional spatial data can be added to account for carbon emissions not included in the GHG inventory, specifically those from unmanaged forests, wetlands and peatlands that have not been reported. A European productivity proxy map is used to represent gross primary biomass productivity and to model the spatial distribution of net sequestration. The aim of the carbon retention model is to calculate the difference between the opening and closing stocks of carbon for the reporting period. This can be achieved using either the gain-loss or stock-difference method.

For carbon retention, the tool offers two options:

- The gain-loss method, which calculates the net annual change in carbon stocks as the difference between carbon gains (e.g. biomass growth) and losses (e.g. harvesting, disturbances);
- The stock-difference method, which computes the difference in total carbon stocks (aboveground, belowground and soil carbon) between two time points.

Both methods require different input data, but they both calculate and spatially distribute aboveground, underground and soil carbon stocks for the reporting area.

The *supply table* allocates carbon sequestration by ecosystem type, based on land cover and ecosystem function. The *use table* attributes the service collectively to society, reflecting its global nature.

Data Sources and Key Considerations

We used EUROSTAT statistics on greenhouse gas emissions combined with European forest productivity data as a proxy map for modelling net annual carbon sequestration. In order to calculate carbon retention, we used the gain-loss baseline stock method with a look-up table on carbon stocks per ecosystem type that allowed us to estimate the extent of the ecosystems' carbon stocks.

This included forests, grasslands, croplands and wetlands. Carbon pools considered were aboveground biomass, belowground biomass, litter, deadwood and soil organic carbon. It is important to note that, while the tool facilitates the technical workflow, accurate results depend heavily on the availability of national spatial datasets for carbon density and land-cover change. In the absence of national inputs, as in our case, the tool uses EU-level proxies with known limitations in granularity.

Local Climate Regulation Ecosystem Service

The local climate regulation ecosystem service quantifies the contribution of ecosystems to moderating local temperature extremes, especially the reduction of heat stress. According to Regulation (EU) 2024/3024, it is expressed as the cooling potential provided by ecosystems, measured in degree-days (°C·days) avoided per year. The definition of thermal comfort threshold, used to identify “heat stress days”, follows standard practice in urban climate modelling and typically ranges from 25 °C to 30 °C, depending on local climatic conditions. In this study, we applied a threshold of 25 °C, which aligns with INCA Tool defaults and is supported by literature on human thermal discomfort and health risk (e.g. urban heatwave classification in Europe). This service is based on the ability of ecosystems, particularly vegetated areas, to reduce surface and air temperatures through shading, evapotranspiration and changes in surface albedo.

Measurement Framework

The supply of local climate regulation is modelled using the potential temperature difference between vegetated and non-vegetated areas, scaled over time and space:

$Cooling\ Potential = (\Delta T) \times (Days\ with\ Heat\ Stress)$ (eq. 10),

where:

- ΔT = average temperature reduction (°C) attributable to ecosystem cover;
- Days with Heat Stress = number of days exceeding a defined thermal comfort threshold (e.g. 25°C) .

Ecosystem cooling effects are primarily estimated from land surface temperature (LST) observations, adjusted by land-cover class and urban structure.

Key Formula

When geospatial modelling is used, the avoided heat stress is calculated as:

$Avoided\ Heat\ Exposure = \sum(A_i \times \Delta T \times D_i)$
(eq. 11),

where:

- A_i = area of ecosystem type i;
- ΔT_i = average temperature reduction for ecosystem type i;
- D_i = number of heat stress days in area i.

The *supply table* allocates the cooling benefit to ecosystem types such as forests, urban green areas, grasslands, wetlands and waterbodies. The service is attributed to urban and rural populations collectively as societal use and, therefore, no individual economic sector is identified as a user.

Data Sources and Key Considerations

Primary inputs include land-cover and land-use datasets (e.g. Copernicus Urban Atlas, CORINE), satellite-based land surface temperature products (e.g. MODIS, Sentinel-3) and local meteorological data for defining heat stress thresholds. When available, high-resolution urban morphology and vegetation structure data could improve accuracy.

The modelling approach considers only the warm season (typically April to September), when vegetation-driven cooling effects are most relevant. Cooling contributions are particularly pronounced in urban–rural transition zones, where vegetation cover helps mitigate the urban heat island effect. In addition to physical cooling, the service yields co-benefits for public health and labour productivity by reducing exposure to heat stress, particularly in densely populated areas.

Air Filtration Ecosystem Service

The air filtration ecosystem service represents the removal of air pollutants by ecosystems through dry deposition processes, thus improving ambient air quality. It does so by considering spatial data on leaf area, pollution concentrations and wind speed and allowing for input of monthly data, seasonal data or annual data. Regardless of the chosen timestep, the output is aggregated over the chosen reporting year. The model can be used to simulate either PM2.5 or PM10, provided that data on the chosen fraction are available. However, it only models the supply of the ecosystem service, not its actual use, which is obtained by relating the supply to population density across space. Air filtration supply is quantified, based on the dry deposition flux calculated via the model:

$F = C \times V_d$ (eq. 12),

where:

- F = pollutant flux (μg/m²/s);
- C = ambient concentration of the pollutant (μg/m³);
- V_d = deposition velocity (m/s).

Deposition velocity is derived using the resistance model:

$\frac{1}{V_d} = R_a + R_b + R_c$
(eq. 13),

where:

- R_a = aerodynamic resistance;
- R_b = boundary layer resistance;
- R_c = canopy resistance.

Each resistance term depends on ecosystem type, vegetation characteristics (e.g. Leaf Area Index), meteorological conditions (temperature, humidity, wind speed) and pollutant properties.

The *supply table* allocates pollutant removal to ecosystem types according to the spatial distribution of vegetation and land cover. Ecosystem types with substantial vegetative cover (e.g. forests, grasslands, wetlands) show higher removal capacities. The *use table* assigns the air filtration service as a non-market benefit consumed collectively by society. No economic sector is identified as an individual user.

Data Sources and Key Considerations

Concentration fields are obtained from validated air quality models or monitoring networks (e.g. Copernicus Atmosphere Monitoring Service). Deposition velocities use standard parameterisations or national models when available. The modelling process accounts only for the vegetative growing season, during which active pollutant removal by leaves occurs. Any negative fluxes i.e. cases where vegetation acts as a source rather than a sink of pollutants, are set to zero to avoid offsetting positive removal values. Final ecosystem service values are obtained by aggregating hourly or daily fluxes across the year and across spatial units, yielding an annual total in tonnes removed.

Recreation-Related Ecosystem Services

According to the EU Guidance Note on ecosystem services accounts, the default methodology for measuring recreation-related ecosystem services relies on official tourism statistics, particularly the number of overnight stays. These figures serve as a proxy for the recreational use of ecosystems by both domestic and international visitors. To assign these overnight stays to specific ecosystem types, the methodology uses a spatial allocation matrix, based on recreational suitability and accessibility. This matrix links observed tourism flows to ecosystems likely to contribute to the recreational experience, such as forests, grasslands, coastal zones and inland waters. Two main variants of this approach can be adopted depending on data availability and the desired granularity: Method D1, Extended Allocation Approach: this method distributes overnight stays more broadly across multiple ecosystem types, including those that may not host accommodation facilities directly, but offer substantial recreational value (e.g. forests, lakes, mountain areas). It emphasises the multifunctionality of natural areas and the role of ecosystems in attracting visitors beyond built infrastructure. Method D2, Refined/ Filtered Allocation Approach: this method applies stricter spatial filters, allocating overnight stays primarily to ecosystems in direct proximity to tourist infrastructure or reported accommodation locations. As a result, ecosystems, like cropland and artificial surfaces, may receive a higher share of tourism values, while more remote or dispersed ecosystems may be under-represented. Both methods maintain the core principle that recreation is a final consumption service. Accordingly, the service is allocated to households (for domestic tourism) and exports (for non-resident visitors). The choice between D1 and D2 reflects a trade-off between capturing the broader recreational function of landscapes (D1) and maintaining a conservative link to actual recorded accommodation patterns (D2).

Data Sources and Key Considerations

Inputs include land-use and land-cover maps (e.g. Copernicus, CORINE), demographic data (population density grids), road networks and accessibility data, recreation site inventories (parks, trails, beaches). Where national visitation data are available (e.g. tourism or parks statistics), they should be used to calibrate and validate the model. Calibration of the model requires a two-stage pathway, consisting of quantification of the service, based on supply data and the subsequent distribution to the ecosystem types

(Supply table), based firstly on what was found in households. The methodology ensures comparability across Member States, while also allowing flexibility to use nationally relevant data and models to improve the precision with which recreational ecosystem service flows are estimated.

Urban green spaces represent crucial providers of recreational services, particularly for daily and frequent use, offering accessible opportunities for outdoor activities and well-being to urban residents. Seasonal variability plays an important role in determining visitation rates, which tend to fluctuate across the year; therefore, annual estimates of recreational use should, where possible, account for these seasonal patterns to provide a more accurate picture of demand. In highly urbanised contexts, it is also important to consider the phenomenon of visitor displacement, whereby excess demand for recreation in urban areas may "overflow" to nearby rural ecosystems, influencing both the spatial distribution of visits and the associated service values.

Results

Wood Provision - Supply and Use Table

The total wood provision in Italy in 2021 is reported as 30,018.58 thousand m^3 (Suppl. material 1), fully attributed to the "Forest and woodland" ecosystem category. This is consistent with the methodological scope of the account, which considers only productive forest areas within the FAWS definition. All other ecosystem types, including cropland, grassland, wetlands and artificial or marine areas, are assigned zero or missing values, confirming that they are either excluded by definition or non-contributory to wood production in this context. The result reflects the ecosystem growth capacity in cultivated forests, aligned with the accounting principle of measuring the ecosystem service flow at the point of production (i.e. increment or harvest), not at the point of transformation or consumption. In the use table (Suppl. material 2), the entire volume of wood provision (30,018.58 thousand m^3) is attributed to intermediate consumption by industries, particularly the forestry and wood processing sectors. No volume is allocated to final consumption (households or government), capital formation or exports within this table. This allocation is coherent with the SEEA EA principle that ecosystem services should be recorded at the first point of use, in this case, the economic sectors that harvest and process wood, rather than final consumers.

The wood provision account presented in this study refers to the reference year 2021, consistent with the scope of this first national experimental account and offers a focused and a first indicative estimate of the ecosystem contribution of Italian forests to the national wood supply chain and might be instrumental for integrating ecosystem accounts with forest management and resource policy, especially in the context of bioeconomy, circularity and climate-smart forestry. The results confirm that forest ecosystems are the sole suppliers of this service within the FAWS scope and the accounting method faithfully reflects the biophysical potential of forests to provide renewable material flows. The service is entirely absorbed by the industrial sector, enabling downstream economic activities and value chains.

Crop Provision - Supply and Use Table

The total volume of crops harvested in Italy in 2021, as attributed to ecosystem contribution, amounts to approximately 55.45 million tonnes. This value is distributed across a wide range of crop categories, with the following key contributors: Fruits: 17.2 million tonnes, Vegetables: 13.7 million tonnes, Cereals: 16.3 million tonnes, Oil-bearing crops: 3.5 million tonnes, Sugar crops and roots/tubers: together approx. 3.3 million tonnes (Suppl. material 1). The entire supply is attributed to cropland ecosystems, which provide 100% of the service flow. All other ecosystem types (e.g. grasslands, wetlands, forests, artificial areas) register zero contribution in the supply matrix, which is consistent with the methodological choice of including only cultivated crops (as per MFA classes 1.1 and 1.2). This aligns with the regulation's exclusion of wild biomass and uncultivated land. The only exception is a placeholder column for “settlements and artificial areas”, which also shows zero supply, indicating that greenhouse or urban agriculture was either negligible or not disaggregated in this dataset. The crop provision account for 2021 offers a coherent and policy-relevant quantification of the ecosystem contribution to agricultural biomass production in Italy. The results emphasise the dominance of cropland ecosystems as service providers, reinforce the direct link between natural processes (e.g. soil fertility, rainfall, solar energy) and productive agricultural output, regardless of farm management intensity and provide a robust baseline for integrating ecosystem services into agricultural and land-use planning. The use of the crop provision service (Suppl. material 2) is entirely attributed to intermediate consumption by industries, particularly the agricultural sector itself. No flows are assigned to final consumption by households, government, capital formation or exports, which reflects the accounting logic of ecosystem services being recorded only at the point of first use (not downstream in the supply chain). This avoids double counting and aligns with SEEA EA principles.

Crop Pollination - Supply and Use Table

Results of the model-based method

The 2021 results obtained using the model-based approach indicate a total provision of 145.2 million tonnes of pollination-dependent crop output. The supply table reveals that:

• The vast majority of the service is supplied by cropland ecosystems, with a total of approximately 105.9 million tonnes, representing about 73% of the national total;

• Forests and woodlands contribute an additional 31.7 million tonnes, which underscores their role in hosting wild pollinators in the vicinity of productive agricultural land;

• Other ecosystem types provide smaller, but non-negligible contributions: grasslands (1.16 Mt), heathland and shrub areas (2.68 Mt) and sparsely vegetated ecosystems (1.04 Mt);

• Wetlands, coastal dunes and artificial areas also show measurable contributions, notably settlements and artificial areas (1.79 Mt), likely reflecting the role of urban green infrastructure (Suppl. material 1).

The use table matches the total supply, attributing the ecosystem service as intermediate consumption by the agricultural sector, disaggregated across crop types (Fig. 3). The most significant crop groups benefitting from pollination include: Apples (APPL) – over 43 Mt, Oil-bearing crops – each contributing between 11.5 and 16.5 Mt, Citrus (CITR) and other fruits (OFRU) also exhibiting high dependency. This level of disaggregation provides a detailed picture of the functional linkage between ecosystem supply and agricultural output, supporting both biodiversity and agri-food policies.

Results of the MFA-based method

The alternative estimation, based on the Material Flow Accounting (MFA) approach, reports the same total volume of 145.2 million tonnes in the supply table and the distribution of supply across ecosystem types is identical to the model-based method. This reflects a shared underlying mapping of ecosystem areas and their potential contribution to pollination. However, the use table in the MFA file classifies beneficiaries by aggregated commodity groups, such as: Fruits – 72.8 million tonnes, Oil-bearing crops – 61.2 million tonnes, Fibres, pulses, vegetables – each around 3.3 million tonnes. Here, the total use remains identical (143.98 Mt), but crop-specific information is less granular. This categorisation aligns with MFA categories typically used in national material flow accounts. Although the total national figures are identical across the two methods, significant differences emerge in how the service is distributed and represented. Both approaches identify cropland as the primary source of the ecosystem service and attribute the full amount of pollination benefit to agricultural production within the domestic economy. However, the model-based method enables a finer interpretation of which specific crops are most dependent on pollination, revealing that apple production alone accounts for almost one third of the use, followed by oil-bearing crops and citrus. In contrast, the MFA-based method aggregates usage into broader commodity classes, thereby concealing crop-level heterogeneity and the varying degrees of pollinator dependency across agricultural systems. Furthermore, some ecosystem types, such as settlements and sparsely-vegetated areas, show non-trivial supply figures under both methods, suggesting the presence of wild pollinator habitat beyond traditional agricultural zones. These differences stem not from the methodology, but from the allocation of the same ecosystem service volume to different output categories. Thus, while the quantitative totals coincide, the interpretative value of the results differs. The model-based results support targeted ecological interventions and pollinator conservation strategies at the crop level, while the MFA-based output is better suited for macro-level accounting and integration with economic flows in environmental-economic accounts.

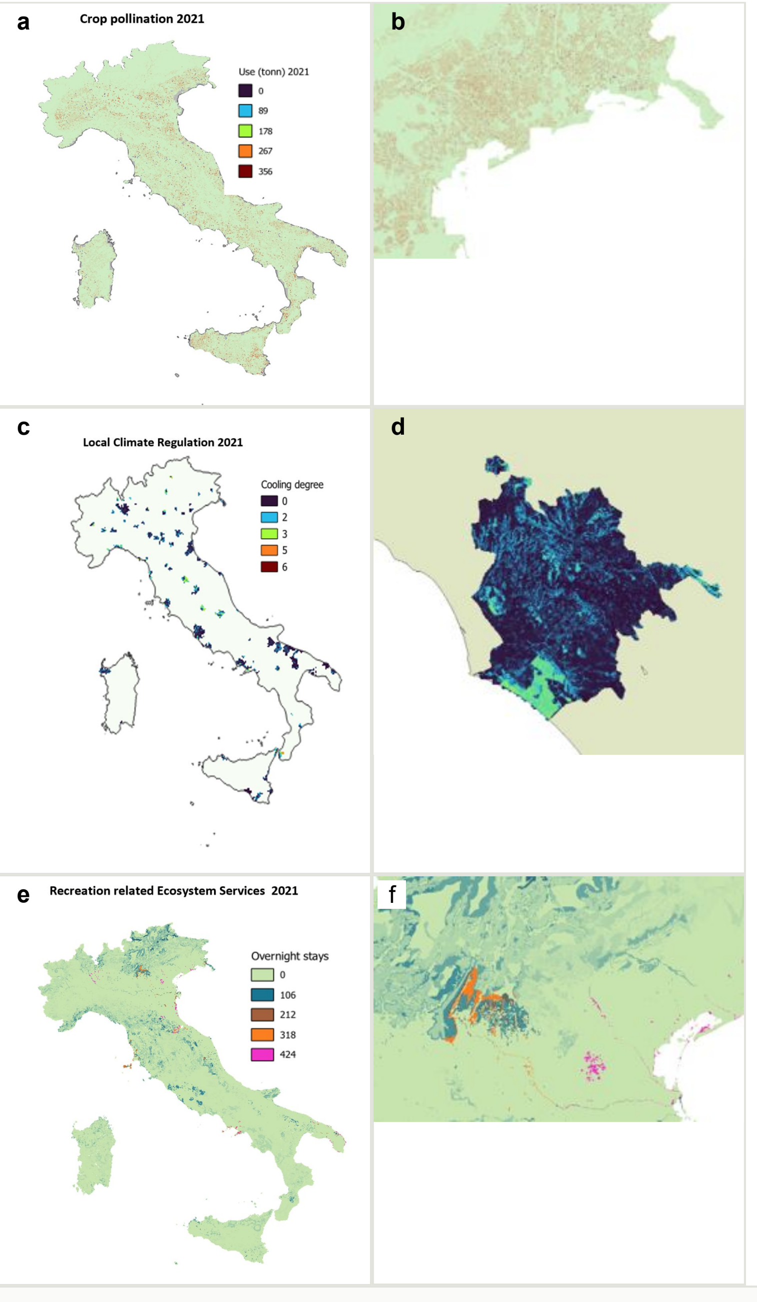

Figure 3.

Maps of ecosystem service uses: Crop Pollination (tonn), Local Climate Regulation (°C) and Recreation (overnight stay).

Global Climate Regulation - Supply and Use Table

Results of the Carbon Retention Method

The carbon retention approach aims to capture the gross ecosystem contribution to climate regulation by accounting for the total amount of carbon dioxide removed from the atmosphere through biological processes, independently of any emissions. According to the 2021 data:

• Forests and woodlands are the dominant ecosystem type, contributing approximately 883.8 million tonnes of CO_2 equivalents, representing the largest share by far of total carbon retention (Suppl. material 1);

• Other significant contributors include cropland (936.9 Mt CO_{2e}) and grasslands (99.9 Mt CO_{2e}) , the latter often underestimated in carbon budgets;

• Heathlands and shrubs (101.7 Mt), sparsely vegetated ecosystems (137.3 Mt) and coastal systems, such as dunes and wetlands (8.8 Mt) also show notable contributions, underscoring the multifunctional climate role of marginal ecosystems;

• Wetlands and aquatic systems (inland wetlands, rivers, lakes and transitional waters) show modest, but non-negligible levels of carbon retention (ranging from 1.4 to 16.9 Mt), likely reflecting vegetated surface areas and high productivity;

• Marine offshore ecosystems are attributed no retention, consistent with methodological constraints or data gaps.

These results provide a broad overview of ecosystems' maximum potential to contribute to carbon removal and are especially useful for evaluating restoration potential and theoretical ecosystem functioning.

Results of the Carbon Net Sequestration Method

The net sequestration method measures the actual net balance between carbon removals and emissions within ecosystems, following the SEEA EA standard and aligned with GHG inventories. The 2021 results present a substantially different picture:

• Forest and woodland areas show a net sequestration of 7.9 million tonnes CO_{2e}, a dramatic reduction compared to the gross removal figure;

• Grasslands contribute only 0.9 Mt CO_{2e} and all other ecosystems report zero net sequestration, indicating either a neutral or negative carbon balance;

• This includes croplands, wetlands, sparsely vegetated areas and marine systems, suggesting that emissions from degradation, drainage or land management fully offset natural uptake.

The earlier figure (Fig. 2) reveals the limited net mitigation currently delivered by ecosystems, a signal of ecosystem degradation or unsustainable land-use practices. The comparison between net carbon sequestration and carbon retention across ecosystem types highlights the complementary nature of these two indicators. Net sequestration reflects actual carbon fluxes between the biosphere and the atmosphere. In contrast, carbon retention captures the stability of long-term carbon stocks, which is particularly relevant for climate policy. For example, while forests retain 883.8 Mt CO_2e under the gross method, they only sequester 7.9 Mt net, a difference of over 99%, illustrating how emissions and removals interact. The low figures of the net sequestration method suggest that emissions from degradation, drainage or land management fully offset natural uptake. Limited net mitigation observed in some ecosystems could be related to land-management patterns, but further investigation is needed to assess the extent to which these practices are sustainable. The discrepancy between the two methods highlights the importance of using both approaches complementarily: the retention-based accounting proves particularly useful for ecosystem potential assessments and biodiversity-linked strategies, the net sequestration method is more indispensable for compliance reporting, climate finance and carbon neutrality pathways.

Local Climate Regulation - Supply and Use Table

The total cooling service recorded is 0.6725°C, distributed as follows:

• The largest contributors are: Cropland : 0.3418°C, accounting for more than 50% of the national total and Forest and woodland 0.2418°C;

• Settlements and artificial areas contribute a very low amount (0.0491°C), reflecting urban vegetation or green infrastructure in built environments.

The data reflect spatially modelled differences in land surface temperature, moderated by vegetation cover during the warm season. The absence of values for marine ecosystems is consistent with the methodology’s focus on terrestrial cooling effects. The entire service flow is attributed to household final consumption, with a total of 0.6725°C perfectly matching the supply. No portion of the service is allocated to industries, government, capital formation or exports. The 2021 accounting of local climate regulation in Italy illustrates some key points. Cropland and forest ecosystems together supply over 85% of the national cooling potential, reaffirming the importance of vegetated landscapes in mitigating heat. Even non-agricultural ecosystems, such as wetlands and shrublands, provide measurable contributions, which may be locally relevant. Accordingly, the entire benefit is allocated to households final consumption, with a total of 0.6725 units. This use structure aligns with the conceptual framing of local climate regulation as a non-market, collective benefit primarily being received by the population in terms of improved thermal comfort, reduced health risks and enhanced urban livability. These results might provide a policy-relevant entry point for integrating local climate regulation into spatial planning, urban greening and environmental equity strategies.

Air Filtration- Supply and Use Table

PM2.5 Filtration Results- Supply and Use

The total removal of PM2.5 (fine particulate matter) by ecosystems in Italy during 2021 amounts to approximately 224.2 thousand tonnes. According to the supply table:

• the largest contributors to PM2.5 filtration are: Cropland 107.5 kt and Forest and woodland 84.7 kt;

• additional contributors include: Grassland 8.4 kt, Heathland and shrub 6.9 kt, Sparsely vegetated ecosystems 6.5 kt, Settlements and artificial areas 9.6 kt.

Minor contributions are observed from wetlands, rivers and coastal areas, though marine ecosystems are not assigned any filtering function in this account.

PM10 Filtration Results

For PM10 (coarse particulate matter), the total amount removed by ecosystems is reported as 263.2 thousand tonnes, following a similar distribution pattern across ecosystem types:

• The primary contributors are again: Cropland 121.8 kt and Forest and woodland 100.2 kt;

• Further contributions come from: Grassland 10.0 kt, Heathland and shrub 9.5 kt, Sparsely vegetated ecosystems 8.0 kt and Settlements and artificial areas 11.4 kt Additional minor amounts are recorded for wetlands, rivers, lakes and coastal areas. Marine ecosystems again register zero. The use table mirrors the PM2.5 account: all benefits are assigned to households, consistent with the classification of this service as a public good, particularly relevant for urban health and well-being.

Comparative Interpretation

Although both pollutant types (PM2.5 and PM10) follow the same accounting structure, their quantitative outcomes differ:

PM2.5 = 224.2 kt;

PM10 = 263.2 kt.

Key points of comparison:

• Absolute filtration is higher for PM10 across all ecosystem types, as expected due to the generally larger size and higher atmospheric abundance of PM10 particles;

• Relative contributions from different land-cover types are very similar between the two pollutants: cropland and forests remain the top contributors, followed by shrublands and grasslands;

• Households are the sole beneficiaries in both accounts, underlining the non- market, social nature of this ecosystem service.

The results of the two methods, one for PM2.5 (224.2 kt) and one for PM10 (263.2 kt), show similar spatial patterns, but different total volumes of filtration (Fig. 2). PM10, being more abundant and coarser in particle size, results in higher absolute values of removal across all ecosystems. These results illustrate how vegetated ecosystems —especially cropland and forest — play a vital role in removing atmospheric pollutants, contributing directly to public health outcomes. The distinction between PM2.5 and PM10 allows for a more granular understanding of the filtration function and supports targeted urban greening and land-management policies. In the use table, 100% of the service is attributed to households' final consumption, with no allocation to industries or government. This reflects the collective, non-market benefit of air purification as a public health service delivered by ecosystems. Despite the difference in pollutant type, both accounts confirm the dominant role of cropland and forests in atmospheric filtration, followed by shrublands, grasslands and vegetated artificial areas. These results highlight the multifunctional importance of vegetated ecosystems, not only in rural areas, but also in urban contexts. The exclusive allocation of the service to households in both cases is consistent with the *Guidance* and with the classification of air filtration as a non-market ecosystem service contributing to collective well-being.

Recreation- Supply and Use

In this account, the service is measured through the number of overnight stays in areas associated with ecosystem enjoyment. These results provide an essential baseline for integrating recreation-related ecosystem services into land-use planning, rural development and tourism strategy, as foreseen by the Regulation and the Guidance. The comparison between D1 and D2 reveals significant differences in the quantification and distribution of the recreation-related ecosystem service. Method D1 (Extended Allocation Approach) reports almost twice the volume of overnight stays compared to method D2 (Refined/Filtered Allocation Approach): 289.2 vs. 148.7 million (Suppl. material 1). This reflects a broader allocation of tourism to ecosystem types in D1. Furthermore, while D1 heavily emphasises forest and semi-natural habitats (e.g. grassland, heathland), attributing most of the tourism value to them (this highlights their multifunctionality, offering provisioning and recreational benefits simultaneously), D2 shifts some weight towards cropland and artificial areas, likely based on a stricter spatial linkage between tourism facilities and ecosystem presence. Water ecosystems, such as lakes and rivers, receive far less recognition in D2. These differences highlight the sensitivity of recreation service accounting to the underlying assumptions and spatial models used. While method D1 offers a more comprehensive view of potential recreational use, method D2 is more conservative and may align more closely with actual overnight accommodation patterns. In terms of use allocation, both methods assign the entire service to households (domestic tourism) and exports (non-residents) (Suppl. material 2), aligning with the SEEA EA principle that recreational services are final consumption benefits. However, D1 reports a significantly larger value in both categories, reinforcing Italy's global role as a nature-based tourism destination.

Discussion

As we have seen, the INCA-Tool requires different datasets for each ecosystem service model. However, it is also necessary for the data to conform to the INCA-Tool requirements set by the model design in terms of content, spatial and temporal resolution and for the data to be available nationwide. If we consider these four criteria, we can assess models for each of the ecosystem services (Table 1).

- Spatial resolution: the closer the input data are to the INCA model's 100-metre resolution, the lower the uncertainty in the results. Higher resolutions allow for a more accurate representation of spatial variations in ecosystems and ecosystem services;
- Temporal resolution: the model produces results for a specific year. Using data from that specific year reduces uncertainty, whereas using data from other years reduces the representative nature relative to the mandatory reporting period;
- Accuracy: input data are often derived from models whose fidelity to reality may vary. The way in which data are collected and aggregated also affects accuracy. Qualitative assessments can be made by considering the representative nature of the models and the collection methods used;
- Data availability refers to the presence or absence of accessible databases. Those that are specially created or non-public are less usable.

Wood Provision

The INCA tool has limited utility in developing national-level Italian accounts for the wood provisioning ecosystem service. Its spatial resolution is insufficient to generate precise national estimates and the temporal resolution is constrained by incomplete data at key time points. Although the tool is relatively accurate, its effectiveness is hindered by the absence of spatial input data tailored for national accounting across the full reporting area. Future improvements could include merging national forest inventory data with detailed land-cover maps to enhance spatial precision. Collaboration with regional forestry agencies may also help broaden the data coverage.

Crop Provision

The INCA tool is well-suited to support Italian crop provisioning accounts, but its effectiveness is reduced by the lack of spatial datasets needed to refine MFA (Material Flow Analysis) data. Without these spatial inputs, the tool does not offer advantages over currently available official statistics. However, for required datasets, both temporal detail and accuracy are high, as they rely on validated statistical sources. To improve spatial relevance, using national agricultural parcel databases could allow for a more granular, bottom-up modelling approach, which would increase the tool's overall value.

Table 1.

Models assessment for each of the Ecosystem Services.

Ecosystem Service	INCA-Tool Capacity	Spatial Resolution	Temporal Resolution	Accuracy	Data Availability	Suggested Improvements
Wood Provision	Limited	Not high enough	Limited	Good	Limited	Integrate national forest inventory with high-res land-cover maps; cooperate with regional forestry services
Crop Provision	Good	No spatial data	High (official stats)	High	Mandatory data available	Explore national agricultural parcel registries for spatial modelling
Pollination	Mixed	Adequate (rough estimates)	Fairly good	Limited (model simplicity, crop location missing)	Limited	Integrate crop distribution and pollinator habitat data; explore citizen-science data
Global Climate Regulation	Limited	No spatial data	High (official data)	Meets minimum	Optional data missing	Link with LULUCF reports; include carbon retention in harvested products
Local Climate Regulation	Mixed	Moderate (large scale)	Low (can be improved via remote sensing)	Limited	Good	Use high-res remote sensing and urban heat island models; include urban morphology data
Air Filtration	Low	Sufficient for model, but not for real use	Relatively good	Low (cannot capture small-scale variation)	Good	Refine model with urban green infrastructure and air pollution dynamics; include co-benefits
Recreation related ES	Limited	Good	High	Not specified	Adequate	Use dedicated surveys; calibrate with two-step modelling (supply and household-based distribution)

Pollination

INCA's ability to support national accounts for pollination services in Italy is variable. While spatial resolution is generally adequate for rough estimates and the data are temporally robust, the model's accuracy suffers due to its simplicity in representing a complex ecological process. The model is also hampered by a lack of data on crop locations and technical constraints that currently prevent national-scale application. Enhancing the model with national datasets on crop distribution and pollinator habitats, such as those from local observatories, could significantly improve precision. Including citizen-science data on pollinator presence may also be beneficial.

Global Climate Regulation

INCA's role in generating Italian accounts for global climate regulation is constrained. There are no suitable spatial data to produce accurate national estimates and temporal coverage is limited by data gaps at certain times. While basic accuracy standards are met, the absence of optional data on unmanaged forests, wetlands and unreported peatlands reduces the completeness of the output. In order to enhance results, aligning INCA estimates with LULUCF (Land Use, Land-Use Change and Forestry) reporting and regional assessments of forest carbon stocks would be advantageous. Incorporating data on carbon storage in harvested wood products may also improve the comprehensive nature of the accounts.

Local Climate Regulation

The INCA tool offers moderate support for Italian accounts of local climate regulation. Current temporal resolution is low, but this could be improved by integrating remote sensing technologies. Model accuracy is also limited: while it can estimate large-scale vegetation effects, it falls short in capturing fine-scale temperature variations. However, core datasets are broadly available. Applying high-resolution remote sensing and urban heat island modelling would enhance spatial accuracy. Additionally, incorporating urban structure and vegetation data, like tree inventories, would better reflect local differences.

Air Filtration

Currently, the INCA tool has limited ability to support national accounting for air filtration services in Italy. While the spatial input data meets model requirements, it is not fine-grained enough to reflect where the service is delivered and used. Temporal coverage and data availability are relatively good, but overall model accuracy remains rather low. This is due to its inability to detect local air quality fluctuations and ongoing debate over the role of vegetation in urban air purification. New research on urban greenery and localised air pollution patterns may help improve the model. Considering co-benefits, such as public health impacts, could also enhance its policy relevance.

Recreation related Ecosystem Services

The tool's ability to generate Italian accounts for nature-based tourism is limited. While it handles temporal data well, the accuracy could improve with specialised surveys. The model likely requires a two-phase process: first quantifying supply-side data, then linking it to ecosystem types, based on household-level information. Further developments could include using mobility data to confirm visitor behaviour. Correlating tourist activity with statistics from protected areas would also increase reliability.

Conclusions

This study offers the first national-scale application of the methodology set out in Regulation (EU) 2024/3024, serving as a pilot test-bed for compiling physical ecosystem service accounts in Italy. While the primary goal was operational, namely to test the feasibility of producing standardised supply and use tables using existing data and official guidance, the process itself revealed a number of insights, challenges and opportunities that hold broader relevance for both practitioners and the academic community.

Key Data Challenges and Methodological Reflections

A critical learning point concerns the data heterogeneity and limitations that emerged across the seven ecosystem services analysed. While some services, such as crop provision or air filtration, benefit from relatively robust and harmonised statistical sources, others, like pollination and local climate regulation, suffer from coarse spatial resolution, lack of national models or oversimplified assumptions in the INCA Tool. We also compared trade-offs between methodological consistency and ecological realism. For instance, the use of both gross and net carbon sequestration methods revealed how different accounting perspectives can lead to drastically different interpretations of the climate role of ecosystems. Similarly, the choice between MFA-based and model-based approaches for crop pollination highlighted the tension between policy-orientated macro-indicators and spatially disaggregated outputs. These reflections underline the need to use complementary approaches, especially during the transition phase towards full harmonisation.

Lessons Learned and Future Directions

From an institutional standpoint, the compilation process demonstrated that cross-body collaboration, particularly amongst ISPRA, ISTAT and other institutional data holders, will be essential to improve the quality and granularity of future accounts. In parallel, the lack of national data aligned with accounting needs remains a critical bottleneck. Addressing this gap through a dedicated ecosystem mapping initiative and environmental data collection at national level is a priority. Moreover, this experience has shown that ecosystem accounts, even when still experimental, can already provide information for broader discussions on data governance and spatial planning. For example, the exclusive allocation of regulating services, such as air filtration or local climate regulation to households, brings attention to public health co-benefits and distributional aspects, elements that can connect ecosystem accounting to policy agendas beyond the environmental domain.

Concluding Remarks

Beyond its operational dimension, this pilot application contributes to a collective learning journey on how to implement the EU regulation in practice. By documenting the estimation challenges, modelling assumptions and interpretative choices, we aim to learn from our first test and share critical perspectives with the other Member States. Ultimately, our findings suggest that, while ecosystem accounting is methodologically complex, it is analytically rich and policy-relevant and that progress will depend not only on technical refinement, but also on institutional innovation and open methodological debate.

Disclaimer

Parts of this manuscript were prepared with the assistance of artificial intelligence (AI) tools, which were used to support language editing and text refinement. The authors have thoroughly reviewed and edited the content to ensure accuracy, originality and compliance with academic standards. No AI tool was used to generate original scientific content, perform data analysis or make scientific conclusions. The authors remain fully responsible for the integrity and validity of the content presented.

Conflicts of interest

The authors have declared that no competing interests exist.

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Supplementary materials

Suppl. material 1: Supply Table doi

Authors: ISPRA
Data type: Table account
Brief description: Supply Table for wood provision, crop provision, crop pollination, global climate regulation, local climate regulation, air filtration and recreation-related Ecosystem Services.
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Suppl. material 2: Use Table doi

Authors: ISPRA
Data type: Table account
Brief description: Use Table for wood provision, crop provision, crop pollination, global climate regulation, local climate regulation, air filtration and recreation-related Ecosystem Services.
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Endnotes

*1 Complete technical guidances are available at https://circabc.europa.eu/ui/group/922b4700-1c83-4099-b550-763badab3ec0/library/fadcbec3-e216-45a3-8439-bc5a7dc6b1b7?p=1&n=10&sort=modified_DESC

*2 https://ecosystem-accounts.jrc.ec.europa.eu/inca-tool