Recent advances with Norwegian research and application of Ecosystem Services
An update to NINA Report no. 2012

Services provided by main types of ecosystems in Poland - an applied approach

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Recent advances with Norwegian research and application of Ecosystem Services

An update to NINA Report no. 2012

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Contents

1 Introduction

Ecosystem services-related theory and practice receives a steadily growing role within Norwegian policies and practice for land use, land planning natural resource management. As noted in NINA report 2012, the United Nations System for Economic Environmental Accounts – Ecosystem Accounts (SEEA EA), is based on the ecosystem services (ES) framework using spatial explicit modelling approaches. The SEEA EA is largely built on the conceptualization of ecosystem services (Haines-Young & Potschin 2010, Van Dijk et al. 2018) and the methodological approaches that support their assessment (Dunford et al. 2018, Geneletti et al. 2020, Harrison et al. 2018). Ecosystem accounting aspires to provide ecosystem valuation as integrated geospatial information, in which multiple layers of information (geographical, environmental, ecological, and economic) are brought together and summarized in accounts (UN 2021). In Europe, this collation of spatial data organized as ecosystem services models is also aligned with and builds on the work developed under the Mapping and Assessment of Ecosystem Services (MAES) process to support the EU Biodiversity Strategy 2010-2020[1].

There is great interest in the development of ecosystem accounts/nature accounts in Norway. In the municipal and county council sector, there is a growing demand for ecosystem accounts that can be used as a knowledge base and a tool for local land management and planning. Municipalities in Norway have considerable responsibility for land-use allocations and territorial planning; and ES are among the criteria to be included in Environmental Impact Assessments according to the Planing and Building Act[2] . Ecosystem accounts are explicitly and prominently featured in the “Hurdal platform” that outlines the policy goals for Norway’s current national government (in power from 2021-2025)[3]. In the Hurdal Platform document, the new government stated that it will "develop good methods for how to conduct nature accounts, where different types of nature are weighted in line with their natural value". In its letter identifying the responsibilities and budget for the to the Norwegian Environment Agency for 2022, the Ministry of Climate and Environment (*Klima og miljødepartementet*, or KLD) specified how ES and ecosystem accounting are to serve as a management parameter—stating that "the basis for an ecosystem account in line with international standards and obligations has been established". The KLD letter is also concerned that a national ecosystem account should, as far as possible, be designed to meet management needs at both the national, regional and local levels.

The Norwegian Environment Agency (NEA) set up an interdisciplinary working group in February 2022 with a mandate to investigate various concepts for the development of a national ecosystem account and gain better insight into what is required to develop ecosystem accounts in accordance with international standards, obligations, and national management needs. The working group’s report (Miljødirektoratet 2022) addresses data needs, costs and management benefits associated with four possible concepts for the development of a national ecosystem account. The concepts include biophysical accounts for spatial distribution, condition and ecosystem services. The report does not, however, go into how monetary accounts might be developed for ecosystem services or natural capital.

The NEA working group identified four scenarios for development of ecosystem accounts in Norway, all of which build on the legally binding reporting requirements from Eurostat to which Norway must adhere. The four scenarios differ in terms of how well they correspond to key principles in the UN standard for ecosystem accounting and current management needs (UN 2021), with varying designs for the area and condition accounts that reflect different levels of ambition in the development of national ecosystem accounts.

[1] The EU Biodiversity Strategy to 2020 calls on Member States to carry out a mapping and assessment of ecosystems and their services.
[2] Planning and Building Act (2008) - regjeringen.no
[3] Hurdalsplattformen - regjeringen.no

Based on the review of the different scenarios, the NEA recommends that further efforts should develop ecosystem accounts the spatial resolution that can support the natural resource management at the local scale, while still compatible with the UN’s SEEA EA standard (United Nations 2021). The working group also concluded that development of accounts in accordance with the recommendation will require a national initiative with a time perspective of 5-10 years. Because there is great uncertainty about the technical possibilities and costs of establishing accounts in accordance with the UN standard, the NEA’s working group advocated that the implementation of the initiative should be gradual and periodically re-evaluated as the knowledge base improves.

The project team at the Norwegian Institute for Nature Research (NINA) has been extensively involved in the process of developing and testing different elements of the ecosystem accounts in Norway. We have used these experiences as the basis to gain insights and know how necessary to build a data infrastructure suited to compile maps of the extent and condition of ecosystems, of ES models, and of their outcomes with the aim to inform decisions on land allocation and levels of land-use about the multiple functions with social importance provided by nature, including the intrinsic value of biodiversity (La Notte et al. 2021). Based on this experience we have provided insights into the work on ES mapping and assessment of our colleagues at the Adam Mickiewicz University and their partners in Poland.

2 Activity within mapping of ecosystem extent

2.1 National level initiatives

An important basis for using ecosystem services to inform management of Norwegian nature is access to geospatial data (i.e., maps) that describe the main ecosystem types with complete national coverage. In 2021, the NEA commissioned NINA and Norwegian Institute of Bioeconomy Research (NIBIO) to produce a report to investigate possible approaches to produce complete-coverage maps of ecosystem types (Framstad et al. 2021). This report includes assessing relevant divisions of ecosystem types, existing map data and new mapping techniques.

Framstad et al. (2021) identified several useful national and international applications for having maps of major ecosystem types with complete national coverage. These include serving as a basis for a national system of ecological condition, ecosystem-based management, municipal management, and analysis of land use and land cover change—in addition to providing the data necessary for international reporting. An important goal is also inter-sector applicability, since Norway follows the principle of Sector Responsibility, which included taking into consideration environmental externalities. This is also a challenge because no single map product can meet all relevant sectors' needs with respect to spatial and thematic resolutions. In some cases, this might be solved in applications by linking other location-based ecosystem attributes (e.g., species occurrences, valuable natural areas or levels of carbon stocks) to a map of major ecosystem types.

There are several challenges associated with determining the appropriate ecosystem classification typology with unambiguous definitions. These mainly relate to the delineation of boundaries across ecological gradients, such as between land and wetland, the degree of tree cover and the degree of human impact. Many different national and international classifications can be considered as a basis for a classification of main ecosystems. Norway's different national classification systems are largely consistent, although the criteria for delimitation between the units vary. Among the various international classifications, the classifications used in the EU (EUNIS, CLC, new classification for ecosystem accounting) and the IUCN's new Global Ecosystem Typology are probably the most relevant to consider for the classification of Norwegian main ecosystems. Framstad et al. (2021) propose a typology with nine classes of major ecosystems: mountain, forest, wetlands, snow/ice, freshwater, marine, and three categories of open solid ground: cultivated, built and that covered by natural vegetation (but not forested).

Norway currently obtains data for statistics on the distribution of ecosystems from both sample surveys[4] and from maps[5]. While data can be considered reasonably good, it is at least partly fragmented, has varying degrees of detail, update frequency and accuracy, and is not linked to defined ecosystem types (Miljødirektoratet 2022). Significant parts of Norwegian nature are not adequately covered by current data sources. In particular, wetlands (with mires covering ca 12% of the land area (Bakkestuen et. al. 2023)) and mountain areas are generally poorly mapped.

There are international and to some extent national land cover products based on remote sensing techniques that could (in the long term) be used to develop a comprehensive map of ecosystems. This applies to various Copernicus services (high resolution layers), the EU's further development of Corine Land Cover (CLC+Backbone), ESA WorldCover, and various research initiatives such as NINA's ELC10 (Venter & Sydenham 2021). The accuracy and relevance of such products will require access to national reference data/background ground-truthing to be

[4] Examples include National forest inventory (Landsskogstakseringen), the area frame survey of land resources in Norway (AR18x18) and area-representative nature monitoring (ANO)

[5] Relevant map series with information on major ecosystems are: N50 land cover, Common Map Database (Felles KartDatabase, or FKB), SSB-Arealbruk, resource map (Arealressurskart) AR5, AR50, ARSTAT, AR-Fjell, AR250 and Corine Land Cover Norge.

developed and verified. The NEA working group concluded that it is currently unclear whether the international produc's will be able to be adapted to national needs and meet user needs that require more detailed mapping tools or datasets (Miljødirektoratet 2022).

The Norwegian Environmental Agency has assigned the Norwegian Institute of Bioeconomy Research (NIBIO) with responsibility for generating the first draft of a map for major ecosystem types (*Hovedøkosystemtyper*, or HØK). This map is to be developed using the ecosystem typology that is required for European countries' reporting of national ecosystem accounting to Eurostat, provided below in Table 1 (Eurostat 2022). Eurostat specifies that minimum mapable units (MMU) must be no larger than 100 acres, but can be smaller. In urban areas, the MMU can be no larger than 10 acres. NIBIO delivered is working draft, or test version, of this map to the NEA earlier this year (Strand et al. 2023). The NEA commissioned NINA to participate in quality assurance of this first draft: work that is expected to be completed in the first part of 2024. Norway's map for main ecosystem types will be based on its AR50 dataset, which provides a comprehensive overview map of the country's land resources that was developed for use at scales from 1: 20 000 to 1: 100 000. The minimum area size in AR50 is 15 acres (Heggem et al. 2019).

Table 1. Main Ecosystem categories according to the EU typology to be used in reporting to Eurostat.

Ecosystem types	
1) Settlements and other artificial areas	7) Inland wetlands
2) Croplands	8) Rivers and canals
3) Grasslands (pastures, semi-natural and natural grassland)	9) Lakes and reservoirs
4) Forests and woodlands	10) Marine inlets and transitional waters
5) Heathlands and shrubs	11) Coastal beaches dunes and wetlands
6) Sparsely vegetated ecosystems	12) Marine ecosystems (coastal waters, shelf and open ocean)

NIBIO is also presently working on developing what they refer to as a "cross-sectoral basemap" (*sektorovergripende grunnkart*) that can serve as a foundation for developing biophysical ecosystem accounts that are built on ecosystem services concepts at higher resolution than the minimum required for reporting to Eurostat. Aune-Lundberg et al. (2023) described which existing map layers will be used to develop such base maps, and how these can be used to generate accounts of ecosystem extent. The Statistics Norway (*Statistisk sentralbryrå*, or SSB) maintains a nationwide dataset that provides an overview of built-up and developed land and how it is used. The most central datasets used for this map are Matrikkelen (a database of property ownership) and Felles kartbase (FKB, or common map database), which also includes FKB-AR5. AR5 is a nationally comprehensive dataset adapted to a scale of 1:1000 and above. It displays land resources with an emphasis on the production basis for agriculture and forestry, where land area is divided by area type, forest quality, tree species and soil conditions. A forest resource dataset, Skogressurskartet SR16[6], serves as a supplement to the AR5 data on land resource.

Within built-up areas, where land use is most intensive, NIBIO's proposes using its green structure map to differentiate between open green areas, parks and corridors between buildings. NIBIO's national green structure map described vegetation within built-up areas using automated classification of high-resolution infrared satellite images in either 2x2 meter or 4x4 meter

[6] https://www.nibio.no/tema/skog/kart-over-skogressurser/skogressurskart-sr16

resolution (Mathiesen et al. 2022), using Copernicus[7] satellite imagery. The national digital elevation model in 1 x 1 meter resolution[8] is used to identify the height of the vegetation, which is grouped into three layers. Vegetation below 1 meter is defined as field layer. Vegetation between 1 and 3 meters is defined as shrub layer and vegetation above 3 meters goes into the category tree layer.

NIBIO proposes that annual changes in land cover/ ecosystem extent may be detected from satellite imagery. NIBIO, NINA and several other academic environments in Norway are involved in many parallel R&D projects related to such issues (see chapter 2.3).

[7] https://land.copernicus.eu/pan-european/high-resolution-layers
[8] https://www.kartverket.no/geodataarbeid/nasjonal-detaljert-hoydemodell

2.2 Local level initiatives

County and municipal level governments recognize the potential utility of using ecosystem services maps to inform land planning decision-making and many counties are eager to establish their own systems for this purpose. Several county-level government entities have already initiated work on the development of ecosystem accounts that can provide insight into how changes in land use result in changes in the delivery of ecosystem services. Here we provide brief descriptions of two examples from Agder and Viken counties.

2.2.1 Agder County

Agder County lies in south central Norway, covering 16.495 km^2. In 2022 the county published it area extent account, which provided its first ever comprehensive overview of areas that have been put into use either by being built on or developed, distribution of land types and planned land uses. It uses many of the data sources identified in NIBIO's planned cross-sectoral base map. Areas that are built on or developed are based on Statistics Norway's (SSB) dataset for land use (2022). Land type information is based on the AR5 and AR50 (land resource) datasets described above, while planning information is based on municipal plans, municipal sub-plans and zoning plans.

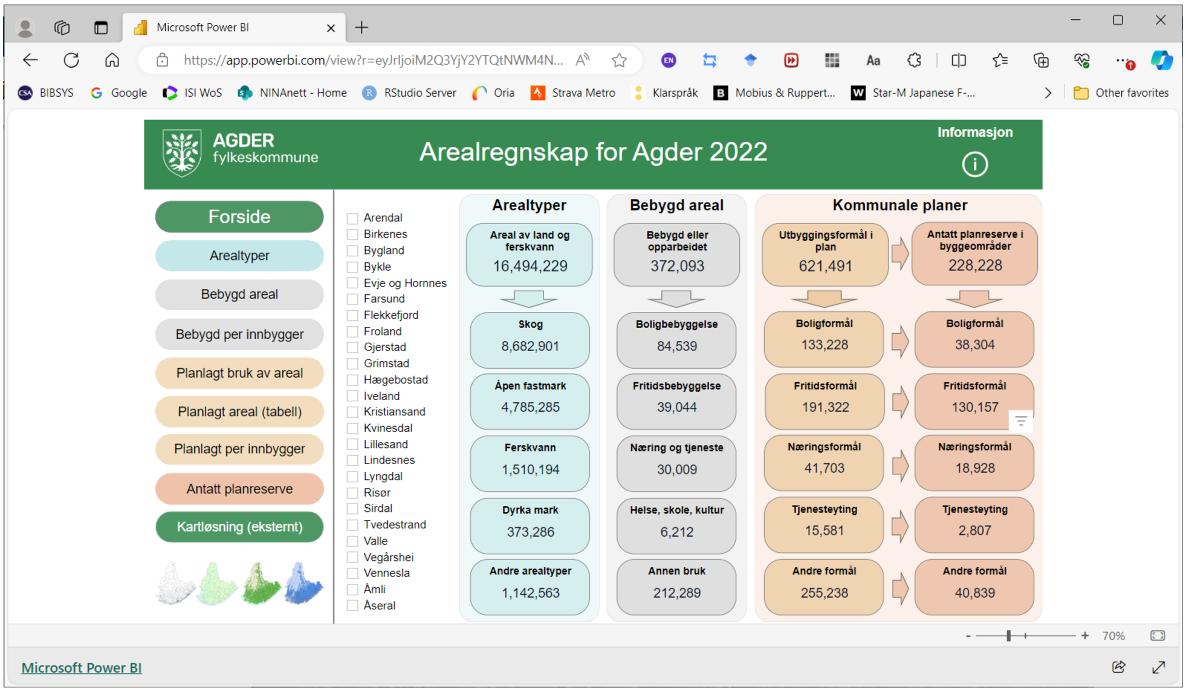

Figure 1. Screen shot of Agder county's area extent account web portal[9]*.*

The web portal (Figure 1) gives the user the option of extracting data either at the county level or at the level of individual municipalities. At each level of administration, a user can view data through a dashboard-style interface (Figure 2). The portal also features a map-viewer (Figure 3).

[9]https://app.powerbi.com/view?r=eyJrljoiM2Q3YjY2YTQtNWM4NS00ZTQ0LWI1OTct-NDU4MTI0YzBmNjUxIiwidCI6IjUyYTlINTJlLWQ5MTgtNDAxZC1hYWZiLTBkYzE0YWMwOGUxNy-IsImMiOjh9&pageName=ReportSection4e3b5748b96810354c05

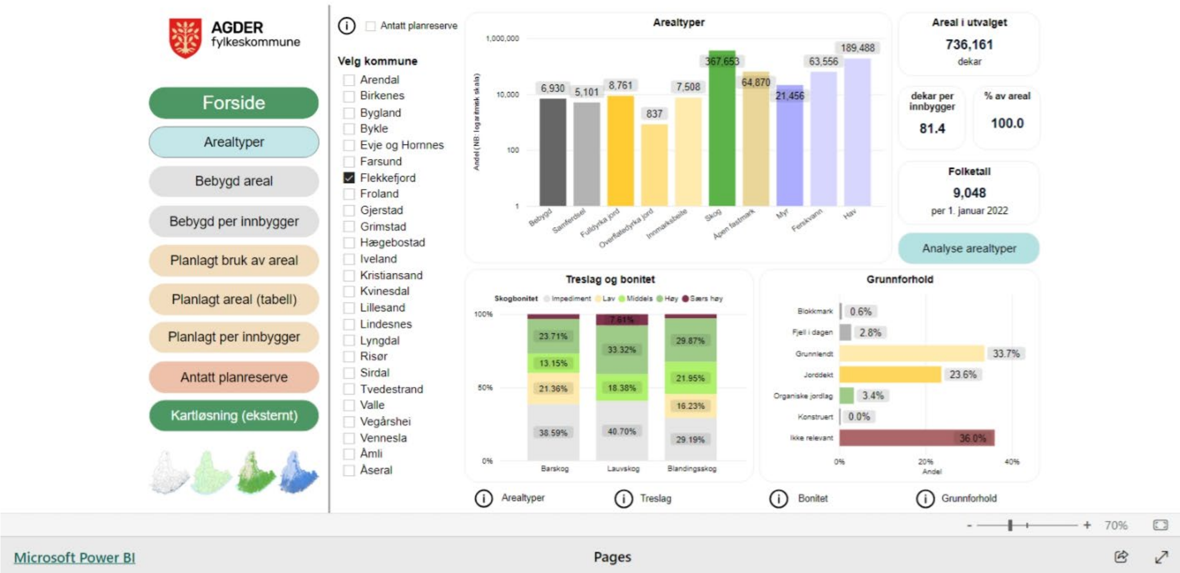

*Figure 2. Dashboard interface illustrating area statistics according to ecosystem type (*Arealtype*), dominant tree types and growth potential (*Treslag og bonitet*) and the geological conditions (*Grunnforhold*). This example shows statistics for Flekkefjord municipality.*

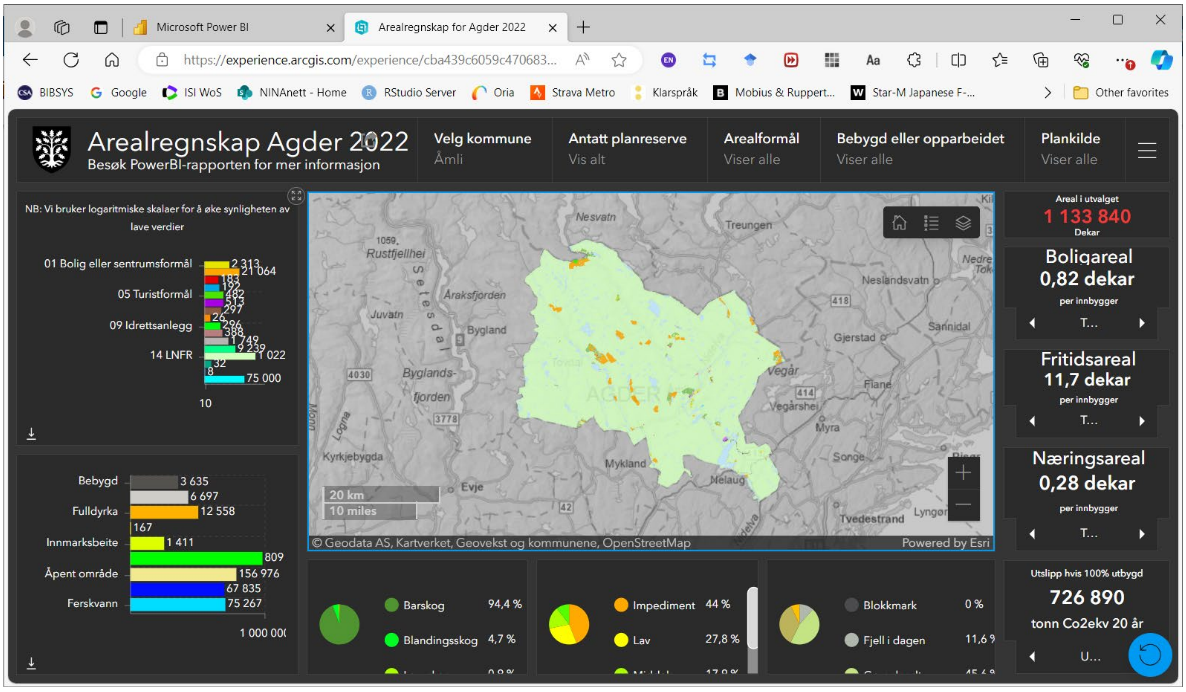

Figure 3. Map viewer developed for Agder county's area extent web portal.

This product from Agder is a work in progress. The original ambition was to be able to calculate changes in land cover over time, however the current solution only provides a static picture of the situation from 2022. The original vision also involved establishing a more complete ecosystem account for the county, consistent with the framework provided by the SEEA-EA. However, the developers struggled with determining how to incorporate information on ecological condition of areas, including a general lack of appropriate data that covered the entire area within the county. Gunnar Owen Lindaas—who led the development of Agder county's area account tool—

writes, “The area accounts do not contain information about natural values. This is because there is currently no comprehensive data on the distribution of ecosystems, habitats or species”.. However, we are monitoring developments in this area and hope to be able to present nature accounts in the not-too-distant future.”[10] The general design of this interface, and how it uses and accesses existing data, has been well received by other county governments, and seems likely to serve as a template for similar initiatives in other parts of Norway.

2.2.2 Viken County

Viken County lies in the area surrounding the upper reaches of the Oslofjord (but does not include Oslo municipality), covering 24.593 km^2. In April 2023, it published its version of an area account, based primarily on geographical data from the national databases of Statistics Norway, NIBIO, the Norwegian Environment Agency, Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Directorate for Civil Protection (DSB). The geographical datasets were downloaded from Geonorge in the period October 2022 to February 2023. The map-based area account for Viken has eight main themes with interactive maps: Built-up area, nature, outdoor recreation, water, agriculture, climate and energy, wetlands, and natural disaster risk areas. Its web-based interface is a map viewer [11] also shows a comprehensive map of the land resources in Viken.

As with Agder Country, the developers of the Viken County area account insight tool also recognized that the municipal sector in Norway currently lacks a functional system for monitoring the state of nature. The Viken County solution was to include a selection of the available data on what valuable nature in found within the county, and which species and habitat types should be given special consideration in management. The maps presented in their area account show natural values that the development team considered particularly important to take into account in land management, and which they believe should be included in an area account. Among the maps included in the area account interface are a map showing how well the individual municipalities in the county are mapped for consideration of natural values and maps of habitat types according to DN handbook 13 and Nature in Norway (NiN) -mapped habitat types (a far more detailed typology than the EU level 1 presented earlier). There are several map layers for selected habitat types in Viken: ravine valley/clay ravine (landform), rich bog and warm spring forest, open shallow limestone soil (selected habitat types), bog, low herbaceous deciduous forest and limestone forest. There is a map of the pristine natural areas are defined as natural areas that are specified distances (i.e. 1-5 km as the crow flies) away from major technical interventions. Finally, the interface provides access to maps displaying the distribution of areas presently under conversation protection.

The web interface for Viken County consists primarily of semi-interactive map viewers using arcgis software (Figure 4). The series of thematic maps provided within the Viken area account interface also both implicitly and explicitly account for a range of ecosystem services. For example, the maps for climate and energy include maps for wetlands and mires that are important for carbon storage, as well as maps of forests whose land masses store large amounts of below ground carbon. The maps for natural disaster risk areas include maps of areas that are susceptible to flooding, avalanches and landslides. These risks are estimated using a set of hydrological models that include vegetation cover as a factor determining water flows (Rusch et al. 2023)..

[10] https://agderfk.no/vare-tjenester/regionplan-agder-2030/aktuelt-fra-regionplan-agder-2030/presenterer-et-helhetlig-arealregnskap-for-agder.52395.aspx
[11] Arealregnskap 2022 (arcgis.com)

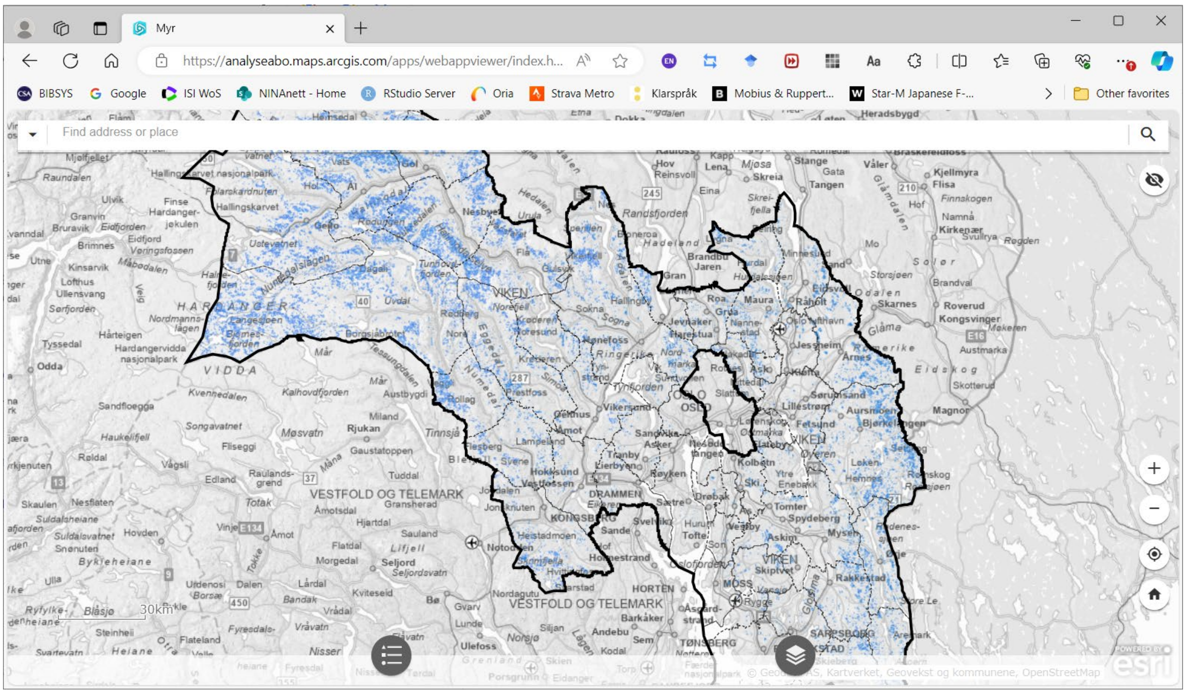

Figure 4. Example of the web-based map view provided by the Viken County area account interface. This screenshot shows a map of wetlands and mires, which are presented as being important areas for continued storage of carbon.

2.2.3 The KS initiative

The Norwegian Association of Local and Regional Authorities (KS) is the organization that represents all local governments in Norway. In recent years, KS has responded to the groundswell of municipalities' interest in area and ecosystem accounting by organizing several ecosystem services-related projects, including a 2023 series webinar series titled "Area and ecosystem accounting as a useful tool for regional and municipal planning," which NINA helped organize. Representatives from county governments and administrations, state administrators, research organizations and regional authorities with responsibilities for various sectors gathered to discuss how they use the concepts within the ecosystem services framework. Insights gained from this series includes the following:

- Development of ecosystem accounts according to UN SEEA-EA standards will take time, but municipalities and county authorities need a better basis for decision-making quickly.
- Area (extent) accounts used in municipal planning require better and more up-to-date data on ecosystem-based extents, ecological status and fragmentation in nature. This is data that is currently lacking.
- As a knowledge base for planning at a strategic level, land use accounts must show development over time, but today we lack time series for the development of land use. Existing maps are updated irregularly, and not frequently enough to report on 1-3 yrs. periodical changes.
- There is a need to clarify how land and nature accounts can be used at different planning levels and planning phases, clarify what the land and ecosystem accounts should provide answers to, and create an agreed methodology that can strengthen and simplify regional guidance and interaction with municipalities in the planning processes.
- Communicating a complex knowledge base about nature to politicians and decision-makers requires facilitation for decision-makers through simplification and visualization.

These insights formed the basis for a project to develop innovative solutions to better incorporate ecosystem services concepts in municipal planning. One of the project's central goals is to develop a model of a web portal, likely built on the work from Agder County, that can improve local government, administrators, and authorities' access to the information that comprises the steps within an ecosystem services cascade conceptual model: ecosystems' extent, the ecological condition, and the ecosystem services provided. Other goals include methodological advances in the how to model and communicate information related to ecosystem service supply (i.e., ecological condition and ecosystem service models). Work on this project will begin in early 2024 and is expected to last until at least 2026, and NINA is contributing with much of the technical competence needed for mapping nature values and ecosystem services

2.3 Using satellite-based tools for ecosystem extent accounts

NINA is involved in several research projects designed to explore how satellite-based imagery can improve both the accuracy, resolution, and regular updating of data used to estimate the extent of areas that provide ecosystem services. Quantifying error in ecosystem extent maps and accounts is a priority because ecosystem extent is the foundation for biophysical modelling of ecosystem condition and services. Dynamic World is one example of an online map displaying ecosystem extent, with functions to calculate changes over user-specified time intervals. This 10m resolution global land use land cover dataset is produced using deep learning: the result of a partnership between Google and the World Resources Institute. It provides near-realtime updates and is freely available and openly licensed. The typical approach for estimating area size from satellite-based extent maps, as used by Dynamic World, is 'pixel counting.' In pixel counting, the number of pixels per ecosystem type are summed and multiplied by the pixel area. However, pixel counting does not account for either classification errors caused by algorithms in artificial intelligence (AI) models that are used to convert satellite imagery into a categorical map, or errors in the data used to calibrate the AI models themselves (Olofsson et al. 2014).

In a manuscript that is presently in review for the journal *Ecosystem Services*, NINA researchers used Oslo, Norway as a case study to address these research gaps by exploring how bias and uncertainty in ecosystem extent estimates vary with input data type and accounting period. The study investigates how bias and uncertainty in ecosystem extent differ between 1) a custom Sentinel-2 land cover map vs the globally available Dynamic World land cover map, and 2) between 3- and 6-year accounting periods. This work found that the pixel counting practices currently adopted by the SEEA EA community led to highly biased extent accounts, particularly for ecosystem conversions, with biases averaging 195% of the true change value derived from design-based methods. The uncertainty inherent in state-of-the-art satellite-based maps exceeded the ability to detect real change in extent for some ecosystem types including water and bare/artificial surfaces. In general, uncertainty in extent accounts is higher for ecosystem type conversion classes compared to stable classes, and higher for 3-yr compared to 6-yr accounting periods. Custom, locally calibrated satellite-based maps of ecosystem extent changes were more accurate (81% overall accuracy) than globally available Dynamic World maps (75%). This work suggests that rigorous accuracy assessment in SEEA EA is necessary to ensure that ecosystem extent (and consequently condition and service) accounts are credible. NINA researchers also used a similar analytical approach to explore the potential utility of Dynamic World for municipal level land planning and area accounts within a pilot project in Viken County (Figure 5). Unsurprisingly, the accuracy of Dynamic World maps of ecosystem extent in the work from Viken was no better than it was in the Oslo study. However, the exercise of manual interpretation of orthophotos which participants used to assess Dynamic World accuracy will provide a steadily growing dataset that can be used to train future maps of ecosystem extent developed through machine learning.

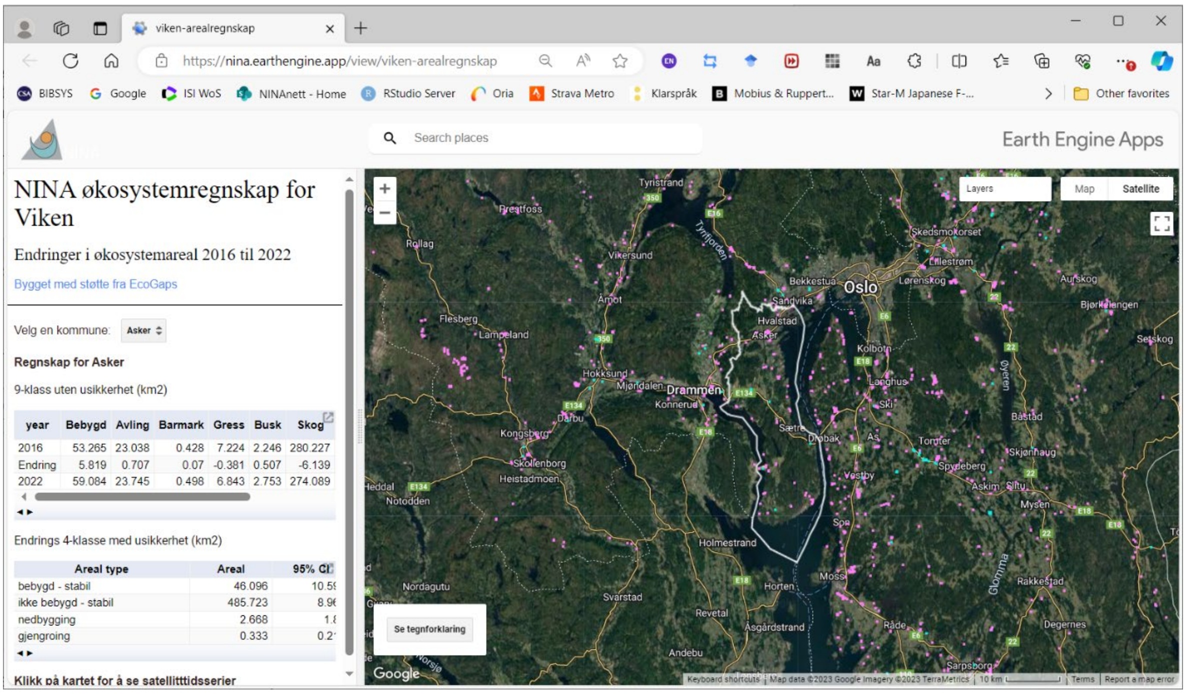

Figure 5. Screen shot of a web-based map viewer developed by NINA researchers to calculate changed in built areas between 2016 and 2022 for Viken County in eastern Norway. This example from the Asker municipality provides both a map of the locations where ecosystem type changed from “undeveloped” to “built” (pink spots) or from “built” to “vegetation” (turquoise spots). Based on accuracy estimates derived from manual comparisons of satellite-derived maps of land cover and orthophotos, the interface provides 95% confidence intervals for the estimates of area change. Funding from the ECOGAPS[12] project supported the development of this web app.

12 EcoGaps - CIENS

3 Mapping ecological condition

After base maps that provide comprehensive (wall-to-wall) spatially explicit information about ecosystem extent, the ecosystem services approach within ecosystem accounting uses ecological condition to capture variation in area's ability to provide various ecosystem services. The consistency of the SEEA-EA framework lies in the fact that it links the area and condition of ecosystems to their ability to make important contributions to society. The ecosystem services model is what ties the various accounting components together. Ecosystem accounting will enable quantitative analysis of the state of ecosystems and the benefits they generate. In this way, the framework makes it possible to monitor both changes in ecosystems and the consequences of these changes for society.

Accounting for variation in ecological condition is a particularly challenging area of applying the SEEA-EA framework, since there are presently no existing datasets that meet these needs at a spatial scale beyond the national level. NINA submitted reports in 2021 that assess the condition of forests and mountains throughout Norway, as well as the condition of the Arctic tundra, and the Barents Sea, North Sea and Norwegian Sea. While the indicators used in these reports are all spatially explicit, the assessment of ecological condition is made at the national scale, and therefore only suitable for use for reporting within the ecosystem accounting approach.

NINA is preparing an overview of the which data sources might be available for use in developing accounts for ecological condition within a SEEA-EA framework and in line with the NEA's ambition for use of ecosystem accounting within land use and land planning. This report should be ready to deliver to the NEA in the coming weeks. There are also other initiatives designed at providing complimentary approaches to depicting spatial and temporal variation in ecological condition, with methodology that might be more appropriate for use at smaller scales and therefore ready for use sooner. Within the ECOGAPS project, NINA researchers are exploring how different methodologies for quantifying biodiversity might be used to assess ecological condition at the level of individual parcels. Such methods could be used, in combination with a mitigation hierarchy, to determine how development might be conducted as to minimize any loss to the biophysical elements that provide ecosystem services. These may also help quantify how much compensation through restoration activities might be necessary to offset losses in biophysical attributes from development.

Work within ECOGAPS[13] will explore several different systems for assessment of ecological condition that vary in terms of the level of detail they entail, and how well assessment results align with one another. One approach to be used is the Biodiversity Metric version 4.0[14] system for quantifying nature values. Biodiversity Metric is an accounting tool designed for the purpose of calculating biodiversity net gain within the context of English legislation and habitat types. Its condition assessment sheets provide a list of difference criteria that can be assessed with relative ease and limited taxonomic knowledge. Biodiversity Metric is the inspiration for a Swedish version called CLIMB (Changing Land use Impact on Biodiversity)[15], which will also be explored. Oslo municipality's Blue Green Factor[16] represents the end of the spectrum as the simplest, and NEA's protocol for mapping habitat types on land[17] represents the most complex.

Another promising approach to expressing variation ecological condition is the Land Use Intensity index (LUI; Erikstad et al. 2023). NINA researchers developed the LUI as a means to express the changes in landscape patterns with a gradient-based index that could be calculated with publicly available data. The index in its basic form consists of two parts where the first is based

[13] EcoGaps - CIENS
[14] https://publications.naturalengland.org.uk/publication/6049804846366720
[15] https://climb.ecogain.se/en
[16] Oslo BGF Norm
[17] https://www.miljodirektoratet.no/tjenester/natur-i-norge/

on the data of buildings and roads and the second of infrastructure land cover. Compared with two frequently used ‘wilderness indices’ in Norway (INON and the Human Footprint Index), the LUI captures important elements of infrastructure in more detailed scales than the other indices. The LUI is also based on map databases that are updated regularly. The LUI therefore has potential to serve as an important tool in land use planning as well as a basis for monitoring, the assessment of ecological state and ecological integrity and for ecological accounting as well as strategic environmental assessments, with lower information costs than more complex indicators of ecological condition. Figure 6 shows the web viewer[18] developed with Google’s Earth Engine that displays how land use intensity varies in Norway. While the screen shot only displays southern Norway, the map viewer can display the index as it is calculated for the entire country, at a 100 x 100 m resolution.

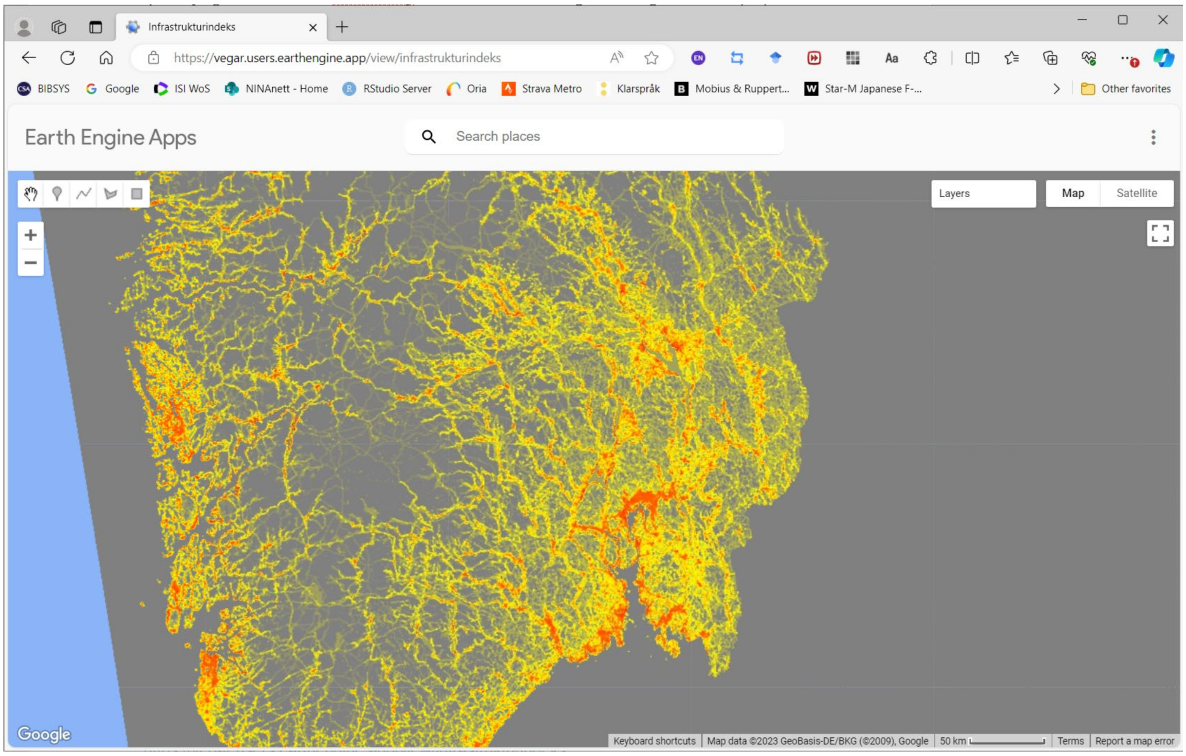

Figure 6. A screenshot of the Land Use Intensity index.

[18] https://vegar.users.earthengine.app/view/infrastrukturindeks

4 Modelling Ecosystem Services

4.1 Testing the INCA Tool within Norwegian conditions

The Integrated Natural Capital Accounting (INCA) project is jointly undertaken by European Commission services (Eurostat, the Joint Research Centre, DG Environment and DG Research and Innovation) and the European Environment Agency to support the development of the SEEA EA framework to better account for ecosystems and ecosystem services in national economic planning and policy decision-making. NINA has the responsibility for testing the ES models in the INCA-tool (Buchhorn et al. 2022, European Commission 2023), a work package within a Eurostat project, led in Norway by Statistics Norway (Figures 7-8) with Norway as its accounting area. NINA's activities will test results of INCA tool models of ecosystem services for more limited geographical areas to evaluate model results' quality. NINA activities have begun with tests of the carbon sequestration, flood control, crop provision and recreation models (Figure 7).

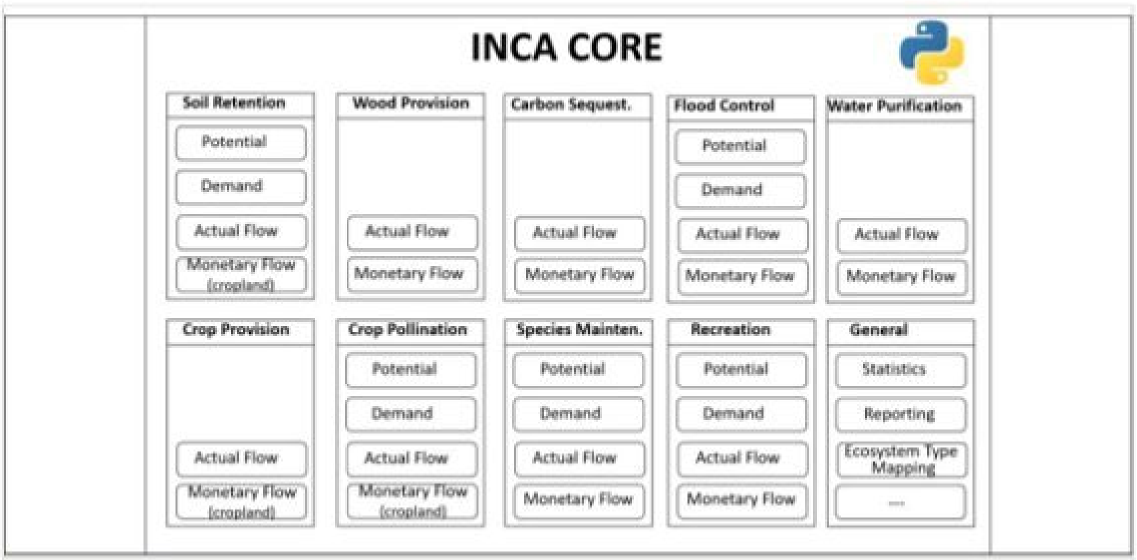

Figure 7. Overview of the ecosystem services model included in the INCA tool core. From Buchhorn et al. (2022).

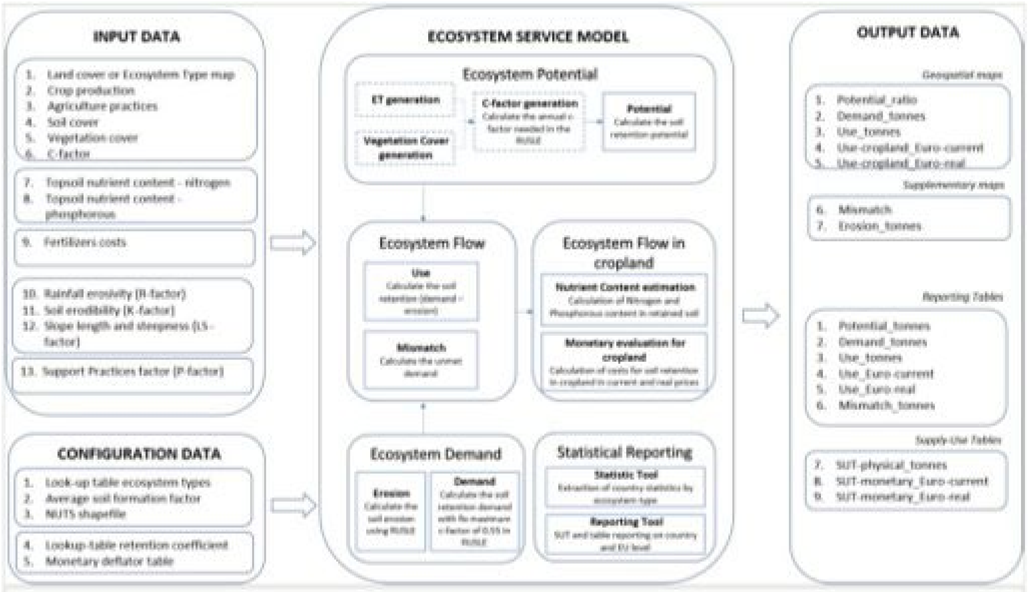

Figure 8. Flow chart diagram of the modular setup of the soil retention ecosystem service as implemented in the INCA-tool. From Buchhorn et al. (2022)

4.2 Review of the data basis for biophysical modelling of ES in Norway

The NEA commissioned NINA in 2023 to compile a survey of the available data and the data requirements for *biophysical* modelling ecosystem services according to the UN SEEA-EA standard (Rusch et al. 2023, in press). The report first establishes the theoretical foundations for the existing suite of biophysical models for provisional, regulating, and cultural ecosystem services. This included the "Tiered" approach of ecosystem modelling according to the UN standard (United Nations 2022), where successive tiers provide advances in spatial detail, computational complexity and local accuracy:

- Tier 1: Biophysical modelling that relies on globally available data sets and pre-constructed ecosystem service models using freely available tools, requiring very little user input.
- Tier 2: Biophysical modelling that relies on national data sets, requiring some customization and validation of ecosystem service models.
- Tier 3: Biophysical modelling that is implemented based on the best available local data using customized models that have been parametrized for local contexts.

The NINA report also cites criteria the UN identifies in its guidelines for what types of models are appropriate for use within the SEEA EA framework: measurable, sensitive to change, scalable, spatially explicit, and coherent (United Nations 2022).

In the report, NINA researchers go systematically through which available data sources are appropriate for use within modelling, grouped first by ecosystem service category (provisional, regulating, and cultural). For provisional services, the report discussed models grouped according to ecosystem type (using the EU level 1 ecosystem typology) for all ecosystem types except settlements and artificial areas. The report addresses biophysical models listed in Table 6.3 in the SEEA EA guidelines (United Nations 2022) of regulating services for climate regulation (global, under-continental, and local climate), soils (erosion and sediment control), filtration (water filtering, solid waste remediation, and noise reduction), water regulation and flood control, regulating services within waterways and coastal areas, intermediate services associated with agriculture, forestry and fishing (i.e. pollination, biological control of pest species and diseases) and nursery and habitat maintenance. The cultural services addressed in the report include recreation-related services (outdoor based recreating or "*friluftsliv*", hunting, and berry picking), aesthetics, educational, and services related to spiritual, artistic and symbolic values.

The report also evaluates the status of understanding of ecosystem services within the ecosystem types defined by the EU level 1 typology. Some examples of the conclusions include the following:

1. Many of the models for settlements/built environments have potential to be used in most urban/populated areas, although to date most models have only been tested in the Oslo area.
2. The extent of areas used for agricultural production are updated annually. However there are no registers that link specific types of agricultural production to the land areas. This makes it difficult to assess how habitat for wild pollinators might contribute to agricultural production. The INCA tool identified above includes models and data for calculating provisional services from cultivated lands (using Corine Land Cover Accounting Areas), and updated ecosystem extent maps can replace the coarser and less accurate Corine maps. Testing of INCA models will help assess whether they are appropriate for Norwegian conditions.
3. There is a mismatch between Norwegian and EU definitions of grassland areas, because Norway considers the areas used to produce fodder as cultivated lands, whereas the EU does not. Other types of grass areas are hard to identify with existing data. There is also no model presently developed for how populations of insects help regulate outbreaks of pest species that can damage agricultural production.
4. Existing forest inventory data does not distinguish between forest types or contain other information with relevance for modelling supply of a range of ecosystem services. The report describes a need to further develop models for regulating and cultural ecosystem services through incorporating a more detailed typology of forest type.
5. Existing data are available for ecosystem service models for sparsely vegetated ecosystems (i.e. areas dominated by heather) that correspond to a tier 1 level, and provide a basis for further development of tier 2 and 3 models for services like habitat maintenance for select species.
6. Wetlands are poorly represented in existing map layers of ecosystem types, even though wetands occupy approximately 10% of Norway's land area. Bogs are the most common type of wetland, and regulation service are the most important category of ecosystem service. The effects of bog type, location in the landscape, peat density and depth do not currently appear to be included as factors in, for example, hydrological models currently used to predict flood control and water flow regulation. In terms of global climate regulation, carbon stock accounting may be a relevant way to assess the importance of peatlands. In this context, the work done in developing the carbon calculator is a useful starting point. The report's authors conclude that model development and empirical validation will be necessary to produce meaningful accounts of these services.

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