PEOPLE-EA: Earth Observation for Ecosystem Accounting

Ecosystem Accounting is a **statistical framework** to quantify and integrate the value of natural ecosystems, and the services they provide, into national economic planning, accounting (System of National Accounts), decision and policy making. The framework underpins the development of Ecosystem Accounts that **measure the stock, geographic extent and state of natural capital** and the **changes** thereof.

The United Nations System for Economic Ecosystem Accounts (UN **SEEA EA**) offers a **standardized** statistical framework for Ecosystem Accounting. In Europe, this standard was adopted by the European Parliament and Council and amended to the EU Regulation No 691/2011 on environmental economic accounts, which mandates countries to report ecosystem accounts yearly, from 2026 onwards.

Given that the accounts measure the extent of natural capital and location-dependent ecosystem services, Ecosystem Accounts are **inherently spatial** and strongly depend on the availability of spatially explicit datasets. The emergence of dense **Earth Observation (EO) data streams**, like those offered by the EU Space/Copernicus programme, combined with advancements in digital technologies offer **unprecedented opportunities** for countries to monitor ecosystems and account systematically and efficiently for their value. The **Pioneer Earth Observation apPLications for the Environment (PEOPLE) Ecosystem Accounting (PEOPLE-EA)** project financed by the European Space Agency (ESA) developed and demonstrated innovative Ecosystem Accounting applications using EO data streams. This policy brief highlights key outputs of the PEOPLE-EA project and features case studies where the outputs have been implemented.

Key PEOPLE-EA outputs

Ecosystem Extent Accounts

How can I compile ecosystem extent accounts according to the EU Typology?

hEUNIS is an open-source toolbox to transform EO time series data into maps of habitat types that follow the European Nature Information System (EUNIS), as a base for EU extent accounting.

Ecosystem Condition Accounts

How can I assess the condition of an ecosystem?

Aries4People is an open-source, web-based application to compile forest condition accounts in real-time. It aggregates thirteen forest condition variables, using EO data and semantic modelling techniques.

Ecosystem Service Accounts

How can Earth Observation dataset contribute to report for service accounts?

WoodP is an open-source accounting methodology to quantify and track the supply of wood products over time. It calculates the ecosystem contributions to the growth of trees from EO time-series data.

Accessing the PEOPLE Ecosystem Accounting Tools

Demonstrator accounts were generated for five countries (the Early Adopters) within Europe.

Ecosystem account*	Greece	Italy	Norway	Slovakia	the Netherlands
Ecosystem extent	X			X	
Forest ecosystem condition	X	X	X	X	X
Coastal ecosystem condition	X	X			X
Wood provision ecosystem service	X	X	X	X	
Nature-based tourism ecosystem service	X		X		

(*) The Global Climate Regulation ecosystem service was explored but demonstrator accounts could not be generated due to limitations found in the EO input datasets.

In accordance with the **Findable, Accessible, Interoperable, Reproducible (FAIR)** principles, and to enhance knowledge sharing, all algorithms and products from PEOPLE-EA are available on **publicly accessible** environments with transparent access conditions.

	Tool	Codebase	TRL level**
hEUNIS (Ecosystem extent)	Terrascope	Github*	4
Aries4People (Forest condition)	People EA	Github	6
CoastC (Coastal condition)	-	On request	3
WoodP (Wood provision)	-	On request	3
dRPM (Nature-based tourism)	INCA Tool	On request	4

(*) Upcoming
(**) The Technology Readiness Level defines the readiness of the actual system in operational environment (TRL level = 9). The current workflows are still experimental and require further R&D work and validation according to the European Statistics Code of Practice (CoP) before being used for official statistical reporting.

Support to International Policies and Commitments

The outputs and knowledge generated in the PEOPLE-EA project can support the implementation of several international policies and commitments.

European Commission	The amendment of the EU Regulation No 691/2011 on **Environmental Economic Accounts** requires countries to annually report ecosystem accounts (following SEEA EA) from 2026 onwards. The **Nature Restoration Law** (EU Regulation 2024/1991) is crucial to restore the **EU's biodiversity by 2030** and will require to monitor the ecosystem extent and condition.
Convention on Biological Diversity	The United Nations **Global Biodiversity Framework** defined headline indicator A.2 (extent of natural ecosystems) with the aim to increase the area (extent) of natural ecosystems by 2050. Further, headline indicators B8.1 (services provided by ecosystems) and B9.1 (benefits from the sustainable use of wild species) aim to track trends in the provision of ecosystem services.
SUSTAINABLE DEVELOPMENT GOALS	**Target 15.9** of the **Sustainable Development Goals** (SDGs) aims for countries to integrate ecosystem and biodiversity values into national and local planning and development processes. Moreover, SEEA EA accounts are directly relevant to several SDG **indicators** related to ecosystem services, biodiversity, and natural resource management in Goals 14 and 15.
UNFCCC	As part of the **United Nations Framework Convention on Climate Change** (UNFCCC), countries are increasingly required to track and report on **ecosystem-based approaches to climate change mitigation and adaptation** (e.g., REDD+, nature-based solutions).

Other relevant policies and commitments include:

- The **OECD Green Growth Strategy** encourages its member countries to use environmental and ecosystem accounting to measure green growth.
- The **Global Environment Facility (GEF)** and **Green Climate Fund (GCF)** increasingly emphasize the importance of tracking ecosystems and ecosystem services in funded projects.
- The **Global Program on Sustainability (GPS)** from the World Bank Group promotes the use of natural accounting to guide green growth strategies and sustainable development planning, particularly in developing countries.
- The **Ramsar Convention** promotes the use of ecosystem accounting to track the health and benefits provided by wetlands.
- The **Economics of Ecosystems and Biodiversity (TEEB)** initiative focuses on making economic value of biodiversity and ecosystem services visible.
- The **United Nations Decade on Ecosystem Restoration** emphasizes the need for countries to track ecosystem health and progress towards restoration.
- The **Natural Capital Protocol** is a global framework encouraging the integration of natural capital into business decision-making.

Ecosystem Extent Case Studies
Slovakia and Peloponnese

National Statistical Offices (NSO) assess a country's ecosystems at national scale either from the European CORINE Land Cover (Minimum Mapping Unit of 25 hectares) or from an ecosystem extent map derived from a geodatabase with various datasets from agricultural, forestry and nature protection sectors (mostly with inconsistent timesteps and poor delineations). Alternatively, at sub-national level, detailed information on natural classes is available for protected areas (e.g., Natura 2000) or derived from field work for a limited area.

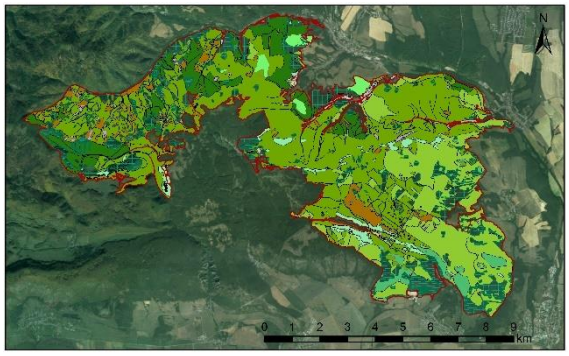


Figure. Local habitat map, Slovak Karst National Park

Objective: To assess the compilation of high-resolution (10-20m) ecosystem extent accounts at (sub)-national scale according to the EU extent typology with a focus on a high thematic detail (Level-3) for Forest and woodland ecosystem (Slovakia) and Coastal ecosystem (Peloponnese) derived from Sentinel-1 and Sentinel-2 time series

Method: A hEUNIS, a hierarchical workflow was set up to generate EUNIS habitat maps through Machine Learning, using EO time-series data, a Digital Elevation Model, vegetation height, climate, and soil data, and trained with in-situ information gathered from different sources, respectively 40 thousand points for Slovakia and 20 thousand points for the Peloponnese. The EUNIS habitat maps are thereafter integrated in a preliminary EU extent workflow, which merges these data with other anthropogenic datasets (e.g., CORINE Land Cover Back-Bone, Imperviousness layer, OpenStreetMap) to generate ecosystem extent maps and accounting tables according to the EU typology.

Outputs: An ecosystem extent map of the whole of Slovakia was generated for the year 2020. A comprehensive validation showed 90+% accuracy (compared to ground truth data) for the Slovak Karst National Park, at levels 1 and 2, and about 70% accuracy at level 3 (the lower accuracy was mainly due to biases over the Ravine Forest and Mesic deciduous forest). A lower accuracy was also observed in wetland ecosystems. A second extent map was generated over the Peloponnese, which showed a good visual match. The output is the base for ecosystem accounting and reporting to the Global Biodiversity Framework.

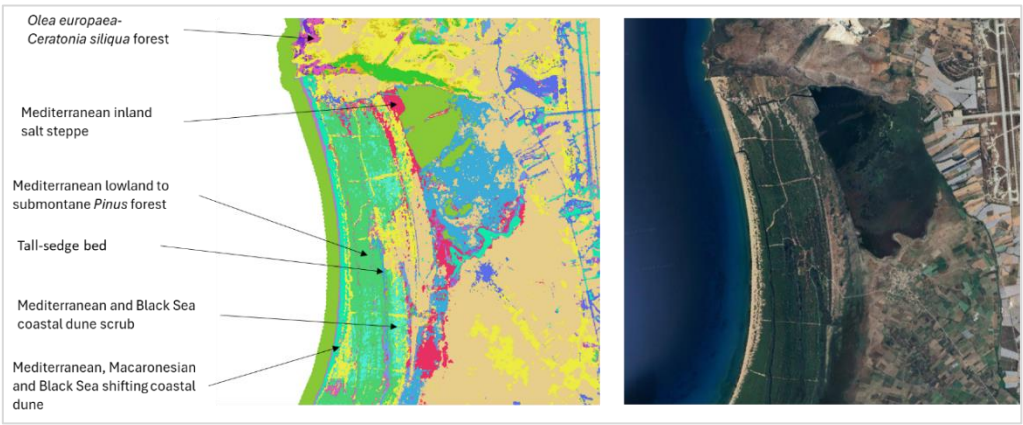


Figure. High-resolution EUNIS level-3 map over an area of West-Peloponnese.

Ecosystem Condition

Forest Condition Case Studies the Netherlands and Italy

Forest ecosystems are a critical component of the world's biodiversity, but pressures like deforestation and forest degradation contribute significantly to the ongoing loss of biodiversity. Individual characteristics of forests and other ecosystem assets can be quantitatively described by ecosystem condition variables. The SEEA-EA Ecosystem Condition Typology provides a comprehensive set of metrics to assess ecosystem condition, including two abiotic, three biotic and one landscape-level characteristic. While a method to account for forest condition in Europe exists (Maes et al., 2023), it is not reproducible by National Statistical Offices and does not exploit the full potential of EO.

Figure. 80% of natural habitats in poor condition in the EU (EEA [3])

Objective: To develop a workflow to regularly monitor the forest condition and support forest management using EO data

Method: The k.LAB (ARIES) explorer was connected to a computing platform via the OpenEO web interface. A set of thirteen forest condition variables were integrated for Tier-1 from 2000 onwards, and six variables for Tier-2 from 2016 onwards. The platform calculates the forest condition variables in real-time given the context (spatial and temporal extent). Eight variables are directly derived from EO data, three variables are indirectly derived from EO data through modelling. A set of reference conditions per environmental zone were calculated to convert the variable (physical unit) into an indicator (0 to 1) and aggregated into a single index through a weighting methodology.

Outputs: To facilitate the production of forest condition accounts and benefit fully from the potential of EO data streams, the workflow was embedded in the ARIES for People-EA explorer web-application and is available for the entire EU28 at Tier-1 (100m) and Tier-2 (20m) for selected areas. Italy, the Netherlands, and all other Early Adopters were trained to use the tool and validated the results amongst their national datasets. They evaluated the Earth Observation data products as useful and suggested improving the integration of national forest type maps and biodiversity data.

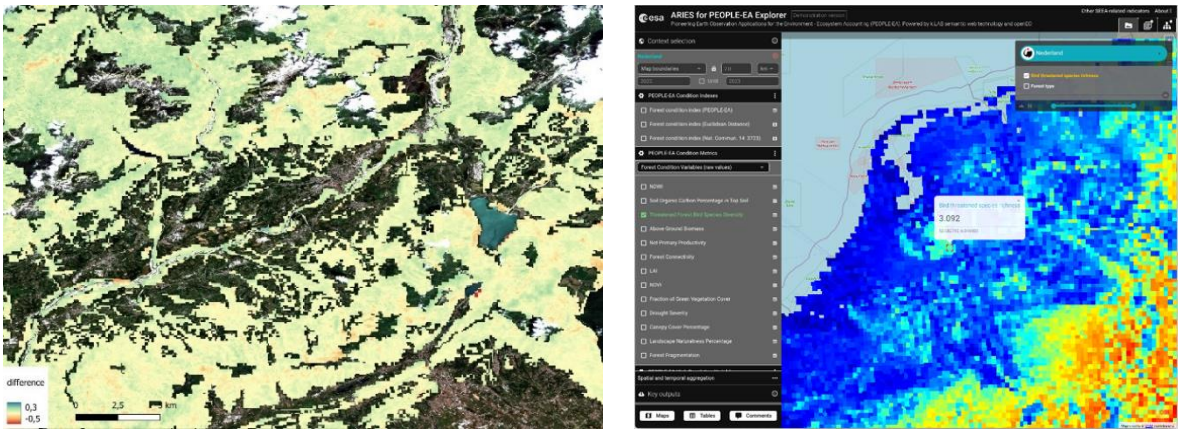


Figure. Evolution of forest condition index from 2018 to 2022 (Italy, left); Aries4People application (Netherlands, right)

Ecosystem Condition

Coastal Condition Case Studies
Italy and the Peloponnese

Coastal zones rank among the most productive regions, offering a diverse array of valuable habitats and ecosystem services that have consistently attracted human presence and activities. The EU legislation on ecosystem accounting defines one mandatory (abiotic) indicator for countries to report on the coastal condition, i.e., the share of artificial impervious area cover (%), as a national average for the reporting period. National Statistical Offices use either the Copernicus HRL Imperviousness maps, which currently does not allow to report in time and only partially detects imperviousness areas, or, for example in Italy, they use a semi-automated process based on aerial images and extensive photointerpretation.

Figure. Artificial imperviousness area close to a nature protected area in the Peloponnese

Objective: To develop an automated workflow to report on a 3-yearly basis on the substitution of original (semi-)natural land cover or water surface in coastal areas with an artificial, impervious cover, i.e. a coastal condition index. The index is an indicator for ecosystem degradation, reflecting the encroachment of built-up land (e.g., roads, residential development, holiday houses) in coastal zones.

Method: A workflow was developed to produce annual imperviousness density maps using features derived from Sentinel-1 and Sentinel-2, with the Copernicus HRL Impervious density map of 2018 as a baseline. First, a binary classification was performed to detect sealed surfaces, iteratively trained for each region using the Copernicus HRL baseline. Thereafter, the density (1-100%) is estimated using the Sentinel-2 features and the coastal condition index is calculated.

Outputs: Coastal condition accounts for the period 2018 to 2022 are available for the east of Italy, the Peloponnese. Major imperviousness changes are detected well while smaller ones may not be detected, thus yielding a slightly underestimating indicator. The accounts were also prepared for the Netherlands.

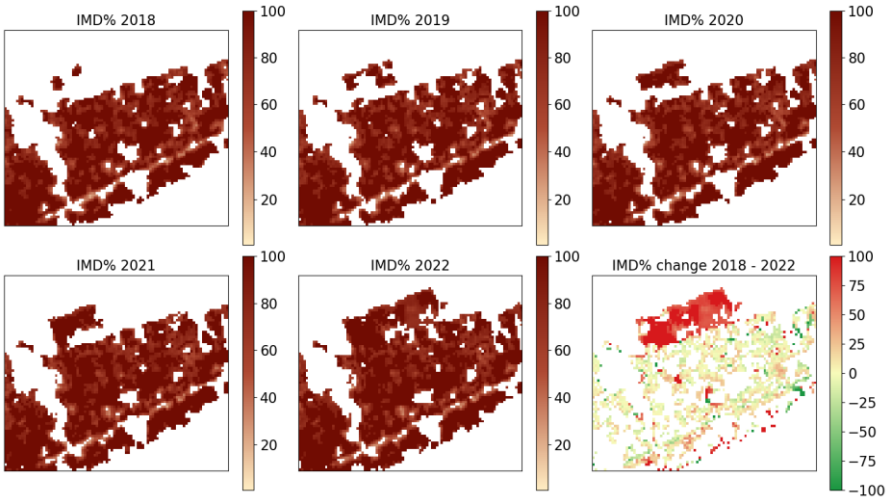


Figure. Imperviousness and its change in the Venice region, Italy, from 2018 to 2022

Wood Provision Service Case Studies Slovakia and Norway

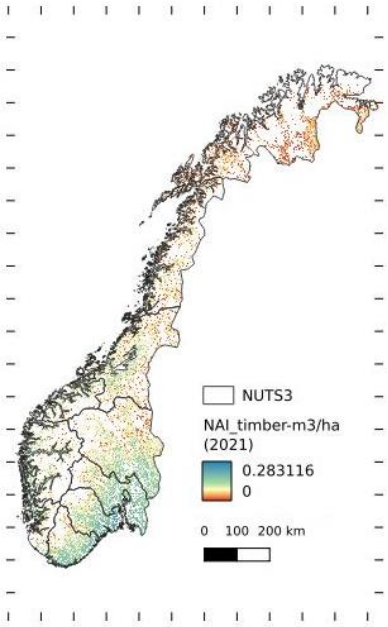
Wood provision is a service provided by nature to the benefit of people or - in this case – to the forestry industry. It considers the ecosystem contributions to the growth of trees and other woody biomass. According to an amendment to EU Regulation (No 691/2011), it shall be reported as the net annual increment (NAI) of timber, i.e., the average annual volume growth of live trees, calculated from the stock of live trees available at the start of the year minus the average annual mortality, expressed in thousand m^3 overbark. Most National Statistical Offices, as well as the European INCA tool for ecosystem service accounts, generate the account based on harvest statistics, which offer only limited information on the geospatial distribution of the ecosystem service.

Figure. Wood provision through timber harvest

Objective: To explore the development of a methodology to generate wood provision accounts (as NAI, or timber volume in m^3 overbark per year) for cultivated forests using Earth Observation data complementary to statistics.

Method: An experimental approach was developed to generate Wood Provisioning accounts using EO data products through quantifying the stock of live trees at high spatial resolution (20m), identifying the merchantable forest area, and estimating the NAI for the living tree maps within the forest available for wood supply (FAWS). Copernicus datasets were used in a model, with parameters calibrated at country level for hardwood, softwood, and mixed forest types.

Outputs: Wood provision accounts were generated for the year 2021 for Norway, Slovakia. Where possible, comparison of accounts to national data showed a good agreement of the accounts with the statistics, e.g., a higher mean value in lower latitudes in Norway compared to higher latitudes as shown in the accounting Table. While these results at national scale are promising, further improvements are to be made by calibrating the model parameters at regional level and downscale to plot level. Wood provision accounts were also generated for Greece and Italy.



NUTS-3 region	NAI [m3 overbark]	mean_NAI_per_ha [m3 overbark/ha]	forest_area [ha]
Oslo and Viken	4,415,176	4.1	1,076,515
Rogaland, Vestland and More og Romsdal	3,521,113	3.1	1,135,711
Trøndelag	2,819,319	2.5	1,126,883
Troms og Finnmark	1,155,342	1.3	861,044
Innlandet	5,877,166	3.0	1,959,810
Vestfold og Telemark	2,810,378	4.2	672,228
Agder	2,574,535	4.1	626,072
Nordland	1,266,325	1.9	662,814
TOTAL	**24,439,354**	**3.0**	**8,121,077**

Figure. Wood Provision map (net annual increment) for Norway in 2021 (left), wood provision accounting table per administrative (NUTS level 3) region for 2021 (right).

Recreation Case Studies
Norway and the Peloponnese

Nature-based recreation services are defined as the contributions that ecosystem make, through their biophysical characteristics and quality, to enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. They are typically reported in the number of overnight stays (e.g., hotels, camping grounds) for local and non-local visitors (tourists).

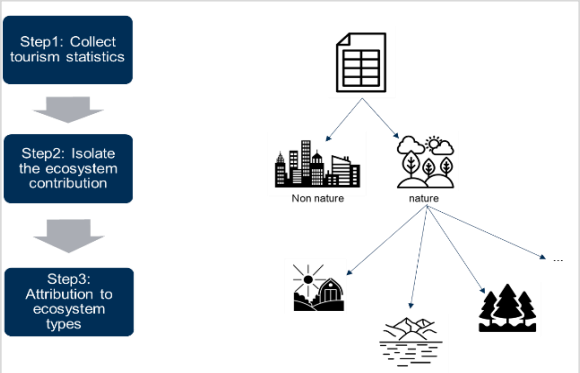


Figure Eurostat guidance on assessment of nature-based services

The attribution of the service to the ecosystem is computed from a cross-tabulation of metrics related to landscape attractiveness and accessibility. The ESTIMAP model, developed by the Joint Research Centre [6], integrates different datasets into the Recreation Potential Map (RPM) that underpins this attribution and is available per 6-year period. However, input data gaps for these RPMs exist, for example as is the case for water quality since only EU member states are required to execute monitoring activities and report on bathing water quality monitoring activities.

Objectives: To extend or enhance the RPM by using EO data sources and evaluate the impact of the RPM update on the recreation accounts.

Method: For the Peloponnese, EO data on annual forest loss was integrated to decrease the recreation potential values and its attribution to forest and woodland ecosystem type in the year following the loss. For Norway, water quality data (i.e., nutrient content or trophic state) from EU Space/Copernicus was used to increase the recreation potential values for inland lakes and coastal areas. As such, existing input data gaps related to the fact that only EU member states are required to report on bathing water quality monitoring activities.

Outputs: There was a significant improvement in the accounts, namely a decrease of up to 4% for some regions in recreation value in Greece and an increase of up to 1.1% in recreation value in regions in Norway, with the direction of change according to the expectations.

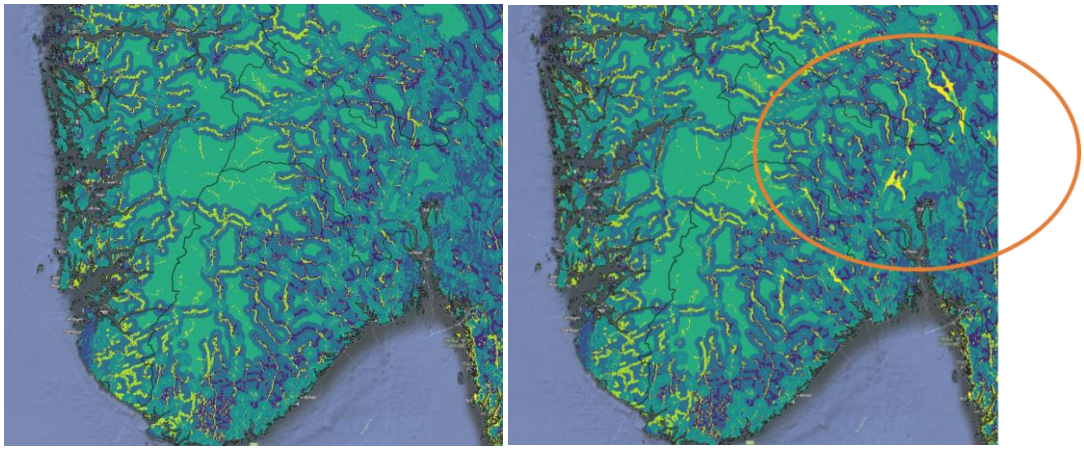


Figure. Recreation Potential Map over Norway (left original, right improved).

PEOPLE Ecosystem Accounting Partners

Consortium Members

A consortium of leading companies and research institutions came together in a collaborative, user-focused and knowledge-sharing approach to deliver the PEOPLE-EA project.

VITO is a leading European independent research and technology organization in the areas of cleantech and sustainable development. The **VITO Remote Sensing** unit provides technical solutions in applying Earth Observation and large-scale geospatial data processing to better manage, predict and control our scarce natural resources.

The **Basque Centre for Climate Change (BC3)** is an international and multidisciplinary research institute based in Bilbao, Spain. BC3 is devoted to advancing scientific knowledge of climate change causes and impacts relevant to decision-making by integrating environmental, socioeconomic, and ethical dimensions of climate change.

Ecounting is an SME specialised in providing services in the field of Ecosystem Accounting. Ecounting staff has been involved in the development of the System of Environmental Economic Accounting - Ecosystem Accounting (2014 - 2021) and has been involved in advising on the compilation of ecosystem accounts in various countries.

University of Patras (UPATRAS) is the 3rd largest University in Greece. The Department of Biology - Laboratory of Botany focuses on the documentation and mapping of biodiversity (species, habitats, ecosystems), implementation actions for conservation and management, ecosystem services mapping and assessment and terrestrial ecology.

Early Adopters

"Early Adopters" explore the generation of ecosystem accounts using Earth Observation. They contribute by expressing their needs and testing of innovative solutions into their operational practices.

Institute of Landscape Ecology of the Slovak Academy of Sciences (SK) is an interdisciplinary scientific institution for basic and applied research in landscape ecology. It is a governmental research organization that is a part of the Slovak Academy of Sciences.

Statistics Norway (NO) is a professionally independent institution and the central authority for the development, production and dissemination of official statistics in Norway.

Centraal Bureau voor de Statistiek (CBS) is the Dutch national statistical office. CBS is responsible for the independent publication of all national statistics, as well as a wide range of innovative statistics and statistical reports.

University of Patras (UPATRAS) is the 3rd largest University in Greece. The Department of Biology - Laboratory of Botany focuses on the documentation and mapping of biodiversity (species, habitats, ecosystems), implementation actions for conservation and management, ecosystem services mapping and assessment and terrestrial ecology.

Italian National Institute of Statistics and National Institute for Environment Protection and Research (IT) in joint collaboration, have the mandate to monitor ecosystems at national level and producing ecosystem accounts.

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