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Eurostat mandatory condition variables applied to Norway

Erik Framstad, Balint Czúcz, and Megan Nowell

Norwegian Institute for Nature Research

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Trine Heill Braathu Randen (SSB), Lucrezia Gorini (NEA)

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Dead wood in northern forest, Øvre Dividal National Park, Troms County © Erik Framstad

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CONTACT DETAILS

NINA head office	NINA Oslo	NINA Tromsø	NINA Lillehammer	NINA Bergen:
P.O.Box 5685 Torgarden	Sognsveien 68	P.O.Box 6606 Langnes	Vormstuguvegen 40	Thormøhlens gate 55
NO-7485 Trondheim	0855 Oslo	NO-9296 Tromsø	NO-2624 Lillehammer	NO-5006 Bergen.
Norway	Norway	Norway	Norway	Norway
P: +47 73 80 14 00	P: +47 73 80 14 00	P: +47 77 75 04 00	P: +47 73 80 14 00	P: +47 73 80 14 00

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Abstract

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As part of efforts to develop a European system for ecosystem accounts, Eurostat is developing guidance notes (GN) on accounts for ecosystem extent and condition as well as for ecosystem services. Eurostat has invited Member States to produce draft estimates of ecosystem accounts according to the proposed EU regulation for such accounts. Statistics Norway and the Norwegian Environment Agency, with NINA as a subcontractor, have taken on a project to test the Eurostat GN on ecosystem condition accounts applied to Norway.

In this report we present the results of the testing of the eight mandatory condition variables. These are specified in the EU legal text for ecosystem accounts and elaborated in the Eurostat GN and apply to the ecosystems *Settlements and other artificial areas, Cropland, Grassland, Forest and woodland*, and *Coastal beaches, dunes and wetlands*. The concepts and practical implementation of the variables are discussed, in particular with respect to their adherence to the principles of the internationally recognized framework for ecosystem accounts SEEA EA.

For three of the variables, the GN specifies ‘target areas’ for the variables that cover more than one ecosystem, something we find to conflict with the recommendations of the SEEA EA. For these variables we propose alternative approaches that are more consistent with the SEEA EA. In two alternatives for a fourth variable, we test the effect of using Norwegian versus European data sources, as updating frequency of the Norwegian data is uncertain.

The quantification of values for the various variables is based on existing map data for ecosystem extent and distribution, data from representative sampling of ecosystems, data from modelling combined with observation data, and data from products based on remote sensing data. This has resulted in values for seven of the eight mandatory condition variables. For soil organic carbon in cropland and grassland sufficient data are not yet available in Norway. The results of the testing of the mandatory ecosystem condition variables are summarized in Table 6 at the end of the report. For the variables 1.1 Green areas in cities and adjacent towns and suburbs and 11.1 Share of artificial impervious area cover for coastal beaches, dunes and wetlands, the results of the respective alternatives are quite different, due to different ‘target areas’ and variable data. For other variables, the results are close to what we would expect from other studies.

Some challenges relating to the allocation of variable data to their respective ecosystem types and the access and handling of the various data sources are discussed. Before a regular implementation of ecosystem condition accounts, these challenges should be resolved. Although not required for the current EU ecosystem condition accounts, we also reflect on how reference levels for the respective condition variables may be determined.

Erik Framstad (erik.framstad@nina.no) and Megan Nowell (megan.nowell@nina.no), NINA, Sognsveien 68. NO-0855 Oslo
Balint Czúcz (balint.czucz@nina.no), NINA, PO Box 5685 Torgarden, NO-7485 Trondheim

Sammendrag

Framstad, E., Czúcz, B. & Nowell, M. 2024. Eurostats obligatoriske tilstandsvariabler anvendt for Norge. NINA Rapport 2480. Norsk institutt for naturforskning.

Som ledd i å utvikle et europeisk system for naturregnskap er Eurostat i ferd med å utvikle retningslinjer for regnskap for økosystemers arealomfang og tilstand, så vel som for naturgoder. Eurostat har invitert medlemslandene til å produsere utkast til naturregnskap i henhold til EUs foreslåtte forordning for slike regnskap. SSB og Miljødirektoratet, med NINA som underleverandør, har satt i gang et prosjekt for å teste Eurostats veiledning for økosystemers tilstandsregnskap for Norge.

Her presenterer vi resultatene av testingen av de åtte obligatoriske tilstandsvariablene. Disse er beskrevet i både EU forslag til lovtekst og i Eurostats veiledning og gjelder for økosystemene byer og annen kunstig mark, dyrket mark, grasmark, skog, samt kyststrender, dyner og våtmark. Vi diskuterer både konseptuelle og praktiske forhold ved fastsetting av verdier for tilstandsvariablene, spesielt i hvilken grad Eurostats spesifikasjoner overensstemmer med prinsippene i det internasjonalt anerkjente rammeverket for naturregnskap SEEA EA.

For tre av variablene angir Eurostats veiledning at beregningene skal omfatte områder med mer enn én økosystemtype, noe vi finner å være i konflikt med anbefalingene til SEEA EA. For disse variablene foreslår vi alternative tilnærminger som er mer konsistente med SEEA EA. I to alternative tilnærminger for en fjerde variabel tester vi hvordan data fra henholdsvis norske og europeiske kilder påvirker resultatet, siden oppdateringsfrekvensen for de norske dataene er uavklart.

Fastsetting av verdier for tilstandsvariablene er dels basert på eksisterende kartdata for økosystemers arealomfang og fordeling, data fra representativ feltinnsamling, data fra modellering kombinert med feltdata, og dels data fra fjernmålingsbaserte produkter. Dette har gitt grunnlag for å beregne verdier for sju av de åtte obligatoriske variablene. For organisk jordkarbon er ennå ikke tilstrekkelige data tilgjengelig. Resultatene fra testingen av de obligatoriske tilstandsvariablene er oppsummert i tabell 6 på slutten av rapporten. For variablene 1.1 Grønne områder i byer og tilknyttete tettsteder og 11.1 Arealandel av kunstige tette flater for svaberg, kyststrender og dyner er resultatene for de enkelte alternativene ganske forskjellige, noe som skyldes ulike områder og data for beregning av variabelverdier. For øvrige variabler er verdiene omtrent som forventet ut fra resultater i andre studier.

Noen utfordringer knyttet til tilordning av variabelverdier til deres respektive økosystemer og tilgang og håndtering av de ulike datakildene er diskutert. Før man innfører ordinært økologisk tilstandsregnskap, må disse utfordringene løses. Selv om EUs opplegg for økologisk tilstandsregnskap foreløpig ikke krever fastsetting av referanseverdier, har vi diskutert hvordan slike verdier eventuelt kan fastsettes for de enkelte tilstandsvariablene.

Erik Framstad (erik.framstad@nina.no) og Megan Nowell (megan.nowell@nina.no), NINA, Sognsveien 68. 0855 Oslo
Balint Czúcz (balint.czucz@nina.no), NINA, Postboks 5685 Torgarden, 7485 Trondheim

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Foreword

The European Union (EU) has initiated work to establish a system of ecosystem accounts for Europe. A Task Force coordinated by Eurostat is in the process of developing Guidance Notes for accounts for ecosystem extent and condition, as well as for several ecosystem services. The aim of the EU is to have established European ecosystem accounts by the end of 2026, with 2024 as the reference year. In the process of developing the supporting documentation, Member States have been invited to test the various Guidance Notes. As the relevant national statistical body, Statistics Norway (SSB) has entered into an agreement with Eurostat to test the Eurostat Guidance Note (GN) for ecosystem condition accounting as well as the data and processes for Material Flow Accounts. In this project the Norwegian Environment Agency (NEA) is a formal project partner. The Norwegian Institute for Nature Research (NINA) is a subcontractor with particular responsibility for the testing of Eurostat's GN on ecosystem condition variables. This report presents the results of NINA's work on the mandatory condition variables. This will be followed in February 2025 by a final report on testing of both the mandatory and voluntary variables according to the Eurostat GN. Erik Framstad has written most of the current report, with contributions from Balint Czúcz. Megan Nowell has been responsible for the GIS-based analyses of variables. Trine Heill Braathu Randen (SSB), Lucrezia Gorini (NEA), and other staff at NEA have commented on earlier drafts of this report. This work has been financed by grant from Eurostat for project 101157104— 2023-NO-EGD.

Oslo/Trondheim, June 2024

Erik Framstad

1 Introduction

The concept of ecosystem accounting is an approach to document the level and changes of ecosystem extent, condition, and flows of ecosystem services in a systematic way (UN et al. 2021). The information provided by ecosystem accounts should make it possible for policymakers and management authorities to make more informed decisions about the management of ecosystems and their biodiversity. The System of Environmental-Economic Accounting, Ecosystem Accounting (SEEA EA), developed by the United Nations (UN et al. 2021), represents an international agreed, integrated and spatially explicit framework for ecosystem accounting. The European Union has adopted the SEEA EA framework for its work on ecosystem accounts (EU 2022a), as have several countries working on national ecosystem accounts. Eurostat is currently coordinating the development of Guidance Notes for ecosystem extent, condition and ecosystem services as a basis for the implementation of ecosystem accounts in the European Union by the end of 2026.

This report covers the testing for Norway of the Eurostat Guidance Note (GN) on ecosystem condition accounting for the proposed mandatory condition variables (Eurostat 2023b). The testing of the mandatory condition variables includes the following elements:

- Delimitation of ecosystem assets for the relevant ecosystem types to be characterised by the mandatory condition variables.
- Assessment of data availability and construction of metrics.
- Assessment of data structure compatibility.
- Assessment of reference levels.
- Documentation of data flows.
- Identification of conceptual and practical challenges.

The challenges of each mandatory condition variable and the delimitation of their respective ecosystem types vary considerably among the variables. With the exception of delimitation of the relevant ecosystem types and the assessment of reference levels, the elements listed above have been considered for each condition variable separately.

The proposed EU legal text (EU 2022a) and the draft Eurostat GN for condition accounting (Eurostat 2023b) represent the specific framing of the testing of the mandatory condition variables. The legal text specifies that the EU's system for ecosystem accounting shall be consistent with the UN framework for ecosystem accounting (SEEA EA; UN et al. 2021). Adherence to the main principles of the SEEA EA framework is a key requirement for developing robust and internationally comparable ecosystem accounts. Hence, we have checked the consistency of the specifications of the EU documents with the SEEA EA. Where we have found discrepancies between the EU and the UN frameworks, we have provided alternative solutions to satisfy each of these frameworks as well as possible.

Below we use the term 'target area' to denote the area over which the value of the condition variable shall be calculated. In the SEEA EA each condition variable represents an aspect of ecosystem condition for one specific ecosystem type (i.e., its 'parent' ecosystem type). This means that the 'target area' is expected to be equal to the area covered by the 'parent' ecosystem type within the Ecosystem Accounting Area (EAA) of interest (see e.g. SEEA EA 5.2, 5.7, 5.20). This approach is only partly followed by the EU legal text and the current Eurostat GN for condition accounting: Each condition variable (except the common farmland bird index) is linked to one specific 'parent' ecosystem type, but the 'target area' for some variables is decoupled from this 'parent' ecosystem type. This is inconsistent with the principles of SEEA EA. As all condition variables are supposed to characterise their 'parent' ecosystem types, this inconsistency can potentially confuse the users of the accounts and open the door for a broad range of misinterpretations and artefacts.

We expect that the results of our testing of the Eurostat GN on ecosystem condition accounting will provide valuable insights into practical and conceptual aspects of ecosystem condition accounting, at the European, national and, possibly, sub-national levels.

2 Ecosystem typology and delimitation of ecosystem types

The EU legal text for ecosystem accounting (EU 2022a) specifies that ecosystem accounting shall use the following ecosystem types (EU 2022, Annex IX, section 5):

1 Settlements and other artificial areas
2 Cropland
3 Grassland (pastures, semi-natural and natural grassland)
4 Forest and woodland
5 Heathland and shrub
6 Sparsely vegetated ecosystems
7 Inland wetlands
8 Rivers and canals
9 Lakes and reservoirs
10 Marine inlets and transitional waters
11 Coastal beaches, dunes and wetlands
12 Marine ecosystems (coastal waters, shelf and open ocean)

This EU ecosystem typology is explained and developed in further detail at levels 2 and 3 in the Guidance Note on ecosystem extent accounting (Eurostat 2023a). Mandatory ecosystem condition accounting is so far, however, only specified for ecosystem types 1, 2, 3, 4, and 11, at level 1 of the typology.

As a basis for identifying and delimiting ecosystem assets of the ecosystem types at level 1 of the EU typology presented above, a new 'basic map for ecosystem extent accounting' has been developed for Norway (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no); Strand et al. 2024). The map is produced through cooperation between SSB, NEA, the Norwegian Mapping Authority (Kartverket), and the Norwegian Institute of Bioeconomy Research (NIBIO). The map is based on a re-classification of various existing land cover and land use map data to fit level 1 of the EU typology as well as possible (and levels 2 and 3 where possible). The map provides a detailed and rather precise representation of ecosystem types *1 Settlements and other artificial areas*, *2 Cropland* (although it includes cultivated grassland), and *4 Forest and woodland*. However, ecosystem types *3 Grassland* and *11 Coastal beaches, dunes and wetlands* are only partly covered, with the former limited to infield grazing areas and the latter to sparsely vegetated ecosystems satisfying specific conditions for coastal proximity. Regular production of the basic map for ecosystem extent accounts, with annual updates, is expected from 2025.

The individual condition variables vary in their association with the specific ecosystem types that they characterize (cf. the discussion for each variable below and in Chapter 6.1). Some of these variables will need a precise map-based association, but not the bird indices or variables based on data samples from known specific ecosystems.

3 Specification of ecosystem condition variables in the EU legal text

The EU legal text for ecosystem accounts specifies the following mandatory condition variables (EU 2022a, Annex IX, section 3):

"Ecosystem condition accounts recording ecosystem characteristics as follows:
(a) for settlements and other artificial areas:

- *green areas in cities and adjacent towns and suburbs shall be reported in % of total area, calculated for the entire area of the cities and adjacent towns and suburbs, including all ecosystem types in that area*
- *concentration of particulate matter, with a diameter up to 2.5 μm in cities, shall be reported in μg/m^3 as a national average for the reporting period.*

(b) for cropland:

- *soil organic carbon stock in topsoil shall be reported in tonne/ha, as a national average for the reporting period.*

(c) for grassland:

- *soil organic carbon stock in topsoil shall be reported in tonne/ha, as a national average for the reporting period.*

(d) for cropland and grassland together:

- *common farmland bird index shall be reported as a national aggregate index for the reporting period.*

(e) for forest and woodland:

- *dead wood shall be reported in m3/ha, as a national average for the reporting period;*
- *tree cover density shall be reported in %, as a national average for the reporting period.*

(f) for coastal beaches, dunes and wetlands:

- *the share of artificial impervious area cover, present in coastal area that includes ecosystem type coastal beaches, dunes and wetlands shall be reported in % as a national average for the reporting period.*

Cities, towns and suburbs are local administrative units, categorised according to the degree of urbanisation typology set out under Regulation (EU) 2017/2391."

An additional mandatory condition variable for forest and woodland, a common forest bird index, has been included as a result of the final discussions of the legal text among the relevant EU institutions in February 2024 (revised text for amended of Regulation (EU) 691/2011):

"- common forest bird index; the forest bird indicator describes trends in the abundance of common forest birds across their European ranges over time; it is a composite index created from observational data of bird species characteristic for forest habitats in Europe; the index is based on a specific list of species in each Member State."

This new variable is not yet described in an updated version of the Eurostat GN for condition accounts. However, we assume that this variable is equivalent to the common farmland bird index in its construction, except that a different set of bird species are included.

Note that the legal module on ecosystem accounting is limited to step 1 in the UN framework for ecosystem accounting (SEEA EA), i.e., accounting for condition variables in their original measured units. Nevertheless, we present some thoughts on possible reference values for the mandatory variables in Chapter 5.

4 Definition and measurement of ecosystem condition variables

In the Eurostat Guidance Note (GN) for condition accounts (Eurostat 2023b) the specification of the mandatory condition variables in the legal text (cf. Chapter 3) is further elaborated (cf. the full variable descriptions in **Appendix 1** below). Here we present the essence of the GN for each variable and add our reflections on the possible data sources and challenges in applying the Eurostat procedures to Norway, as well as the results for variables where data are available. The numbering of the condition variables follows the GN.

Variable 1.1 Green areas in cities and adjacent towns and suburbs

The EU legal text specifies this variable as "*green areas in cities and adjacent towns and suburbs shall be reported in % of total area, calculated for the entire area of the cities and adjacent towns and suburbs, including all ecosystem types in that area*". Presumably, the underlying purpose of this condition variable is to measure the proportion of ecologically functioning vegetated surfaces nested within urban ecosystems (*1 Settlements and other artificial areas*). An urban ecosystem is always a 'mosaic' of several land use and land cover classes, predominantly diverse artificial and vegetated surfaces, but often also water and bare ground/rock. Vegetated ('green') surfaces are vital components of this 'mosaic', with a key role for maintaining ecological functioning and providing various ecosystem services. According to SEEA EA (e.g. 5.39) the abundance of such key components in a 'mosaic' ecosystem type can be seen as relevant ecosystem characteristics. These can be quantified using a variable describing the share of 'green areas' within the total area covered by the 'parent' urban ecosystem (i.e., *1 Settlements and other artificial areas*). Nevertheless, this would imply that the 'target area' for the variable coincides with the 'parent' ecosystem type, and that the delineation of green areas is based on ecological principles (rather than just ad hoc technical thresholds).

Whereas values for all other mandatory variables should be national averages or aggregates, this is not specified explicitly for this variable. Nevertheless, we assume that the value also for this variable should be a national average value.

The legal text defines the 'target area' for this variable as the entire area of the specified cities and adjacent towns and suburbs. As we have shown above, this formulation is not in line with the principles of SEEA EA. In addition, this formulation raises two main questions: (1) How do we define and delimit the areas of 'cities and adjacent towns and suburbs', and (2) how do we define and delimit urban 'green areas' in this context? And from the perspective of SEEA EA, there is a third, even more fundamental question: how does the definition of the 'target area' relate to the ecosystem type *1 Settlements and other artificial areas*? (cf. our discussion below).

Defining and delimiting 'cities and adjacent towns and suburbs'
The legal text states that "*cities, towns and suburbs are Local Administrative Units*" (LAUs) which should be "*categorised according to the degree of urbanisation typology*" outlined in Regulation (EU) 2017/2391 (EU 2017). The said regulation specifies three categories of urbanisation: cities/densely populated areas, towns and suburbs/intermediate density areas, and rural areas/thinly populated areas, each category being more explicitly defined in EU (2019), cf. **Appendix 2** below. Eurostat regularly updates lists of such LAUs in Member States and other European countries. For Norway, LAUs are equivalent to municipalities, and Eurostat has classified each of these to an urbanisation category (cf. **Appendix 2**). From the legal text it appears that not all LAUs classified as 'towns and suburbs' should be included, only those that are *adjacent* to LAUs classified as cities. *Adjacent* in this context might mean 'town and suburb LAUs' with common boundaries to 'city LAUs'. However, grouping LAUs defined as 'cities' or 'towns and suburbs' by Functional Urban Areas (FUAs), as done by Eurostat, may represent relevant urban agglomerations in a more meaningful way than by 'common boundaries' (cf. **Appendix 2**).

In general, LAUs do not coincide with the parent ecosystem type *1 Settlements and other artificial areas* and will in most cases include several other ecosystem types at level 1 of the EU typology. Directly applying the legal text means that the values of the condition variable will characterise a larger (often much larger) area than that of *1 Settlements and other artificial areas*. Hence, the approach of the legal text is not consistent with the UN framework (SEEA EA; UN et al. 2021), where values for condition variables should be specific for each ecosystem asset of a given ecosystem type, to be aggregated for that ecosystem type in the accounting. To be consistent with the SEEA EA framework it would be more relevant to consider the parent ecosystem type (*1 Settlements*…) as the 'target area', and LAUs as Ecosystem Accounting Areas (EAAs), i.e., as administrative units for which ecosystem accounts can be made, to be further aggregated to higher administrative units, like countries.

In Norway, the use of LAUs for delimitation of cities, towns and suburbs is particularly ill suited. Even the largest cities are part of municipalities (i.e., LAUs) where *Settlements and other artificial areas* constitute at most 25 % (in the case of Oslo; Arealbarometer - Nibio). Including all such non-urban area as 'green area' within LAUs defined as cities and adjacent towns and suburbs does not seem to reflect the essential purpose of this condition variable.

The Eurostat GN on ecosystem condition accounting presents two options for delimitation of the relevant urban area, one based on LAUs, and another one based on the parent ecosystem type *Settlements and other artificial areas*. The LAU approach is consistent with the legal text. In this approach all identified pixels of terrestrial ecosystems (except *Settlements and other artificial areas*) within the boundary of the LAU, whether larger or smaller than the minimum mapping unit (MMU), are included in the calculation of the proportion of green areas in cities and adjacent towns and suburbs. As noted above, this will in most cases not reflect the essential purpose of this condition variable, by including large areas of non-urban ecosystems, often remote from the areas of *Settlements and other artificial areas*. In the second approach based on *Settlements and other artificial areas* only, the mapped occurrences of other terrestrial ecosystems within the outer boundary of *Settlements and other artificial areas* are included as a basis for calculating the condition variable. Note that to be fully compatible with the SEEA EA framework, the full extent of the ecosystem type *1 Settlements and other artificial areas* should be used, not just those parts which fall within the LAUs specified by the legal text.

Possible implementation for Norway
Technically, it would be unproblematic to use the boundaries of LAUs classified as cities and adjacent towns and suburbs to delimit urban areas, e.g., with land cover data from the new basic map for ecosystem extent accounts (cf. below). However, as noted above, this would not be a meaningful way to represent the purpose of this condition variable, given that LAUs cover far more than *Settlements and other artificial areas*. Hence, a better approach would be to base the boundary of urban areas on a delimitation of *Settlements and other artificial areas*. Some recent mapping developments are relevant here:

- A new 'basic map for ecosystem extent accounting' has been developed for Norway (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no); Strand et al. 2024; cf. Chapter 2 above). The map is a vector map based on a re-classification of existing map data. The delimitation of *Settlements and other artificial areas* is based on the land use categories for built-up areas, buildings and technical infrastructure from Statics Norway (SSB), and, where the SSB classification is lacking, built-up areas and transport infrastructure in the AR5 data set from the Norwegian Institute of Bioeconomy Research (NIBIO). Urban green areas (class *1.4 Urban greenspace* in the EU typology) are defined as the SSB land use classes for parks and areas for sports and recreation. The class *1.5.2 Cemeteries* of the EU typology could also have been included as urban green area since these tend to be quite park-like in Norway. Other types of green areas are defined as other terrestrial areas in NIBIO's AR5 dataset, not covered by the SSB land use data. These are re-classified to level 1-units of the EU typology: cropland, grassland, forest, heathland, sparsely vegetated ecosystems, open mires, and open sparsely vegetated coastal land. The spatial resolution of this map varies with ecosystem types but is generally finer than 0.2 hectares. Annual updates are planned.

- NIBIO has developed a national map of urban green areas within built-up areas (FKB-Grønnstruktur - Kartkatalogen (geonorge.no), Borchsenius et al. 2023). The delimitation of *Settlements and other artificial areas* is based on the class for built-up area and transport infrastructure in NIBIO's data set AR5, supplemented with the SSB land use classification (which mainly covers built-up areas). The occurrences of these classes of built-up areas are surrounded by a buffer strip to aggregated small urban fragments into more contiguous areas. Occurrences of urban green areas have been defined from remote sensing data from the Copernicus Very High Resolution data set with a 2x2 m spatial resolution for the reference period mid-summer 2021 (supplemented by some data from mid-summer 2020). In addition, Norwegian laser data were used to classify the identified vegetation structures into three layers: field (<1m), bushes (1 – <3m), and trees (≥3m). The resulting map is divided into eight classes: field layer, bush layer, tree layer, exploited surfaces (paved, gravel or other man-made or natural surfaces without vegetation), roads, water, buildings, agricultural land. The plan is to update the urban green areas map at 3-year intervals. Note that natural unvegetated surfaces and agricultural land are not included as urban green areas, although agricultural areas are identified as a separate class and could be aggregated with the urban green areas if required. Note also that the 2x2 m resolution of NIBIO's urban green areas map is much finer than the MMU of the basic map for ecosystem extent accounting. Hence, several smaller occurrences of urban green areas are likely to be identified in this map than in the basic map for ecosystem extent accounting.

The implementation of the condition variable *Green areas in cities and adjacent towns and suburbs* based on NIBIO's urban green areas map will yield the best representation of urban green areas. To be consistent with the SEEA EA framework, all built-up areas in NIBIO's map should be included as 'target area', not just for those LAUs classified as cities and adjacent towns and suburbs. An alternative based on the basic map for ecosystem extent accounting would also be consistent with SEEA EA, although this alternative will have a more limited coverage of urban green areas, i.e., the ecosystem type *1.4 Urban greenspace*.

Calculating values for the condition variable

The testing of the Eurostat GN for condition accounting requires that we follow the GN as far as possible. However, as pointed out above, for condition variable 1.1 the legal text is not consistent with the SEEA EA framework as the defined 'target area' includes more than one ecosystem. Hence, we present three different alternatives to quantify this variable, each with a different definition of 'target area': (a) LAUs as the 'target area', as specified in the legal text and the GN, (b) the representation of *Settlements and other artificial areas* in the basic map for ecosystem extent accounts as the 'target area', and (c) the representation of built-up areas in NIBIO's urban green areas map as the 'target area'. We also use different representations of urban green areas for these alternatives: (a) relevant level 1 and 2 ecosystem types in the basic map (Strand et al. 2024), (b) type *1.4 Urban greenspace* in the same map, and (c) the green surfaces in the NIBIO urban green areas map (Borchsenius et al. 2023). In all alternatives the condition value is calculated as a national average for the defined 'target area'.

(a) LAU-based alternative:

- *Definition of 'target area'*: The non-marine area of all LAUs defined as 'cities' plus the non-marine area of those LAUs defined as 'towns and suburbs' included in the FUAs of cities LAUs, according to Eurostat's list of Norwegian LAUs (cf. **Appendix 2**).
- *Definition of condition variable*: The area of the EU ecosystem types 3, 4 and 5 at level 1, as well as type *1.4 Urban greenspace* at level 2, as a proportion (%) of the total 'target area'. The effect of adding ecosystem types 6 and 11 (inland and coastal sparsely vegetated ecosystems) is documented.

- *Basic data source*: Map of Norwegian municipalities. The basic map for ecosystem extent accounting (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no)).
- *Calculation of variable value*: The value of the condition variable can be calculated as a national mean value by taking the proportion of the total area of the relevant ecosystem types within the 'target area' and diving by the total 'target area'. Simple GIS analysis is needed to extract the areas for relevant ecosystems for the 'target area'.

(b) Basic map for ecosystem extent accounting alternative:

- *Definition of 'target area'*: The complete national area of all occurrences of ecosystem type *1 Settlements and other artificial areas* as defined in the basic map on ecosystem extent accounting.
- *Condition variable definition*: The complete national area of ecosystem type *1.4 Urban greenspace* as defined in the basic map on ecosystem extent accounting as a proportion (%) of the total 'target area' for the whole country.
- *Basic data source*: The basic map on ecosystem extent accounting (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no)).
- *Calculation of variable value*: The value of the condition variable can be calculated as a national mean value by talking the total area of *1.4 Urban greenspace* and diving by the total 'target area'. No GIS analysis should be needed since the extents of 'target area' and urban green areas are given as the sum of areas for polygons of ecosystem types 1 and 1.4, respectively.

(c) Green infrastructures map alternative:

- *Definition of 'target area'*: The defined built-up area in the green infrastructures map for the complete national coverage of NIBIO's urban green areas map (Borchsenius et al. 2023).
- *Condition variable definition*: The area of the defined green areas (i.e., field, bush, and tree layers) in the urban green areas map as a proportion (%) of the total 'target area' for the whole country.
- *Basic data source*: The urban green areas map produced by NIBIO (FKB-Grønnstruktur - Kartkatalogen (geonorge.no)).
- *Calculation of variable value*: The value of the condition variable can be calculated as a national mean value by talking the total area of urban green areas and diving by the total 'target area'. No GIS analysis should be needed since the extent of green areas will be distributed over the entire area of the urban green areas map and can presumably be extracted directly from the map data.

Results

Table 1 shows the results for the three alternative approaches for variable 1.1 Green areas in cities and adjacent towns and suburbs (see above for specification of each alternative). As argued above, alternative (a), as specified in the legal text and the Eurostat GN, is not consistent with the SEEA EA framework. This alternative also results in a rather meaningless measure of urban green areas by covering extensive non-urban areas remote from cities, towns and suburbs. Alternatives (b) and (c) are based on two different definitions of urban areas, both covering more reasonable concepts for urban green areas, although the resulting proportions of urban green area are very different.

For alternative (a), the inclusion of sparsely vegetated ecosystems (cf. numbers in parentheses in **Table 1**) adds about 800 km^2 of green area and increases the variable value by about 9%. For alternatives (a) and (b), ecosystem type *1.5.2 Cemeteries* could have been included in the urban green area, but since this type covers <1% of *Settlements and other artificial areas* at the national level in the basic map for ecosystem extent accounting it would have limited effect on the variable value. The very different results for alternatives (b) and (c) are mainly due to their different definitions of urban green areas. In alternative (b), this is limited to a particular classified ecosystem type (1.4), mapped at a coarser resolution than the more general urban green areas mapped by remote sensing at finer resolution in alternative (c). The larger 'target area' of alternative (c) than (b) may also lead to inclusion of more green area in the buffer zones used in the urban green areas map to aggregate smaller fragments of urban area.

Table 1 *Results of three different approaches to quantify variable 1.1 Green areas in cities and adjacent towns and suburbs (see description of alternatives above). Numbers for ecosystem types refer to the ecosystems of the EU typology. For alternative (a), separate measures of urban green area have been included: vegetated ecosystems (grassland, forest, heathland, and* 1.4 Urban greenspace *at level 2) only, and with the addition of sparsely vegetated inland (6) and coastal (11) ecosystems. For alternative (b) urban green areas only include* 1.4 Urban greenspace*. For alternative (c) urban green areas include areas of tree, bush, and field layers.*

Alternative	Target area	Target area size	Urban green area	Urban green area size	Variable value
(a) LAU-based	Defined municipalities (LAUs) in the Functional Urban Areas (FUAs) of Oslo, Bergen, Trondheim, Stavanger*	8 647 km^2	All vegetated ecosystems (3, 4, 5) plus *1.4 Urban greenspace* (with addition of sparsely vegetated ecosystems 6, 11)	5 181 km^2 (5 986 km^2)	59.9% (69.2%)
(b) Ecosystem extent map	All polygons of ecosystem type *1 Settlements and other artificial areas*	5 691 km^2	All polygons of ecosystem type *1.4 Urban greenspace*	245 km^2	4.3%
(c) Urban green areas map (UGM)	All polygons defined as urban area in UGM	13 117 km^2	All polygons defined as urban green in UGM	6 841 km^2	52.2%

* LAUs: Local Administrative Units (= municipalities), FUAs: Functional Urban Area; both as specified for Norway in the 2023 list from Eurostat (cf. **Appendix 2**).

Variable 1.2 Concentration of Particulate Matter (PM) with a diameter up to 2.5 μm in cities

The EU legal text specifies this variable as the "*concentration of particulate matter, with a diameter up to 2.5 μm in cities, shall be reported in μg/m^3 as a national average for the reporting period*". It appears that the legal text also in this case refers to 'cities' as LAUs classified as cities according to Regulation (EU) 2017/2391 (EU 2017). As argued for condition variable 1.1 above, using LAUs as a basis for calculating this condition variable is not ecologically meaningful nor consistent with the SEEA EA framework.

The Eurostat GN on ecosystem condition accounting is not quite clear on how 'cities' should be defined for this variable. On the one hand the GN states "*For the spatial delineation, local administrative units (LAUs) categorised as cities according to the degree of urbanisation typology set out under Regulation (EU) 2017/2391 are considered*." On the other hand, it states (at the very end) "*In a national ecosystem account, the concentration would be averaged over all pixels classified as 'Settlements and other artificial areas*'". The latter is also illustrated by the example given (cf. figure 2 in **Appendix 1**). However, it is still unclear in the GN whether the latter approach should cover the full extent of *Settlements and other artificial areas* or whether only those parts that fall within LAUs defined as cities should be included. To be consistent with the SEEA EA framework, the full extent of *Settlements and other artificial areas* should be used.

The relevance of this variable as an ecosystem condition variable is questionable. It may primarily be considered as an ecosystem pressure variable, or alternatively as a negative ecosystem services variable, rather than as an ecological condition variable.

As a dataset for this variable at the European level, the Eurostat GN refers to annual air pollution data at 1 km spatial resolution provided by the European Environment Agency (EEA), based on data provided by the member states. The GN states that national data at higher spatial and temporal resolution should be used where available.

Possible implementation for Norway
The concentration of PM2.5 is available for all of Norway as modelled gridded data at 100 x 100 m resolution from the Norwegian Environment Agency (Fagbrukertjeneste for luftkvalitet - Miljødirektoratet (miljodirektoratet.no)). The modelled data are based on the urban EMEP model with input data from local monitoring, data on local and long-range emissions, and weather data. The modelled data are given as annual means per grid cell and may be calculated as means for specific delimitations of urban areas, i.e., for the whole municipality or for a more restricted delimitation of built-up area. At the NEA website (Fagbrukertjeneste for luftkvalitet - Miljødirektoratet (miljodirektoratet.no)) the last year with presented data is 2022.

Calculating values for the condition variable
As for condition variable 1.1, specification of the ‘target area’ for this variable in the legal text is not consistent with the SEEA EA framework. Hence, we present two alternative approaches for this variable, one with a ‘target area’ based on LAUs defined as cities and another where the ‘target area’ covers the full extent of the ecosystem type Settlements and other artificial areas.

(a) LAU-based alternative:

- *Definition of ‘target area’*: The non-marine area of all LAUs defined as ‘cities’ (cf. **Appendix 2**).
- *Definition of condition variable*: Concentration of PM2.5 particles (in μg/m^3) as an annual mean for the whole ‘target area’.
- *Basic data source*: Map of boundaries for municipalities. Modelled data from NEA (Fagbrukertjeneste for luftkvalitet - Miljødirektoratet (miljodirektoratet.no)).
- *Calculation of variable value*: The value of the condition variable can be calculated as a national mean of values for the 100 x 100 m grid cells within the total ‘target area’. Simple GIS analysis will be needed to extract PM2.5 values for the ‘target area’.

(b) Full coverage of Settlements and other artificial areas alternative:

- *Definition of ‘target area’*: The full national extent of *Settlements and other artificial areas* as defined in the basic map for ecosystem extent accounting.
- *Definition of condition variable*: Concentration of PM2.5 particles (as μg/m^3) as an annual mean for the whole ‘target area’.
- *Basic data source*: Basic map for ecosystem extent accounting (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no)). Modelled data from NEA (Fagbrukertjeneste for luftkvalitet - Miljødirektoratet (miljodirektoratet.no)).
- *Calculation of variable value*: The value of the condition variable can be calculated as a national mean of values for the 100 x 100 m grid cells within the total ‘target area’. Simple GIS analysis will be needed to extract PM2.5 values for the ‘target area’.

Results
Table 2 presents the results of the two alternative approaches. The national mean values of 3.76 and 3.25 μg/m^3 are rather similar for both alternatives, compared to a total national mean value of 1.85 μg/m^3. In alternative (a), non-urban parts of the selected municipalities probably have average values considerably lower than the urban parts. In alternative (b), there is probably considerable variation in concentrations between urban centres or main highways and less densely populated parts of the ecosystem type *Settlements and other artificial areas*. This is illustrated for both alternatives by detailed maps for the selected municipalities (Fagbrukertjeneste for

luftkvalitet - Miljødirektoratet (miljodirektoratet.no)). Nevertheless, only alternative (b) is in line with the principles of SEEA EA (i.e., that the target area coincides with the area of the parent ecosystem type). For alternative (b) the 'target area' of *Settlements and other artificial areas* is slightly larger than the same defined 'target area' used for variable 1.1b; this is due to raster data being used for variable 1.2b.

Table 2 *Results of two different approaches to quantify variable 1.2 Concentration of particles PM2.5 in cities (see text above for description of alternatives). Variable values are annual means for 2022 the respective 'target areas'.*

Alternative	Target area	Target area size	Mean PM2.5 concentration
(a) LAU-based	Municipalities defined as 'cities' in list of LAUs	4 250 km^2	3.76 $\mu g/m^3$
(b) Ecosystem extent map	All polygons of ecosystem type *1 Settlements and other artificial areas*	5 699 km^2	3.25 $\mu g/m^3$

Variable 2.1 and 3.1 Soil organic carbon stock in topsoil in cropland and grassland

This condition variable has the same definition for cropland and grassland but should have separate values for each of these ecosystems. The EU legal text specifies this variable as follows: "*soil organic carbon stock in topsoil shall be reported in tonne/ha, as a national average for the reporting period*." The legal text does not specify what 'topsoil' is in this context. This variable covers both mineral and organic soils.

In the Eurostat GN 'topsoil' is specified as the top 30 cm of soil for the mandatory variable, whereas soil carbon stocks down to 2 m may be reported as a voluntary variable. Exactly how soil organic carbon (SOC) down to 30 cm should be measured is not specified in the GN. Presumably the GN assumes that some 'standard practice' is applied, e.g., as in LUCAS Soil (Tóth et al. 2013). The GN recommends that national data with high spatial resolution be used. If such data are not available, the GN suggests possible European or global data sets, such as the EU LUCAS Soil data set (not available for Norway), raster data for continental Europe at 500 m resolution from the European Soil Data Center (ESDAC) generated from LUCAS data, or alternatively, global datasets of rasterized maps of soil properties for six depth intervals at 250 m spatial resolution from ISRIC – World Soil Information, though the latter has limited accuracy.

Possible implementation for Norway

The identification and delimitation of the EU level 1 ecosystem classes *2 Cropland* and *3 Grassland* in Norway deviate somewhat from the specifications in the EU typology. Whereas the class cropland is rather well matched by the Norwegian agricultural land categories 'fulldyrka' (arable land) and 'overflatedyrka' (agricultural land with surface cultivation), the class grassland is only covered by the Norwegian land category 'innmarksbeite' (infield, actively managed grazing land). This means that outfield semi-natural and natural grasslands which are not actively managed, although may be extensively grazed by livestock, are not yet properly mapped. Such grasslands will therefore not be included in ecosystem extent accounting, and sampling of condition variables from such grasslands will not be representative.

Data on SOC in the top 30 cm for cropland and grassland may become available from two soil monitoring programmes organised by NIBIO:

- The national monitoring programme for soil carbon in forest and managed grazing land ('innmarksbeite') started in 2023, with spatially representative sampling on a total of 3000 sites in forest and 300 sites in grazing land on a 10-year cycle (Monitoring soil organic carbon in forests and grasslands - Nibio). Only few samples will be available for grassland per 2024.

- The national monitoring programme for soil carbon in cropland (JordVAAK) has been planned and tested during 2023 (JordVAAK – Implementation of the Norwegian Agricultural Soil Monitoring Programme - Nibio, Bárcena et al. 2024). The full monitoring programme is planned to cover 805 sites in cropland ('fulldyrka' and 'overflatedyrka') with spatially representative sampling on a 10-year cycle. However, long-term financing to start the regular monitoring of SOC in cropland has not yet been made available. Hence, the first possible year for data collection is 2025.

Note that for 2023, with data available in 2024, there are only a few sampled sites for grassland (≈30) and none for cropland. European-level data based on LUCAS Soil are not available for Norway. Hence, there will be no reliable data for SOC for the relevant ecosystems for Norway, and results for this condition variable cannot be delivered for this test project. If and when these monitoring programmes become fully operational, due to the high spatial variability in soil data, data should probably be aggregated from samples over the three years preceding and including each reference year, rather than just being based on samples from the reference year.

Calculating values for the condition variable

- *Definition of 'target area'*: There are two separate 'target areas': croplands and grasslands. These can be identified from the basic map for ecosystem extent accounting based on re-classification of existing map data (cf. Chapter 2). In practice, these ecosystems will be defined by the specific sites used for sampling SOC in, respectively, cropland and grassland.
- *Definition of condition variable*: SOC stock (in tonnes/ha) in the top 30 cm of soil, as a mean for the whole 'target area'.
- *Basic data source*: For grassland data will be available through the NFI soil monitoring programme. For cropland data may eventually be available through the JordVAAK soil monitoring programme but it is still unclear when.
- *Calculation of variable value*: The mean SOC stock will be given as the mean value for all sampled sites in each 'target area'.

As adequate data are not yet available for this variable, results cannot be given. Care should be taken in both monitoring programmes for recording the actual ecosystem types (and subtypes at levels 2 and 3) at the sites of sampling, as this can help with the setting of reference levels and the identification of ecosystem conversions.

Variable 2.2 and 3.2 Common farmland bird index for cropland and grassland

This condition variable applies to cropland and grassland combined, i.e., there is a common index value for both ecosystems. The legal text specifies this variable as "*common farmland bird index shall be reported as a national aggregate index for the reporting period*." The index is developed at the pan-European level making use of data from the Pan European Common Birds Monitoring Scheme (PECBMS). The index is available at the EU level and at national level for most countries. It is based on selected species that are dependent on farmland habitats for feeding and/or nesting. National common farmland bird indices are based on species sets that are relevant to each Member State. The national indices are based on national monitoring data where the trend for each species is scaled by the estimated abundance for a common base year (specified as 2000 in the Eurostat GN). The relative annual values for each species are aggregated across species as geometric means. Note that it is not meaningful to compare the level of the various national indices for a given year. Comparisons between countries are only meaningful for the relative time trends of the respective national indices.

Possible implementation for Norway

The Norwegian common farmland bird index is aggregated and managed by NINA, based on data from the common breeding bird monitoring scheme managed by BirdLife Norway (Norsk hekkefuglovervåking: Start (nina.no)). A standardised version of this index, consistent with the European method, is used for the Norwegian Nature Index, assessments of ecosystem condition, and international reporting. However, due to harmonisation with equivalent bird indices for other ecosystems, the base year for scaling of individual species abundances is currently 2008. For farmland birds the time series of abundances are sufficiently long to apply 2000 as the base year. There are currently only seven farmland bird species included in this index for Norway: *Alauda arvensis, Hirundo rustica, Motacilla alba, Sturnus vulgaris, Emberiza citronella, Numenius arquata, Vanellus vanellus*. This is rather less than the number of similar species included in the farmland bird indices for Sweden (14) and Finland (11). Note that the habitats of these species are not specific to cropland and/or grassland but are more general open habitats of the wider agricultural landscape.

Calculating values for the condition variable

- *Definition of 'target area'*: In principle, the 'target area' is the combined area of cropland and grassland as identified in the basic map for ecosystem extent accounting (cf. Chapter 1). In practice, the 'target area' is not precisely defined but covers the wider agricultural landscape where the relevant bird species find their habitats.
- *Definition of condition variable*: The relative index of abundance for a specific set of breeding birds with relatively frequent occurrence in the wider agricultural landscape.
- *Basic data source*: The farmland bird index is produced annually by NINA, based on data from the national breeding bird monitoring programme.
- *Calculation of variable value*: The national value is available in the required format from NINA. In this test case we have applied 2008 as the base year; this can be changed to 2000 in a full implementation of the condition accounts.

Results

The index value for the last available year (2023) was 61.8 (with 1 SD of 5.36), compared with a value of 100 for the base year 2008. **Figure 1** shows the time series of the index values since 2008, with a declining trend for the first part of this period and more or less stable values over the last 10 years.

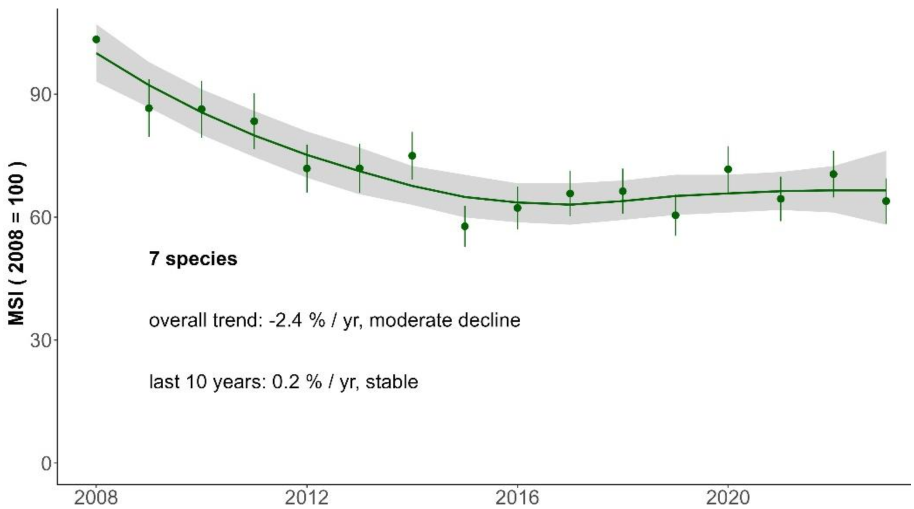

Figure 1 *Values for the common farmland bird index since 2008 (the base year with standard index value set to 100). Vertical bars and the grey area around the trendline indicate ±1 SD. See the text for included species.*

Variable 4.1 Dead wood for forest and woodland

The legal text specifies this variable as "*dead wood shall be reported in m3/ha, as a national average for the reporting period*."

This variable shall be applied to dead wood in ecosystem type *4 Forest and woodlands* in the EU ecosystem typology, specified as "*tree-dominated ecosystems with a canopy cover over 30% (in Mediterranean and temperate ecosystems) or 10% (in boreal ecosystems) or ecosystems where present trees are able to reach these thresholds in situ*." For boreal forest this is consistent with the forest definition of the UN Food and Agriculture Organization (FAO 2018), but it is more restrictive than the FAO definition for temperate and Mediterranean forests. In the Eurostat GN, the ecosystem is specified as "*forest and other wooded land*". The concept 'other wooded land' is generally not considered forest and is defined as wooded land where trees (of at least 5 m height) have a canopy cover of 5–10% or may have a canopy cover of >10% in combination with wooded vegetation <5 m tall (FAO 2018). Hence, it seems that the GN may conflict with the definition of forest and woodland in the EU ecosystem typology, as well as with FAO's forest definition, although the terminology may just be imprecise. Forest Europe (2020) appears to present dead wood for forest (not 'other wooded land') in its Annexes to Part I, Table 31.

The Eurostat GN specifies that dead wood shall include both standing and lying dead woody biomass. This may be interpreted as including all sizes and conditions of dead wood, even very thin or short or much decomposed dead wood. However, it is unrealistic to assume that all such dimensions and varieties of dead wood are measured in practice. Neither the Eurostat GN nor Forest Europe (2020) give any reflections on the kinds of dead wood that should be included (beyond standing and lying dead wood) or how this should be measured. Hence, it is likely that the national measures of dead wood, e.g., as reported to Forest Europe, will vary in how the amount of dead wood is measured. Comparability is one of the most important principles of SEEA EA (e.g. 5.3, 5.65), which can only be ensured by documenting and harmonising the details of how Member States assess and quantify the amount of lying and standing dead wood in their accounts.

The Eurostat GN refers to Forest Europe (2020) for data for this variable at the European level. These data are based on national reporting and are published at 5-year intervals (with the last data available for 2015), i.e., the reporting deviates from the specified reporting schedule of the EU ecosystem accounting. The GN also refers to global data from the FAO. However, these data are less reliable as they are based on data for live standing timber volume and calculated by use of 'biomass expansion factors'.

Possible implementation for Norway

Since 2010 standing and lying dead wood ≥10 cm in diameter has been measured according to a standard protocol as part of the Norwegian National Forest Inventory (NFI; Breidenbach et al. 2020, Viken 2021). The dead wood measurements cover NFI plots in forest (cf. FAO (2018) definitions). There are approximately 12 000 NFI forest plots distributed on a regular grid covering the whole country. Each year 20% of all forest plots are surveyed, covering the entire set of plots on a 5-year cycle. Due to the statistically representative sampling each year, updated annual estimates for the whole country are available (with 1-year lag).

Calculating values for the condition variable

- *Definition of 'target area'*: In principle, the 'target area' is the area of forest as identified in the basic map for ecosystem extent accounting (cf. Chapter 1). In practice, the 'target area' is given by the sampling plots of the NFI for productive and unproductive forest (but not for 'other wooded land').
- *Definition of condition variable*: The variable is the mean national value of the volume (m^3/ha) of lying and standing dead wood ≥10 cm in diameter for the NFI sample plots within the 'target area'.

- *Basic data source*: The data are available from the NFI/NIBIO, either as individual sample plot values or as an overall national mean.
- *Calculation of variable value*: The mean national value is either directly available from the NFI or must be calculated as an area-weighted mean from individual sample plot values, where individual sample plots may represent different proportions of the total area of forest.

Results

The national mean value of the volume of lying and standing dead wood for productive and unproductive forest[1] (covering 120 738 km^2) was 9.4 m^3/ha for the last available inventory period 2018-2022 (Johannes Breidenbach in litt.). For productive forest (covering 85 888 km^2) the mean value was 12.1 m^3/ha, whereas it was 2.7 m^3/ha for unproductive forest (covering 34 850 km^2). The volume of dead wood has increased over the last few decades, although from a low base value (Storaunet 2021).

Variable 4.2 Tree cover density for forest and woodland

The EU legal text specifies this variable as "*tree cover density shall be reported in %, as a national average for the reporting period*." As for condition variable 4.1, this variable applies to ecosystem *4 Forests and woodlands* in the EU typology, i.e., not including land defined as 'other wooded land' according to the FAO (2018) definition. The Eurostat GN specifies that "*Tree cover density reflects the vertical projection of tree crowns to a horizontal earth's surface. This indicator measures the proportional (percent) tree canopy coverage per grid cell, ecosystem asset or ecosystem type.*" According to the GN, this variable is probably best measured by remote sensing methods. The Eurostat GN refers to data from the Copernicus High Resolution Layer for Tree Cover Density for this variable at the European level (High Resolution Layer Tree Cover Density — Copernicus Land Monitoring Service). This data set is based on classification of Sentinel 2 data and covers Europe ('the EEA area') at 10 m and 100 m resolutions. The most recent year for available data is 2018, but the data are supposed to be updated every 3 years.

This condition variable as an overall mean for all forest types is not necessarily ecologically meaningful, i.e., does a denser forest always imply a better condition? (Confer the criterion of 'directional meaning' in SEEA EA Annex 5.1 and Czucz et al. (2021).) The natural tree cover density will vary both with the forest type (e.g., dense moist spruce forest versus open dry pine forest) and the seral stage or mean tree age of the individual forest plots. However, at this stage we calculate the variable as it is defined.

Possible implementation for Norway

In the Norwegian NFI (cf. variable 4.1 above) one of the forest variables measured is the percent crown cover of trees within 0.1 hectare (cf. Kronedekningsprosent KRD, p. 69 in Viken 2021). However, this variable is not measured at NFI plots classified as productive forest, just for other categories of tree-covered land. Hence, the measured data from the NFI are not representative for all forest land. An alternative and representative data set can be found in NIBIO's forest resources map SR16 (Hauglin et al. 2021, NIBIO 2023). This map provides updated modelled information on various forest attributes based on field data from the NFI plots and airborne laser scanning. The variable Kronedekning, represented as percent vertical crown cover per 16 x 16 m pixel for all SR16 pixels, may be relevant here. However, the Kronedekning variable is based on data from laser scanning for the years 2010-2022, and no regular updates are planned for these data. Although values for Kronedekning are set to 0 for pixels where clearcuts have been recorded by Global Forest Watch, any future increase in tree cover will not be recorded with the current implementation of Kronedekning in SR16. Current values for Kronedekning may give a

[1] NFI data normally distinguish between productive and unproductive forest. Productive forest land has a timber production of at least 1 m^3/ha of timber with bark per year, whereas unproductive forest produces less per year.

reasonable representation of present tree cover density but will increasingly deviate from reality in coming years. However, NIBIO is working on procedures for updating values for Kronedekning, possibly based on very high resolution aerial photography at 5-7 year intervals (Marius Hauglin, in litt.). An alternative data source may be Copernicus High Resolution Tree Cover Density (TCD) at 10 m resolution (cf. above). Although the most recent published data are from 2018, i.e., a bit older than the SR16 data, regular updates are planned every 3 years. We propose to use both SR16 Kronedekning and Copernicus Tree Cover Density to quantify values for condition variable 4.2. For both alternatives, we define the 'target area' as the coverage of ecosystem type 4 Forest and woodland in the Norwegian basic map for ecosystem extent accounting (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no)), where, respectively, the SR16 Kronedekning and Copernicus TCD variables have values.

Calculating values for the condition variable

(a) Alternative based on the Norwegian SR16 Kronedekning:

- *Definition of 'target area'*: The 'target area' is ecosystem type 4 Forest and woodland in the Norwegian basic map for ecosystem extent accounting, where the SR16 Kronedekning variable has values.
- *Definition of condition variable*: The variable is the mean national value of the proportion (%) of crown cover given by all values for the SR16 variable Kronedekning within the 'target area'.
- *Basic data source*: The 'target area' is available from the Norwegian basic map for ecosystem extent accounting (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no)). Data for crown cover (Kronedekning) is available from NIBIO's map service (Nedlasting av kartdata - Nibio).
- *Calculation of variable value*: The mean national value is the mean of crown cover values per 16 x 16 m pixels for all SR16 pixels within the 'target area'.

(b) Alternative based on the Copernicus High Resolution Tree Cover Density (TCD):

- *Definition of 'target area'*: The 'target area' is ecosystem type *4 Forest and woodland* in the Norwegian basic map for ecosystem extent accounting, where the Copernicus TCD variable has values.
- *Definition of condition variable*: The variable is the mean national value of the proportion (%) of crown cover given by all values for Copernicus TCD at 10 m resolution within the 'target area'.
- *Basic data source*: The 'target area' is available from the Norwegian basic map for ecosystem extent accounting (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no)). Data for tree cover density is available from Copernicus (Tree Cover Density 2018 (raster 10 m and 100 m), Europe, 3-yearly — Copernicus Land Monitoring Service).
- *Calculation of variable value*: The mean national value is the mean of crown cover values per 10x10 m pixels for all Copernicus TCD pixels within the 'target area'.

Results

The results for the variable tree cover density is 57.9% and 54.1%, respectively, for the two alternatives (**Table 3**). The 'target area' sizes in **Table 3** are based on the area of the grid cells overlapping ecosystem type *4 Forest and woodland* for the respective data sources. The sizes of the 'target areas' for both alternatives are a bit lower than the total area of 122 282 km^2 for ecosystem type *4 Forest and woodland*. This indicates some gaps in the coverage of the data sets for SR16 Kronedekning and Copernicus TCD (but note that the size of 'target areas' are based on grid cells, whereas that for ecosystem type 4 is based on polygon areas).

Table 3 *Results of two different approaches to quantify variable 4.2 Tree cover density for forest and woodland (TCD; see description of alternatives above).*

Alternative	Target area	Target area size	Variable value
(a) SR16 Kronedekning	Extent of ecosystem type *4 Forest and woodland*, where SR16 Kronedekning has values	104 268 km^2	57.8%
(b) Copernicus TCD	Extent of ecosystem type *4 Forest and woodland*, where Copernicus TCD has values	119 366 km^2	54.1%

Variable 4.3 Common forest bird index

This variable has recently been added as a mandatory ecosystem condition variable for the ecosystem forest and woodland (cf. Chapter 3). The full specification of this variable is not yet available in the Eurostat GN. However, this variable is similar in conceptual basis and construction to the common farmland bird index collated at the European level based on data from the Pan European Common Birds Monitoring Scheme (PECBMS), except that a different set of bird species is included for each country.

Possible implementation for Norway
The Norwegian common forest bird index is aggregated and managed by NINA, based on data from the common breeding bird monitoring scheme managed by BirdLife Norway (cf. variable 2.2/3.2). A standardised version of this index, consistent with the European method, is used for the Norwegian Nature Index, assessments of ecosystem condition, and international reporting. It applies the same method as for the farmland bird index. For forest birds, the base year for scaling of individual species abundances is currently 2008, but as for farmland birds, the time series of abundances are sufficiently long to use 2000 as the base year. There are currently 24 species included in this index: *Dryocopus martius, Dendropocos major, Anthus trivialis, Prunella modularis, Erithacus rubecula, Phoenicurus phoenicurus, Turdus merula, Turdus philomelos, Turdus iliacus, Turdus viscivorus, Hippolais icterina, Sylvia borin, Sylvia atricapilla, Phylloscopus collybita, Phylloscopus trochilus, Regulus regulus, Muscicapa striata, Poecile montanus, Lophophanus cristatus, Periparus ater, Certhia familiaris, Garrulus glandarius, Fringilla coelebs, Pyrrhula pyrrhula*. Note that the habitats of these species are not strictly specific to the defined ecosystem of forest and woodland in the GN on extent accounting but represent various wooded habitats.

Calculating values for the condition variable

- *Definition of 'target area'*: In principle, the 'target area' is the ecosystem type *4 Forest and woodland* (cf. variables 4.1, 4.2). In practice, the 'target area' is not precisely defined but covers the wider forested landscape where the relevant bird species find their habitats.
- *Definition of condition variable*: The relative index of abundance for a specific set of breeding birds with relatively frequent occurrence in the wider forested landscape.
- *Basic data source*: The forest bird index is produced annually by NINA, based on data from the national breeding bird monitoring programme.
- *Calculation of variable value*: The national value is available in the required format from NINA. In this test case we have applied 2008 as the base year; this can be changed to 2000 in a full implementation of the condition accounts.

Results
The index value for the last available year (2023) was 96.0 (with 1 SD of 2.96), compared with a value of 100 for the base year 2008. **Figure 2** shows the time series of the index values since 2008, with a weak increase since around 2012.

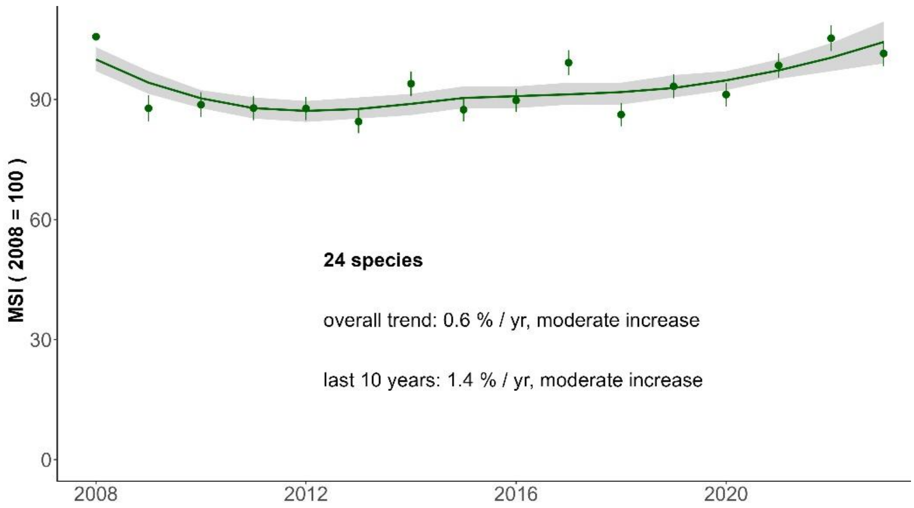

Figure 2 *Values for the common forest bird index since 2008 (the base year with standard index value set to 100). Vertical bars and the grey area around the trendline indicate ±1 SD. See the text for included species.*

Variable 11.1 Share of artificial impervious area cover for coastal beaches, dunes and wetlands

The EU legal text specifies this variable as "*the share of artificial impervious area cover, present in coastal area that includes ecosystem type coastal beaches, dunes and wetlands shall be reported in % as a national average for the reporting period*." It is not entirely clear if this formulation of the legal text refers exclusively to ecosystem *11 Coastal beaches, dunes and wetlands* as the 'target area' or if also other coastal ecosystems should be included. We find it most reasonable to limit the 'target area' to *Coastal beaches, dunes and wetlands*, as this would make it consistent with the SEEA EA framework (cf. below).

The description of *Coastal beaches, dunes and wetlands* in the Eurostat GN on ecosystem extent accounting (Eurostat 2023a, Table A3) indicates that it essentially covers natural and artificial sparsely vegetated coastal terrestrial ecosystems. However, the description is not entirely clear with respect to the precise boundary between this class and class *10 Marine inlets and transitional waters*, i.e., the boundary between terrestrial and marine coastal ecosystems. The description of sub-classes 11.2.2.and 11.2.3 refers to 'at and above the main waterline', which could indicate the mean tide level. However, class 10 includes intertidal flats, suggesting that the marine boundary follows the average high tide level, i.e., the common marine boundary in maps.

The Eurostat GN on ecosystem condition accounting specifies that the 'target area' for this variable is the coastal zone encompassing all ecosystem types within a 1 km buffer zone of the marine boundary. Here the marine boundary is specified as 'the medium high water line'. Using the 1 km coastal buffer zone as the 'target area' for variable 11.1 as specified by the Eurostat GN, may be seen as deviating from the formulation of the legal text by including more than one ecosystem in the 'target area'. It also conflicts with the SEEA EA framework in the same way as using LAUs as 'target areas' for variable 1.1. Although it is easy to understand the motivation for measuring the proportion of impervious artificial area in the entire coastal zone, this approach is not suitable as part of ecosystem condition accounting according to the SEEA EA framework, where ecosystem condition variables should be quantified specifically for their 'parent' ecosystem type.

For data for this variable at the European level, the Eurostat GN refers to an imperviousness product based on classification of NDVI values as part of the Copernicus High Resolution Layer, available at 10 m resolution for 2018, with foreseen updates every 3 years (High Resolution

Layer Imperviousness — Copernicus Land Monitoring Service). This product provides a measure of imperviousness density as the percentage cover of impervious surfaces within 100 m^2 grid cells.

Possible implementation for Norway
Following the Eurostat GN is quite straightforward. The coastal buffer is defined as the 1 km buffer zone above/inland from the mean high tide level, given as the marine boundary in national maps. Artificial impervious areas can be identified within the coastal buffer zone based on the same data sets used to delimit urban areas for condition variable 1.1, i.e., the class *1 Settlements and other artificial areas* (strictly only the impervious subunits of class 1) in the basic map for ecosystem extent accounting (cf. variable 1.1). To calculate the value of the condition variable there is no need to identify or map other ecosystems within the coastal buffer zone.

An alternative approach, in line with the legal text and the SEEA EA framework, would be to delimit the 'target area' to the 'parent' ecosystem type (*11 Coastal beaches, dunes and wetlands*) and to calculate the proportion of this ecosystem that is covered by artificial impervious areas. This implies that a map of coastal beaches, dunes etc must be produced and units of artificial impervious areas within this ecosystem must be quantified through mapping or other means. One approach here would be to use the basic map for ecosystem extent accounting (Strand et al. 2024, cf. variable 1.1) as a basis for delimitation of *Coastal beaches, dunes and wetlands*. In this map this ecosystem is defined as sparsely vegetated ecosystems consisting of coastal polygons that are touching and extending no more than 500 m from the marine boundary, while being no more than 40 m above sea level.

In order to identify artificial impervious units within *Coastal beaches, dunes and wetlands* in this alternative approach, the units of artificial impervious area must be mapped at a finer resolution than that of the ecosystem. In other words, it must be possible to distinguish and quantify units of artificial impervious areas within the polygons of the mapped *Coastal beaches, dunes and wetlands*. There are two options to achieve this. (1) Existing map data for built-up areas and transport infrastructure may be available at a finer resolution than that of the mapped ecosystem (i.e., about 0.2 ha) and may therefore be identified within ecosystem polygons. (2) Mapping of artificial impervious units based on very high resolution (VHR) remote sensing data (cf. NIBIO's green structures map described for variable 1.1) may be used to quantify such artificial units at fine spatial resolution (2–4 m). However, this would require a special classification of artificial impervious areas within the target area. Such a new classification of remote sensing data is beyond the scope of the current test project. The Eurostat GN points to the existing Copernicus product of imperviousness density (ID) per grid cell (cf. above). We consider this data set as the most readily available and possibly with a sufficiently fine spatial resolution to allow identification of such impervious areas within the 'target area' of *Coastal beaches, dunes and wetlands*.

Calculating values for the condition variable
The testing of the Eurostat GN for condition accounting requires that we follow the GN as far as possible. However, as pointed out above, for condition variable 11.1 the proposed 'target area' does not match the area of the 'parent' ecosystem type, and thus the GN is not consistent with the SEEA EA framework. Hence, we present two different alternatives to quantify this variable: (a) based on a 1 km coastal buffer zone as 'target area' as specified in the GN, and (b) based on a representation of the ecosystem type *Coastal beaches, dunes and wetlands* as the 'target area'. Note, however, that the current version of the basic map for ecosystem extent accounts has not included several small islands and skerries on the outer coast, leading to a somewhat low estimate of the 'target area' for alternative (b).

(a) Alternative for a 1 km coastal buffer zone:

- *Definition of 'target area'*: The 'target area' is a 1 km buffer zone inland from the defined boundary between marine and terrestrial ecosystems (i.e., the mean high water mark).
- *Definition of condition variable*: The proportion (%) of artificial impervious areas as the total area of ecosystem type *1 Settlements and other artificial areas*, except non-

impervious areas of *1.4 Urban greenspace*, within the 'target area', relative to the total area of the coastal buffer zone.

- *Basic data source*: Standard topographic map. The Norwegian basic map for ecosystem extent accounting (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no)).
- Calculation of variable value: The area of ecosystem type *1 Settlements and other artificial areas*, except for identified non-impervious areas of *1.4 Urban greenspace*, as identified in the basic map for ecosystem extent accounting, within the 'target area', divided by the total area of the defined coastal buffer zone. Some simple GIS analysis will be needed to calculate the area of the buffer zone and the relevant part of ecosystem type 1.

(b) Alternative for ecosystem type *11 Coastal beaches, dunes and wetlands*:

- *Definition of 'target area'*: The 'target area' is defined as the area of ecosystem type *11 Coastal beaches, dunes and wetlands* in the basic map for ecosystem extent accounting.
- *Definition of condition variable*: The proportion (%) of artificial impervious areas within the defined 'target area'.
- *Basic data source*: The basic map for ecosystem extent accounting for delimitation of the 'target area' (Grunnkart for bruk i arealregnskap (testversjon) - Kartkatalogen (geonorge.no)). Data for artificial impervious areas are available from the Copernicus product for imperviousness density (ID) (Imperviousness Density 2018 (raster 10 m and 100 m), Europe, 3-yearly — Copernicus Land Monitoring Service).
- *Calculation of variable value*: The proportion (%) of identified artificial impervious areas in the Copernicus product within the defined 'target area' of ecosystem type *11 Coastal beaches, dunes and wetlands*. Some GIS work will be needed to calculate the extent of artificial impervious area within the 'target area'. As the Copernicus ID product gives percentage of sealed area within 100 m^2 grid cells, the variable value is the mean imperviousness density for all grid cells within the 'target area'.

Results

The two alternative approaches cover very different 'target areas' and result in rather different values for imperviousness density (**Table 4**). This is to be expected as the 1 km coastal buffer zone covers several other ecosystems types in addition to *Coastal beaches, dunes and wetlands*, including extensive urban areas. On the other hand, *Coastal beaches, dunes and wetlands* would not be expected to contain much impervious area, since larger impervious areas would be classified as *Settlements and other artificial areas*.

Table 4 *Results of two different approaches to quantify variable 11.1 Share of artificial impervious area cover for coastal beaches, dunes and wetlands (see description of alternatives above).*

Alternative	Target area	Target area size	Artificial impervious area	Artificial impervious area size	Variable value
(a) Coastal buffer zone	Coastal buffer zone 1 km above/inland from the mean high tide mark	30 624 km^2	Extent of ecosystem type *1 Settlements and other artificial areas* (except type 1.4) within target area	1 723 km^2	5.6%
(b) Ecosystem extent map	Extent of ecosystem type *11 Coastal beaches, dunes and wetlands* in the basic map for ecosystem extent accounting	1 526 km^2	Not defined as imperviousness density is given as % sealed area for grid cells within target area	Not defined	1.7%

5 Assessment of reference levels for the condition variables

The EU implementation of ecosystem accounts is limited to accounts of condition variables in their biophysical values and does not require scaling of variable values against specific reference values (EU 2022a). In previous work to map and assess ecosystem condition Vallecillo et al. (2021) have discussed various options for setting reference values for proposed condition variables. These include variables which are similar or equivalent to most of the mandatory variables specified in the EU regulation on ecosystem accounts (EU 2022a). As scaling of ecosystem condition variables to a common scale to allow aggregation of condition values for ecosystems may be relevant in future EU-level voluntary or mandatory ecosystem accounting, we present some reflections on the possibility of setting reference values for the mandatory condition variables from a Norwegian perspective.

The setting of reference values for condition variables should be based on an explicitly formulated concept of a reference state for the ecosystem in question. The SEEA EA framework (UN et al. 2021) recommends that for a given ecosystem all condition variables should be related to the same reference state. For ecosystems mainly shaped by natural processes it is also recommended to use a natural or near-natural manifestation of the ecosystem as the reference state. For urban or agricultural ecosystems that are dominated by various human interventions, other reference states must be defined, e.g., based on the ecosystem's ability to provide long-term socio-ecological resilience (Vallecillo et al. 2022).

The SEEA EA presents several possible approaches for setting reference values for condition variables. Vallecillo et al. (2022) have supplemented these, resulting in the following list of approaches:

1. Absolute physical boundaries
2. Reference sites in near pristine conditions or with minimal human impact
3. Modelled condition based on various assumptions of potential vegetation, natural biotic communities or ecosystem processes
4. Statistical methods based on ambient distribution, allowing identification of (a) 'least-disturbed' or (b) 'best-attainable' condition
5. Prescribed reference values based on (a) scientific criteria or (b) policy targets/thresholds
6. Contemporary condition for a specific baseline year or period
7. Expert opinion
8. Combination of several approaches

Alternatives 5 and 6 are not recommended for setting reference values for condition variables of ecosystems dominated mainly by natural processes, as these approaches reflect 'acceptable limits' rather than reference values consistent with a reference state of near-natural ecosystems or 'best attainable condition' in anthropogenic ecosystems. Vallecillo et al. (2022) add a further constraint on the setting of reference values: If a reference value for a variable already exists, this will be used. This is often the case for variables where target values have been set in policies or regulations, i.e., based on approach 5 above. As other condition variables for the same ecosystem may have reference values set according to other approaches, based on other concepts of the reference state, this will introduce an unfortunate heterogeneity in the setting of reference values for condition variables for the same ecosystem.

For variables that are similar to the EU mandatory condition variables, the approaches of Vallecillo et al. (2022) for setting reference values are summarised in **Table 5**. Vallecillo et al. (2022) do not specify any condition variables for the ecosystem class *11 Coastal beaches, dunes and wetlands* (cf. variable 11.1 above). Their representation of soil organic carbon (SOC) is also limited to SOC in cropland mineral soils, whereas the EU mandatory SOC variables cover all types of soils in the top 30 cm layer, for both cropland and grassland (cf. variable 2.1/3.1 above).

***Table 5** Summary of reflections of Vallecillo et al. (2022) on setting reference values for variables similar to the mandatory condition variables specified in Eurostat (2023b). Agroecosystems represent both cropland and grassland. There is no explicit ecosystem for Coastal beaches, dunes and wetlands or a relevant variable for share of impervious area in natural ecosystems.*

Ecosystem	Variable	Data source at EU level	Reference approach	Reference value
Urban	Urban green (%)	Landsat/Corinne++	Combination of methods	To be defined
Urban	Air pollutant concentration (including PM2.5)	EEA air quality data	Prescribed (legal)	Air Quality Directive values
Agroecosystems	Soil organic carbon (kg OC/ha), only for cropland mineral soils	LUCAS/JRC	Prescribed (scientific evidence)	Varies by soil type, >20 g OC/kg
Agroecosystems	Common farmland bird index	PECMBS	Contemporary condition	Value of reference year
Forest	Deadwood (m^3/ha)	Forest Europe	Combination of methods	Scientific evidence, statistical analysis, expert opinion
Forest	Tree cover density	Copernicus	Reference sites	Data for reference sites
Forest	Common forest bird index	PECMBS	Contemporary condition	Value of reference year

Vallecillo et al. (2022) propose reference values set to prescribed levels, with a legal and a scientific basis, respectively, for the levels of urban air pollutant concentration and SOC in cropland mineral soils. Such prescribed values reflect policy targets or a scientific understanding of critical loads, i.e., a concept of ‘acceptable limits’ rather than values in a reference state. For air pollutants it may be possible to apply the ‘absolute physical boundary’ approach by setting the reference value to concentrations that would occur naturally without human activities. For PM2.5 the reference value may then be set to a concentration close to 0, except in areas where natural forest fires or dust storms may occur and produce particles of relevant sizes. For SOC the situation is more complex since the stock of SOC in a reference state will vary with soil types and climate conditions. Here a combined approach with data from reference areas and statistical and/or mechanistic modelling may be needed to set references values for specific formations of cropland and grassland.

For the two bird indices Vallecillo et al. (2022) propose the ‘contemporary condition’ approach, with the index value of a given ‘reference year’ (called ‘base year’ above) being used as a ‘reference value’. It is important to be aware that this so-called 'reference value’ is simply an arbitrary scaling factor to allow combination of abundance estimates for the different species included in the index. It has no direct relationship to bird abundances in the reference state of ecosystems. However, by expert judgement, modelling and possibly data from regions or periods with little human impact it may be possible to assess how much the abundances of the respective bird species in the ‘reference year’ may deviate from their abundances in a true reference state. The size of such a deviation may then be used to re-scale the abundance values for each species, resulting in a re-scaled combined index.

Vallecillo et al. (2022) propose that the reference value for the variable tree cover density can be based on data from reference sites. As remarked above (cf. variable 4.2), tree cover density varies with dominating tree species, growing conditions and stand age. Reference sites are unlikely to be available for all the relevant combinations of such factors, in particular because the extent and nature of human impacts are likely to vary considerably according to the same factors. Hence, a combined approach based on data from available reference sites, statistical and/or mechanistic modelling, as well as some expert judgement will probably be needed to set realistic reference values for this variable. For the proportion of urban green areas (variable 1.1) and the volume of dead wood (variable 4.1), Vallecillo et al. (2022) propose just such a combined approach. Reference values for dead wood in forest of different ages and site productivity were calculated by such a combined approach by Framstad et al. (2022).

Vallecillo et al. (2022) have not considered any variables for ecosystem type *11 Coastal beaches, dunes and wetlands*. The mandatory condition variable for this ecosystem is the proportion of artificial impervious areas within this ecosystem (or within a 1 km coastal buffer zone according to the Eurostat GN). In a reference state no such artificial impervious area should exist in this ecosystem. Hence, the ‘absolute physical boundary’ approach is appropriate here, with a reference value for the variable of 0% coverage of artificial impervious area.

6 Discussion of approaches for mandatory condition variables

6.1 SEEA EA compatibility

Table 6 presents a summary of the proposed approaches for mandatory ecosystem condition variables. As pointed out above, for three of the condition variables (1.1, 1.2, 11.1) we do not consider the approach of the Eurostat Guidance Note for these variables to be compatible with the UN SEEA EA framework. The reason is that the proposed ‘target areas’ for these variables are either administrative (LAUs) or geographical (1 km coastal buffer zone), delimitations that will necessarily include more than one ecosystem type at level 1 of the EU ecosystem typology. This means that values for these condition variables will characterise more than one ecosystem type, conflicting with the basic model of the SEEA EA framework where the condition of each ecosystem type should be characterized by values for a specific set of condition variables.

For variables 1.1 and 11.1 there is the additional problem that these variables could also be considered measures of ecosystem extent, hence, confounding extent and condition accounting. Such cofounding is a general problem when using areas or proportion of areas of ecosystems as condition variables. Although we have presented values for the mandatory condition variables according to the Eurostat GN, we have also presented values according to alternative approaches for the three variables 1.1, 1.2, and 11.1.

Condition variable 2.2/3.2 Common farmland bird index could also be considered to deviate from the SEEA EA framework as it provides one common value for the ecosystems cropland and grassland. To be compatible with the SEEA EA framework, a variable value must be allocated to each ecosystem. Using the same common index value for each of these ecosystems will be quite biased as the relative abundances of the (few) species included in the index are likely to vary considerably between cropland and grassland.

An additional concern is the different ways that variable values as related to ecosystems. For the variables 1.1, 1.2, 4.2, and 11.1, the allocation of values is based on spatial linkages between the geographical distribution of the ‘target area’ (even if this is not SEEA EA compatible in the GN). One advantage of this ‘spatial overlay’ approach is that it allows a straightforward estimation of a specific variable value for each ecosystem asset of the ecosystem type of interest. For variables 2.1/3.1, and 4.1, the allocation of values to ecosystems is sample-based. This may in principle be compatible with the SEEA EA framework, but in practice the sample density will rarely be high enough to allow reliable estimates for each ecosystem asset of the ecosystem type of interest (cf. SEEA EA 5.19).

Finally, the two bird indices (2.2/3.2 and 4.3) have a conceptual linkage of variable values to their respective ecosystems. This approach does not allow any specific allocation of values to ecosystem assets, only (in principle) to the full extent of the ecosystem type. In practice, only values for condition variables based on remote sensing or modelled data (both at high resolution) will be fully compatible with the SEEA EA’s requirement that variable values should be measured or estimated for each individual ecosystem asset. Hence, this is a requirement that we think will limit the possibility of finding meaningful condition variables for a sufficiently wide coverage of ecosystem characteristics.

Table 6 *Summary of proposed approach for calculating the mandatory condition variables for Norway*

Variable	Alternative	Target area	Variable definition (unit)	Target area data source	Variable data source	Variable calculation	Extent of GIS work	Variable value
1.1 Green areas in cities and adjacent towns and suburbs	a) LAU-based	LAUs defined as cities plus towns and suburbs in their FUAs	Proportion (%) of EU ecosystem types 3, 4, 5 + 1.4 within target area	Map of municipalities within target area	Basic map for ecosystem extent accounting	Overall proportion of area of ecosystem types 3, 4, 5 + 1.4 to total target area	Simple GIS overlay of relevant LAUs and ecosystem types	59.9% (based on ecosystems 3, 4, 5 + 1.4)
	b) Basic map for ecosystem extent accounting	*Settlements and other artificial areas* as defined in the basic map for ecosystem extent accounting	Proportion (%) of EU ecosystem type *1.4 Urban greenspace* within target area	Basic map for ecosystem extent accounting	Basic map for ecosystem extent accounting	Overall proportion of the area of ecosystem type 1.4 to the area of ecosystem type 1	No GIS analysis needed as the total areas of target area and green areas should be available directly from the map data	4.3% (based on ecosystem 1.4)
	c) Urban green areas map (UGM)	Urban area as defined in UGM for the whole country	Proportion (%) of areas defined as urban green area in UGM (field, bush, and tree layers)	NIBIO's UGM	NIBIO's UGM	Overall proportion of urban green area to total urban area in UGM.	No GIS analysis needed as urban green area and total UGM area should be available directly from the map data	52.2% (based on field, bush, tree layers)
1.2 Concentration of PM2.5 in cities	a) LAU-based	LAUs defined as cities	Mean concentration of PM2.5 ($\mu g/m^3$)	Map of municipalities within target area	Modelled gridded data from NEA 'Fagbruktjeneste for luftkvalitet'	Mean concentration of 100 X 100 m grid cells within target area	Simple GIS overlay of target area and 100 x 100 m grid	3.76 $\mu g/m^3$
	b) Settlements and other artificial areas	*Settlements and other artificial areas* as defined in the basic map for ecosystem condition accounting	Mean concentration of PM2.5 ($\mu g/m^2$)	Basic map for ecosystem extent accounting	Modelled gridded data from NEA 'Fagbruktjeneste for luftkvalitet'	Mean concentration of 100 X 100 m grid cells within target area	Simple GIS overlay of target area and 100 x 100 m grid	3.25 $\mu g/m^3$

Variable	Alternative	Target area	Variable definition (unit)	Target area data source	Variable data source	Variable calculation	Extent of GIS work	Variable value
2.1/3.1 Soil organic carbon (SOC) stock in topsoil	Sample-based	Respectively, cropland and grassland, defined by sample plots	SOC (tons/ha) in top 0-30 cm of soil, in cropland and grassland, respectively	Sample plots for monitoring of cropland (JordVAAK) and grassland (NFI-jord), respectively	Monitoring data for cropland (JordVAAK) and grassland (NFI-jord), respectively.	Mean stock of SOC (tons/ha) for target area	None	Data not yet available for cropland; too few datapoints for grassland
2.2/3.2 Common farmland bird index	Farmland bird index	Habitat of common farmland-associated bird species	Aggregated relative abundance index for specified set of bird species (% of value in base year)	None, indirectly from habitat of included species	NINA, based on breeding bird census by BirdLife/Norway	Directly available from NINA	None	61.8% of value in base year 2008
4.1 Dead wood volume	Sample-based	NFI sample plots in productive and unproductive forest	Standing and lying dead wood ≥10 cm in diam. (m^3/ha)	NFI, indirectly from included sample plots	NFI, either as national mean or as sample plot values	If sample plot values, area-weighted mean	None	9.4 m^3/ha (productive and unproductive forest)
4.2 Tree cover density	a) SR16 Kronedekning	*Forest and woodland* as defined in the basic map for ecosystem condition accounting, where SR16 Kronedekning has values	Vertical projection of tree crown cover as proportion (%) of forest area	Basic map for ecosystem extent accounting	NIBIO's SR16 map of Kronedekning	Mean value of all SR16 pixels within target area	Simple GIS overlay of SR16 pixels and class 4 of the basic map for ecosystem extent accounting	57.8%
	b) Copernicus Tree Cover Density (TCD)	*Forest and woodland* as defined in the basic map for ecosystem condition accounting, where Copernicus TCD has values	Vertical projection of tree crown cover as proportion (%) of forest area	Basic map for ecosystem extent accounting	Copernicus TCD 2018 at 10 m resolution	Mean value of all TCD pixels within target area	Simple GIS overlay of TCD pixels and class 4 of the basic map for ecosystem extent accounting	54.1%

Variable	Alternative	Target area	Variable definition (unit)	Target area data source	Variable data source	Variable calculation	Extent of GIS work	Variable value
4.3 Common forest bird index	Forest bird index	Habitat of common forest-associated bird species	Aggregated relative abundance index for specified set of bird species (% of value in base year)	None, indirectly from habitat of included species	NINA, based on breeding bird census by BirdLife/Norway	Directly available from NINA	None	96.0% of value in base year 2008
11.1 Artificial impervious area cover	a) Coastal buffer zone	1 km buffer zone inland from mean high tide level	Impervious area of class *1 Settlements and other artificial areas* as proportion (%) of defined coastal zone	Standard topographic map	Basic map for ecosystem extent accounting	Proportion of area of settlements and other artificial areas, except class *1.4 Urban greenspace*, within 1 km coastal zone	Simple GIS overlay of coastal zone and ecosystem map	5.6% of 1 km buffer zone
	b) Coastal beaches, dunes and wetlands	Ecosystem type *11 Coastal beaches, dunes and wetlands* as defined in the basic map for ecosystem condition accounting	Proportion (%) of impervious area of ecosystem type *11 Coastal beaches, dunes and wetlands*	Basic map for ecosystem condition accounting	Copernicus product for imperviousness density (ID)	Proportion of impervious artificial area within mapped ecosystem type 11. Impervious area is the sum of ID values for 100 m^2 grid cells within the area of class 11.	Simple GIS overlay ecosystem type 11 and Copernicus impervious artificial area	1.7% of ecosystem type 11

LAU – Local Administrative Units; FUA – Functional Urban Areas

6.2 Quality of map data and other basic input data

There are various challenges related to the Norwegian data sources available for quantifying values of the mandatory variables. As mentioned above, it varies how the data for the variables are related to their respective ecosystems. Data from representative sampling, where the ecosystem type for each sample point is determined according to clear criteria, is perhaps the most precise way to allocate data to a specific ecosystem type. For the mandatory condition variables, this is done for soil organic carbon (SOC) in cropland and grassland (when data become available) and for dead wood in forests. However, to yield precise estimates of variable values, particularly at sub-national spatial scales, a rather large number of sampling points (>1000 in the case of Norway) may be required, especially for adequate representation of ecosystem types with limited extent. Due to the high cost of field-based sampling, a full cover of all sampling points is often distributed over several (5-10) years. This raises issues of how adequate data for a given reporting year should be handled, i.e., whether only data for the reporting year or aggregated data for the full sampling cycle should be used. Using only data for the reporting year requires that each year of sampling covers a sufficient number of spatially unbiased sampling points, as is the case for dead wood. On the other hand, aggregating data over several years risks using part of the same data in estimates for neighbouring reporting years (e.g., with reporting years on a 3-year schedule and data sampling over a 5-year cycle).

The precision of map-based allocation of data to ecosystem types depends on the thematic and cartographic accuracy of the maps. The basic map for ecosystem extent accounting is a key resource for both extent and condition accounts in Norway. However, in the current version, this map's thematic representation of EU level 1 ecosystems is not satisfactory for open ecosystems such as grassland, heathland, sparsely vegetated ecosystems, inland wetlands, and coastal beaches, dunes and wetlands (Strand et al. 2024). For the mandatory condition variables this lack of thematic accuracy is only relevant for variable 11.1b, where a representation of *Coastal beaches, dunes and wetlands* is used as the basis for the 'target area' of the variable. In future, additional condition variables may require more accurate representation of open ecosystems. For settlements and other artificial areas, cropland, and forests we assess that the thematic representation in the basic map for ecosystem extent accounts is quite good. The schedule for updating of map data is often a bit unclear, where some data, e.g., for built-up areas may be updated often, whereas data for more natural ecosystems may be updated at irregular intervals. There will also be time-lags before real changes in the field are represented in maps. Production of an annual new version of the basic map for ecosystem extent accounts is planned, but the updating of the underlying data will vary from continuous or annual to multi-annual irregular.

The data for the bird indices are collected annually at spatially representative sample points. However, to provide reliable abundance estimates, included species must have observations at a sufficient number of sampling sites. With a total of <500 national breeding bird sample sites (across all ecosystems), the possibility of constructing multi-species indices at sub-national level is limited. Allocation of data to relevant ecosystems is entirely conceptual, by classifying each species as being associated with a specific ecosystem. As noted above, this is not ideal according to the SEEA EA recommendations.

The SEEA EA and the Eurostat Guidance Notes for ecosystem extent and condition accounts do not address issues of uncertainty and bias in the estimates of variable values. In this test of the Eurostat GN for condition accounts we have in most cases not attempted to quantify uncertainty or bias. For sample-based data (cf. condition variables 2.1/3.1, 2.2/3.2, 4.1, 4.3), quantifying uncertainty as sample variability is generally straightforward. An uncertainty measure is reported for the bird indices. This could also be done for dead wood, but here we did not have access to data to allow quantification of an overall uncertainty measure for productive and unproductive forest combined. For data based on remote sensing, maps or modelling (cf. variables 1.1, 1.2, 4.2, 11.1), quantifying uncertainty is more complicated, but nevertheless important to do, especially if estimates are to be compared between years in accounts (e.g., Venter et al. 2024). We will address such issues of uncertainty in more detail in the final report.

Data availability and ease of access varies between the data sources. Map-based and remote sensing-based data covering the whole country at fine resolution represent large bodies of data which are cumbersome to download and handle, particularly for maps in vector format. For instance, the basic map for ecosystem extent accounting contains more than 70 million polygons. The spatial organisation for downloading of data based on maps, models, or remote sensing varies from national to municipal level, complicating the process of data curating and analysis.

6.3 Recommendations

We may draw some conclusions from the previous chapters on the analysis of alternative approaches for defining and measuring the mandatory ecosystem condition variables, as well as from the practical calculation of variable values:

- *Ensure consistency with SEEA EA*: If condition variables are to be used in ecosystem accounts, they must follow the key requirements of the SEEA EA. Values for condition variables must be possible to allocate to a specific ecosystem type for all ecosystem assets of this type within the defined ecosystem accounting area (i.e., Norway in our case). The approaches proposed by Eurostat for variables 1.1, 1.2, and 11.1 define 'target areas' that include several ecosystem types. Hence, these approaches are not consistent with the SEEA EA.
- *The basic map for ecosystem extent accounts must be improved*: In Norwegian ecosystem accounts (at least at the national level), the new basic map for ecosystem extent accounts may be considered a key resource for identifying and delimiting ecosystems according to the EU typology. This map may be used both for extent accounts and for delimiting specific ecosystems for calculation of values for condition variables. However, as noted above, the thematic quality of this map is not satisfactory for open ecosystems, and there is a clear need to improve the identification and delineation for grassland, heathland, and sparsely vegetated ecosystems, including coastal ecosystems. There are also technical issues that should be resolved. Hence, there is a clear need to improve several properties of this map.
- *Recommendations for condition variables*:
    - *1.1 Green areas in cities and adjacent towns and suburbs*: We recommend that the Norwegian implementation of this condition variable is based on NIBIO's urban green areas map, as this is consistent with the SEEA EA and is likely to yield the best representation of urban green areas. If the basic map for ecosystem extent accounts is to be used consistently for the delimitation of ecosystems according to the EU typology, the ecosystem type *1 Settlements and other artificial areas* should be used as the 'target area' for this variable, rather than the urban delimitation of the NIBIO map. However, this may create some technical mismatches. Note also that ecosystem type *1 Settlements and other artificial areas* clearly covers a more restricted urban area than the NIBIO map.
    - *1.2 Concentration of Particulate Matter (PM) with a diameter up to 2.5 µm in cities and 11.1 Share of artificial impervious area cover for coastal beaches, dunes and wetlands*: We recommend that alternatives (b) are used for these condition variables as these alternatives are consistent with SEEA EA and alternatives (a) are not.
    - *2.1/3.1 Soil organic carbon stock in topsoil in cropland and grassland*: To provide data for this important condition variable, implementation of the planned monitoring programme for SOC in cropland should be started as soon as possible. However, as semi-natural and natural formations of grasslands will not be covered by the planned SOC monitoring programmes, the data for this variable will not be representative for all types of grasslands.
    - *2.2/3.2 Common farmland bird index and 4.3 Common forest bird index*: These birds indices should be re-scaled with the year 2000 as the base year.

- *4.1 Dead wood for forest and woodland*: Statistically representative data are available from the National Forest Inventory (NFI). The method for measurement of dead wood in the Norwegian NFI should be checked against any European standard.
- 4*.2 Tree cover density*: Both alternatives for this variable are consistent with SEEA EA. The two data sources also yield rather similar results, but both alternatives have some gaps in coverage of ecosystem type *4 Forest and woodland*. The extent and distribution of such gaps should be investigated. To improve the suitability of Norwegian data sources, the Norwegian NFI programme could be expanded to report tree cover density for all forest categories. As an alternative, improvement in the spatial coverage and systematic updates of the SR16 Kronedekning variable would yield modelled-based tree cover density values at finer spatial resolution than the NFI sample plots.

- *Measures of uncertainty* for condition variables based on various data types should be investigated and estimated for variable values where possible.
- *Full access to all data sets*: All data sources used for the condition variables should be publicly available for ecosystem accounting, at least in anonymised, delocalised, or (minimally) aggregated form (if it is necessary to protect primary data). The main map data used for this report are not yet completely accessible to all types of users, and primary data for some variables (bird indices, dead wood) are currently only available in highly aggregated form.
- *Streamlined data processing workflows should be developed*: It is clearly a need to develop more streamlined workflows from data sources to final ecosystem condition variable values. These workflows should be harmonised with the data management procedures of the key public institutions responsible for ecosystem accounting in Norway, i.e., Statistics Norway and the Norwegian Environment Agency.

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Appendix 1: Description of mandatory condition variables in Eurostat GN

Description of the measurement of mandatory ecosystem condition variables from the Eurostat Guidance Note as of ultimo November 2023 (Eurostat 2023b; with all marked text changes updated, but without comments). Most of the text pertaining to the Nature Restoration Law (NRL) is not included.

1.1 Green areas in cities and adjacent towns and suburbs

Green areas in cities and adjacent towns and suburbs represent the proportion of existing 'urban green space' in urban LAUs and are important as they provide recreational opportunities and support a range of other services such as air filtration and cooling.

Urban green space means all area covered with trees, bushes, shrubs, grass and other permanent herbaceous vegetation found within those urban areas. Many of a city's green areas will be found in the level 2 ecosystem type 'Urban Greenspace' – however green areas below the minimum mapping unit can be included in other ecosystem types. According to the definition of the indicator also the level 1 ecosystem types forest, grassland, and all permanent types of cropland are included in green areas as long as they fall into the urban perimeter.

In the NRL urban green space is defined as all green urban areas; broad-leaved forests; coniferous forests; mixed forests; natural grasslands; moors and heathlands; transitional woodland-shrubs and sparsely vegetated areas - as found within cities or towns and suburbs and calculated on the basis of data provided by the Copernicus Land Monitoring Service.

Consequently, accurate monitoring of urban green spaces including for the purposes of the NRL requires datasets capable of estimating changes in all the potential types of "green" (core land cover components) down to level 2 of the EU ecosystem typology.

Blue areas (in particular those areas that are smaller than the minimum mapping unit and therefore are included in the level 1 ecosystem type 'Settlements and other artificial areas') are excluded, but can be measured as a voluntary indicator. The indicator includes all green areas including accessible and inaccessible (to the public) areas, however on a voluntary basis the accessible urban green areas can be reported as a separate, additional indicator.

Reporting the mandatory condition indicator 'Green areas in cities and adjacent towns and suburbs' requires the delineation of urban areas as the reference area for the share. There are two options for doing this delineation, one based on LAUs, and one based on the ecosystem type 'Settlement and other artificial areas'.

Option 1: LAU-based reference area
This definition of urban area is in line with the definition in the legal proposal as it includes the total area of a city. It is also better aligned with the definition of the indicator on 'Urban green space' in the NRL (see above).

In this example the LAU reference area covers in total 132 pixels, of which 12 pixels are grassland, 30 pixels are forest area, 20 pixels are urban green, i.e. 62 pixels are green areas. Hence the share of urban green areas is 62/132 pixels = 47%.

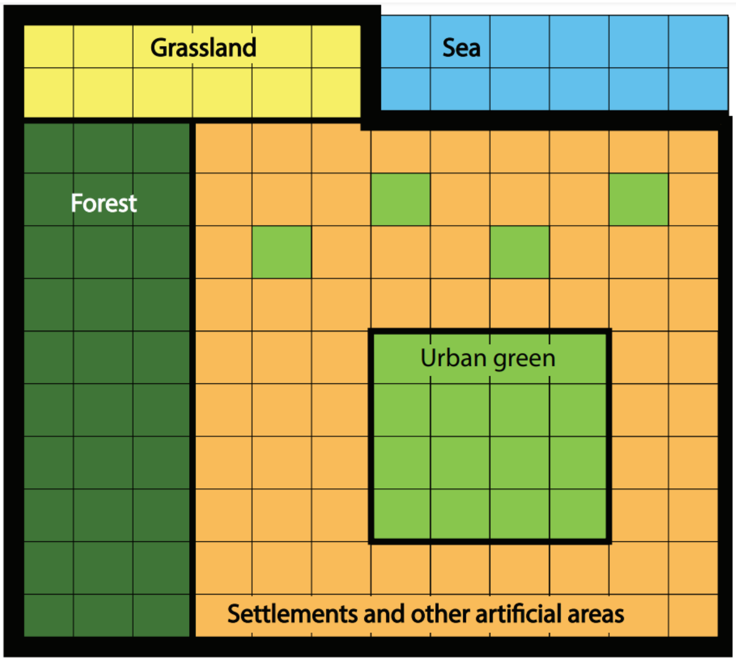

Figure 1. *Measuring the percentage of urban green. The area covered by 'Settlements and other artificial areas' includes both greenspace larger than the minimum mapping unit (the 'urban green' and greenspace smaller than the minimum mapping unit (the four individual green pixels).*

Option 2: Green areas within the ecosystem type Settlements and other artificial areas.
Here the delineation is done using the area covered by the level 1 ecosystem type 'Settlements and other artificial areas' as reference area. Only the level 1 Ecosystem type 'Settlements and other artificial areas' is considered (the bold line in the map depicts the LAU). The areas covered by Forests and Grasslands are ignored. As a result this approach deviates in two ways from the current definition in the legal proposal: The reference area is not the full area of the city, town and suburb and it does not consider ' … all ecosystem types in that area'.

In this approach the total percentage of green areas in this city is therefore 20 / 90 x 100% = 22% (i.e., the sum of all green pixels under the level 1 ecosystem type: 'Settlements and other artificial areas' divided by the total number of pixels in the level 1 ecosystem type: 'Settlements and other artificial areas'. Currently, CLC+ Backbone, a Copernicus Land product, which is in its final stages of validation for 2018 could be used for the monitoring of green areas, depending upon continuity with CLC accounting layers . This dataset includes 18 land cover classes including urban areas, forests, croplands, grasslands, etc., with 0.5 ha MMU. For 11 of these classes, the resolution is very high, they are mapped at 10m spatial resolution. Datasets with a similar thematic and spatial resolution available at national level could also be used. The use of EU ecosystem extent typology level 2, class 1.4. "Urban greenspace" would not cover entirely all potential urban green spaces and therefore may underestimate this condition variable. Therefore, it is useful to consider the Copernicus High Resolution Vegetation Phenology and Productivity (HRVPP) product that provides information on 'seasonal' vegetation, indicating green space at 10m resolution for a given year. This dataset would potentially include urban greenspace in a more comprehensive manner compared to the CLC+ Backbone.

The accounts include as mandatory indicator the percentage of greenspace in the current urban area. This percentage may change over time due to changes in the extent of green area and/or due to changes in the extent of urban areas/LAUs. Both aspects have to be considered, i.e. the indicator will reflect that urban areas expand, or LAUs may change their administrative composition over time, and that the proportion of green areas may change – noting that urban expansion, of course, may also include new greenspaces.

1.2 Concentration of Particulate Matter (PM) with a diameter up to 2.5 µm in cities

The concentration of PM is an abiotic property of an ecosystem and a relevant condition indicator since it is an important indicator for people's health. It is also required to map the air filtration service. Data on air pollutant concentration can be derived from EMEP and CAMS products at 0.1°, which could be later downscaled to 1x1 km resolution using ground-monitoring station data provided in the annual air quality statistics repository of the European Environment Agency. Data are validated, sources are reputable and provide reliable data continuously updated over time. The monitoring of air pollution at 1 km resolution provides spatially accurate data to be used consistently at EU level. The EEA publishes average annual monitoring data for both PM2.5 and PM10, based on data provided by its Member States. Interpolated maps showing air quality in Europe are derived from these data and additional data such as altitude and meteorological data on an annual basis. The dataset provides air pollutants concentrations at 1 km and 2 km grids. Where available, national data at a higher spatial and temporal resolution should be used. Inputs used for this indicator should be the same as the data used for the air filtration ecosystem service accounts to ensure consistency between ecosystem condition and services. The concentration of PM should be averaged, both in time (per year) and in space (all urban areas in a country) using unweighted averaging by area. For the spatial delineation, local administrative units (LAUs) categorised as cities according to the degree of urbanisation typology set out under Regulation (EU) 2017/2391 are considered. Urban expansion may mean that over time a larger area of a city LAU is covered by the ecosystem type 'Settlements and other artificial areas' and would be considered for the calculation of the PM concentration.

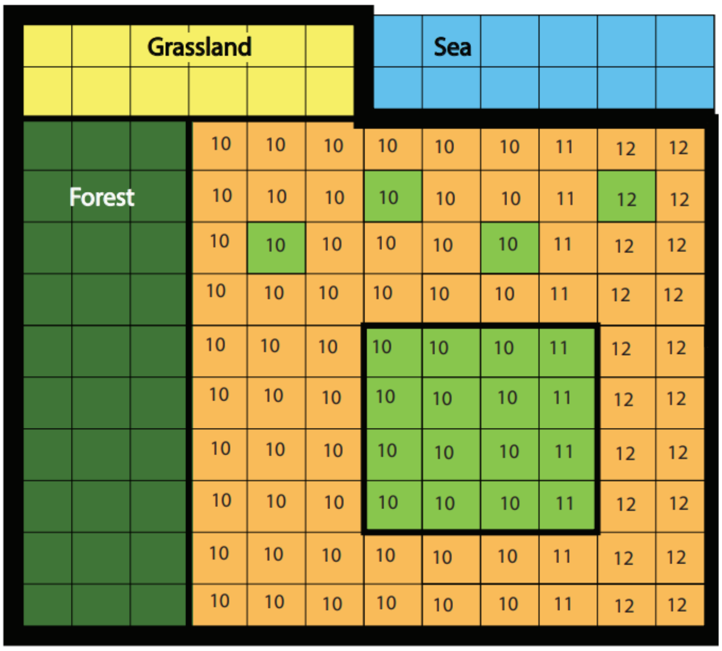

Figure 2. *Measuring the service (in orange: e.g. settlement area; in light green: urban green; see also Figure 1).*

The service only considers the ecosystem type 'Settlements and other artificial areas', which may include, at level 2, urban green. In the case of the imaginary city depicted in Figure 2 all 90 pixels with a number, representing the PM concentration, belong to the ecosystem type 'Settlements and other artificial areas' and are therefore relevant. The average PM concentration for this city is (60 x 10 µg/m^3 + 10 x 11 µg/m^3 + 20 x 12 µg/m^3) / 90 = 10.6 µg/m^3). In a national ecosystem account, the concentration would be averaged over all pixels classified as 'Settlements and other artificial areas'.

2.1 and 3.1 Soil organic carbon stock in topsoil in cropland and grassland

Carbon stored at a depth of 0 to 30 cm below ground is relevant as indicator for soil fertility and for understanding the global climate regulation service of ecosystems. Reporting on carbon stored between 0 and 30 cm is mandatory, and between 0 and 2 or more meters can be reported on a voluntary basis (depth for voluntary reporting to be discussed in the TF). Where possible, there should be consistency between soil organic carbon stock reported in the condition account and used as input in the reporting of the global climate regulation service. Where available, national data at a high spatial resolution should be used to calculate the service. If no national data are available, European continental or global datasets may be used as explained below. Member States are advised to involve national soil experts to review the use of these datasets.

Potential EU data sources are available from LUCAS campaigns (2009 - 2015 – 2018 - 2022). These campaigns measure the topsoil properties at a depth of 0-20cm till 2018 and 0-30cm for 2022.

The European Soil Data Center (ESDAC) has generated raster datasets from these sample point data using a Multivariate Additive Regression Splines (MARS) model, an adaptive procedure for regression (Ballabio C. et al., 2016). The dataset is provided at 500m spatial resolution at continental scale over the geographical extent of Europe.

An alternative data source is the SoilGridsTM from ISRIC – World Soil Information. This global dataset provides rasterized maps of soil properties for six depth intervals at 250m spatial resolution (targeted in future at 100m). The dataset is generated using point measurements across the globe and a machine learning model, hence actually generates predictions at six standard depths (5cm, 15cm, 30cm, 60cm, 1m, 2m) complemented with an uncertainty layer. One parameter is the Soil Organic carbon content in the fine dg/kg earth abstraction expressed in g/kg. Users should be aware that its accuracy is still limited (30% to 70%). For the spatial aggregation, the average concentration across all cropland and all grasslands as defined in the ecosystem extent account needs to be calculated.

2.2 and 3.2 Common farmland bird index for cropland and grassland

The common farmland bird index summarises population trends of common and widespread birds in farmland habitats and is intended as a proxy to assess the biodiversity status of agricultural landscapes in Europe. The index is developed at the pan-European level making use of the Pan European Common Birds Monitoring Scheme (PECBMS). The indicator is available at the EU level, and at national level (except for Malta). It is based on specially selected species that are dependent on farmland habitats for feeding and or nesting. National common farmland bird indices are based on species sets that are relevant to each Member State. It is worth noting that the national monitoring schemes have been set in place in different years but all have been running for at least ten years. The country average is considered representative for cropland and grassland together (hence, this indicator cannot be separately attributed to the two ecosystem types). Year 2000 is the base year (i.e. year in which the index value = 100) for the reporting of the common farmland bird index. The index needs to be reported 3-yearly, according to the legal act, however, countries are encouraged to report the whole time series starting from the base year. If only the index value for the given reference year is reported (i.e. if a country in 2026 only reports the index value for reference year 2024), the reporting country must make sure that the reported value is uses year 2000 as a base year for the index.

4.1 Deadwood for forest and woodland

This indicator shows the amount of dead standing and lying woody biomass in forest and other wooded land. Deadwood provides a microhabitat for various animal and plant species and is an important factor in nutrient cycles. It is also one of the five carbon pools in ecosystem carbon assessments. The indicator is positively linked to biodiversity, yet in southern Europe may contribute to fire risks and some management regimes in fire prone ecosystems aim to reduce deadwood in forests. Hence, the indicator has different implications in different eco-climatic zones and potentially even in different types of forests and woodlands.

This indicator is provided by Forest Europe (FE) for Europe, and globally by the FAO – Forest Resources Assessment (using data reported by countries participating in the FRA). The indicator is reported by FE at country level and (at the time of writing of this GN, mid 2023) is available from FE for the years 1990, 2000, 2005, 2010 and 2015. However, the coarse spatial unit of reporting at country level restricts their usability for the assessment of forest ecosystem condition at high spatial resolution and the country average is considered as the representative indicator for forests.

A possible challenge is dealing with the misalignment between the condition reporting frequency (3 years) and the FE and FAO initiatives. Moreover, different definitions for deadwood are used in these initiatives. Forest Europe process defines deadwood as non-living woody biomass either standing or lying on the ground. The FAO FRA includes deadwood estimates indirectly in the form of volume of biomass and stored carbon in deadwood. In case of FRA reporting and GHG LULUCF reporting (of net emissions in CO_2 eq), the stemwood (wood contained in stems) volume is expanded with biomass expansion factors to include the non-stemwood and below-ground deadwood. For the EU condition accounts, the FE definition should be used since this aims to more directly represent deadwood, rather than deriving it from stemwood.

4.2 Tree cover density for forest and woodland

Tree cover density reflects the vertical projection of tree crowns to a horizontal earth's surface. This indicator measures the proportional (percent) tree canopy coverage per grid cell, ecosystem asset or ecosystem type. Note that it is not equal to the total vegetation cover, where there are no trees, both shrubs and herbs may also cover the soil. In the case of condition accounting, tree cover is to be reported as an average for all forests and woodlands in a country. The indicator is produced as part of the Copernicus' High Resolution Layers for 2012, 2015 and 2018, and updated every three years. The maps representing the indicator cover the whole EU territory. It is noted that the indicator tree cover density is not by itself sufficient to fully understand the state of forests (but no single indicator would suffice), for instance, when a forest stand is clear-cut, sapling stands emerge as the forest regenerates. These stands can be quite dense, and the tree cover density can be high even though the overall condition of the forest is poor. Hence, to obtain a more representative picture of the condition of the forest, this indicator should ideally be combined with all other voluntary indicators, that together provide a comprehensive indication of forest condition (see Section 3).

11.1 Share of artificial impervious area cover for coastal beaches, dunes and wetlands

Mandatory reporting for this indicator is required for the coastal zone, including various ecosystem types including but not limited to the ecosystem type: 'Coastal beaches, dunes and wetlands'. The substitution of the original (semi-) natural land cover or water surface in coastal areas with an artificial, impervious cover is an indicator for ecosystem condition degradation, reflecting the encroachment of built-up land in the coastal zone (e.g., roads, residential development, holiday houses). Hence, this indicator captures if the condition, in particular naturalness, of coastal areas is preserved or if there is a conversion to, for example, tourism infrastructure. As the indicator will be monitored across ecosystem types within the coastal zone, it allows detecting sealing of land which may, but does not necessarily lead to changes in ecosystem extent accounts. This will allow monitoring of the development of the ecological integrity of coastal zones.

Measuring this service requires delineation of the coastal zone. The coastal zone, for the purpose of ecosystem accounting in Europe, is defined as stretching 1 km inland from the seas's medium high water line. This is further defined in Annex 3 (which was developed by the EEA).

Note that imperviousness is not equal to built-up, for instance concrete dykes are impervious but are not built-up (in contrast, built-up areas with green roofs may not be recorded as impervious areas). However, imperviousness is relatively easy to measure, reflects the conversion of natural to artificial ecosystem types, and is also relevant for ecosystem functioning as it partly determines infiltration rates of precipitation. Copernicus provides the impervious areas in Europe at 10m resolution for the year 2018 , and an update is foreseen for every three years (covering the years 2021, 2024, etc.). The Copernicus imperviousness products capture the percentage and change of soil sealing. Sealed/Impervious areas are characterized by the substitution of the original (semi-) natural land cover or water surface with an artificial, often impervious cover. The imperviousness HRL captures the spatial distribution of artificially sealed areas, including the level of sealing of the soil per area unit. The level of sealed soil (imperviousness degree 1-100%) is produced using a semi-automated classification, based on calibrated Normalised Vegetation Difference Index (NDVI).

Figure 3 presents an example of how to measure this condition indicator

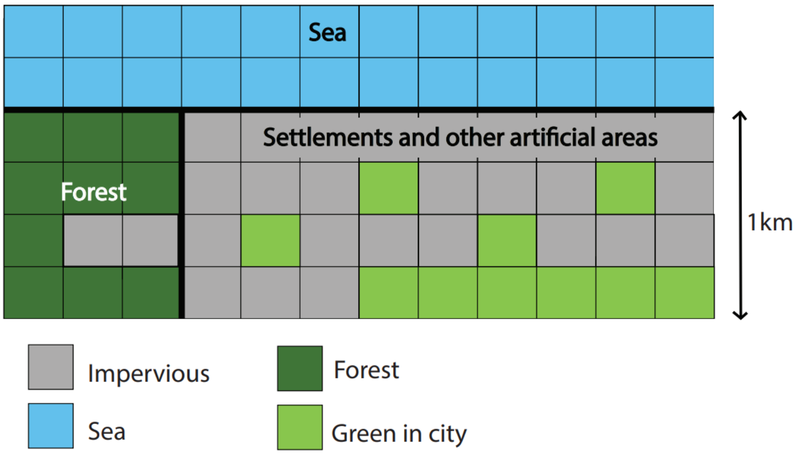

Figure 3. *Measuring the impervious surface indicator.*

The indicator needs to be measured in the coastal zone, i.e. within 1 km from the high tide mark. In the simplified diagram above (not to scale), there are two ecosystem types in the coastal zone: (i) Forests and (ii) Settlements and other artificial areas. In the forest, there is a parking place smaller than the MMU (hence this area is classified as forest in the extent account), of two pixels. In the settlements area, there is a mix of roads including a coastal boulevard (impervious), houses (impervious), and greenspace smaller than the MMU. The greenspace includes, for instance, unpaved gardens and small green parks. The number of cells that are impervious in this ecosystem type is 26. Hence, the total share of impervious surfaces in the coastal zone is (26+2)/48 = 58%.

The full list of mandatory indicators is included in **Table 2** below.

Table 2. *Measurement of mandatory ecosystem condition variables (all indicators to be reported as averages per ecosystem type). NRL refers to the Nature Restoration Law.*

Condition Variables			**Data sources and availability**	**NRL relevance**
Variable Description	**Measurement unit**	**Group / Class**	**Potential data sources**	
1. Settlements and other artificial areas				
1.1 Green areas in cities and adjacent towns and suburbs	% of total area	Biotic / Structural state	Landsat satellite classifications, Corine Land Cover + Backbone, maps to produce ecosystem extent account level 2 (2000-2018) if sufficient details are included.	Yes
1.2 Concentration of Particulate Matter (PM) with a diameter up to 2.5 µm	annual average µg/m^3	Abiotic / Chemical state	Copernicus CAMS PM2.5 (2018)[2], EMEP (2000-2018), Annual AQ statistics from Environment Agencies, yearly available[3]	No
2. Croplands				
2.1 Soil organic carbon stock in topsoil	kg C/ha	Abiotic / Chemical state	LUCAS, JRC (2015-2018), dependent upon national data sources; may not be available for all countries	Yes (partially)
2.2 Common farmland birds index	Dimensionless	Biotic / Compositional state	Pan-European Common Bird Monitoring Scheme (PECBMS) (annual, 1990 – 2021)	Yes (partially)
3. Grasslands				
3.1 Soil organic carbon stock in topsoil	kg C/ha	Abiotic / Chemical state	LUCAS, JRC (2015-2018), dependent upon national data sources; may not be available for all countries	No
3.2 Common farmland birds index	Dimensionless	Biotic / Compositional state	Pan-European Common Bird Monitoring Scheme (PECBMS) (annual, 1990 – 2021)	Yes
4. Forests and woodlands				
4.1. Deadwood	m^3/ha	Biotic / Structural state	Forest Europe/UNECE/FAO (2000,2005,2010, 2015)	Yes
4.2. Tree cover density	%	Biotic / Structural state	Copernicus High Resolution Layer Tree (2012-2015-2018 and assumed continuation every 3 years)	Yes
11. Coastal wetlands, beaches and dunes				
11.1. Share of artificial impervious area cover	%	Abiotic / Physical state	CLC, assumed continuation every 3 years after 2024. EEA-HRL Copernicus (https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness)	No

Spatial resolution

The SEEA EA (p.122) defines that "data for individual variables or condition indicators should be preserved in disaggregated form and at as high as resolution as possible within the information system". This highest level of resolution could refer to an individual ecosystem asset, however in practise is expected to be at a finer level. In practice, it is recommended to store both raster and vector data at the resolution the data was accessed or modelled.

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[2] https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-global-reanalysis-eac4-monthly?tab=overview

[3] https://www.eea.europa.eu/data-and-maps/data/interpolated-air-quality-data-2

Appendix 2: Norwegian LAUs and their degree of urbanisation

The degree of urbanisation is defined as follows (EU 2019):

- *Cities*: LAU level territorial units where at least 50 % of the population lives in urban centres.
    - *Urban centres*: Contiguous (without diagonals) 1 km^2 grid cells within the 'urban cluster' with a density of at least 1 500 inhabitants/km^2 and a minimum of 50 000 inhabitants in the cluster after gap filling.
    - *Urban clusters*: Contiguous (including diagonals) 1 km^2 grid cells with a density of at least 300 inhabitants/km^2, and a minimum of 5 000 inhabitants in the cluster.
- *Towns and suburbs*: LAU level territorial units where less than 50 % of the population lives in rural grid cells and less than 50 % lives in urban centres.
- *Rural areas*: LAU level territorial units where at least 50 % of the population lives in rural grid cells.
    - *Rural grid cells*: 1 km^2 grid cells with density below 300 inhabitants/km^2 and other cells outside urban clusters.

Data are taken from Local administrative units (LAU) - Eurostat (europa.eu) per 2023. The municipalities are listed by decreasing population within each category of urbanization. LAUs classified as 'cities' or 'towns and suburbs' are grouped to Functional Urban Areas (FUAs), where appropriate (but not 'rural LAUs' included in FUAs by Eurostat).

Cities	***FUA***	**Towns/suburbs**	***FUA***	**Towns/suburbs**	***FUA***
Oslo	*Oslo*	Gjøvik		Bamble	
Bergen	*Bergen*	Askøy	*Bergen*	Vestre Toten	
Trondheim	*Trondheim*	Kongsberg		Strand	*Stavanger*
Stavanger	*Stavanger*	Lillehammer		Vefsn	
Bærum	*Oslo*	Sola	*Stavanger*	Notodden	
Sandnes	*Stavanger*	Lier	*Oslo*	Gjesdal	*Stavanger*
Nordre Follo	*Oslo*	Horten		Randaberg	*Stavanger*
Lørenskog	*Oslo*	Færder		Lillesand	
Rælingen	*Oslo*	Holmestrand		Hammerfest	
		Rana		Volda	
Towns/suburbs	***FUA***	Bjørnafjorden	*Bergen*	Ørsta	
Kristiansand		Nittedal	*Oslo*	Sortland	
Drammen	*Oslo*	Harstad		Sula	
Asker	*Oslo*	Grimstad		Fauske	
Lillestrøm	*Oslo*	Stjørdal	*Trondheim*	Flekkefjord	
Fredrikstad		Kristiansund		Ulstein	
Tromsø		Elverum		Brønnøy	
Ålesund		Narvik		Alstahaug	
Sandefjord		Ås	*Oslo*	Gjerdrum	*Oslo*
Sarpsborg		Alta			
Tønsberg		Klepp	*Stavanger*		
Skien		Levanger			
Bodø		Nesodden	*Oslo*		
Moss	*Oslo*	Time	*Stavanger*		
Larvik		Stord			
Arendal		Kongsvinger			
Karmøy		Kinn			
Ullensaker	*Oslo*	Frogn	*Oslo*		
Haugesund		Vennesla			
Porsgrunn		Eigersund			
Molde		Verdal			
Hamar		Namsos			
Halden		Malvik	*Trondheim*		

Rural areas	Rural areas	Rural areas
Indre Østfold	Vestnes	Drangedal
Øygarden	Rauma	Etne
Ringsaker	Jevnaker	Høyanger
Ringerike	Hole	Bardu
Alver	Inderøy	Evje og Hornnes
Eidsvoll	Risør	Skiptvet
Nes	Målselv	Vaksdal
Steinkjer	Trysil	Overhalla
Lindesnes	Nome	Porsanger
Sunnfjord	Nordre Land	Vinje
Stange	Nord-Aurdal	Suldal
Øvre Eiker	Meløy	Aukra
Hå	Tvedestrand	Marker
Vestby	Froland	Våler (Innlandet)
Orkland	Midtre Gauldal	Vågå
Aurskog-Høland	Gausdal	Bremanger
Melhus	Eidskog	Sigdal
Voss	Kvinesdal	Sørreisa
Nannestad	Våler (Viken)	Aure
Østre Toten	Surnadal	Sokndal
Senja	Gloppen	Nesbyen
Modum	Heim	Øystre Slidre
Gran	Averøy	Sør-Fron
Hustadvika	Sveio	Lund
Kvinnherad	Tynset	Fitjar
Sogndal	Røros	Tingvoll
Bømlo	Vadsø	Vanylven
Vestvågøy	Nord-Fron	Askvoll
Tysvær	Sel	Hurdal
Enebakk	Søndre Land	Seljord
Ullensvang	Tinn	Nordkapp
Lyngdal	Balsfjord	Fjaler
Midt-Telemark	Frøya	Tysnes
Ørland	Birkenes	Sør-Aurdal
Kragerø	Luster	Kvæfjord
Indre Fosen	Austevoll	Austrheim
Nærøysund	Hitra	Bjerkreim
Farsund	Årdal	Kautokeino
Sør-Varanger	Øyer	Tana
Vågan	Hareid	Skjervøy
Stad	Nord-Odal	Flesberg
Lunner	Ål	Lyngen
Vindafjord	Nordreisa	Hamarøy
Herøy (Møre og Romsdal)	Gol	Gjemmes
Giske	Hvaler	Steigen
Kvam	Saltdal	Hemsedal
Skaun	Andøy	Frosta
Rakkestad	Grue	Hjelmeland
Råde	Sauda	Bø
Hadsel	Øksnes	Vik
Osterøy	Hol	Karasjok
Sør-Odal	Hemnes	Samnanger
Løten	Stranda	Fjord
Sykkylven	Ringebu	Alvdal
Åsnes	Åfjord	Nore og Uvdal
Oppdal	Åmot	Rennebu
Stryn	Tjeldsund	Dovre
Sunndal	Selbu	Sande

Rural areas	Rural areas	Rural areas
Kviteseid	Aurland	Dyrøy
Meråker	Rendalen	Gamvik
Gjerstad	Hægebostad	Beiarn
Siljan	Masfjorden	Bykle
Grong	Vang	Lavangen
Stor-Elvdal	Hjartdal	Moskenes
Leirfjord	Tolga	Hasvik
Gulen	Folldal	Eidfjord
Lom	Grane	Åseral
Krødsherad	Nissedal	Berlevåg
Tokke	Bindal	Osen
Karlsøy	Dønna	Bokn
Smøla	Rollag	Nesseby
Skjåk	Iveland	Loppa
Vegårshei	Aremark	Namsskogan
Lærdal	Engerdal	Solund
Båtsfjord	Evenes	Tydal
Vestre Slidre	Lierne	Værøy
Salangen	Ibestad	Leka
Snåsa	Hattfjelldal	Kvitsøy
Kåfjord	Hyllestad	Fedje
Holtålen	Etnedal	Røst
Lødingen	Lebesby	Vevelstad
Sømna	Fyresdal	Træna
Lesja	Flakstad	Røyrvik
Rindal	Vega	Modalen
Vardø	Høylandet	Utsira
Gildeskål	Valle	
Lurøy	Rødøy	
Sørfold	Bygland	
Os	Måsøy	
Herøy (Nordland)	Kvænangen	
Sirdal	Flatanger	
Storfjord	Flå	
Åmli	Gratangen	
Nesna	Ulvik	

Note that Eurostat’s classification of degree of urbanisation for LAUs is not always intuitive from the usual Norwegian perspective. For instance, the ‘city LAUs’ Bærum, Lørenskog, and Rælingen would normally be seen as suburbs to Oslo, whereas the ‘towns and suburbs LAUs’ Kristiansand and Drammen (with >100 000 inhabitants) would normally be considered as cities.

www.nina.no

The Norwegian Institute for Nature Research, NINA, is as an independent foundation focusing on environmental research, emphasizing the interaction between human society, natural resources and biodiversity.

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Norwegian Institute for Nature Research
NINA head office
Postal address: P.O. Box 5685 Torgarden,
NO-7485 Trondheim, NORWAY
Visiting address: Høgskoleringen 9, 7034 Trondheim
Phone: +47 73 80 14 00
E-mail: firmapost@nina.no
Organization Number: 9500 37 687
http://www.nina.no

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