STATISTICS
ESTONIA

# "Development of the forestry, environmental subsidies and ecosystem accounts"

**Project number: 101113157**

## D1.7 Description of the feasibility of the compilation of the ecosystem condition accounts and its regular production

**Project acronym: 2022-EE-EGD**

**Final Report**

Kätlin Aun

Kaia Oras

Argo Ronk

Statistics Estonia

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# Contents

# Introduction

During the project period between June 2023 to December 2024, the amendment of EU regulation 691/2011 concerning the new proposed module of ecosystem accounts was finalized and approved. This solidified the list of ecosystem condition indicators to be recorded in ecosystem accounting.

The focus of the current work was to implement the latest suggestions in the Guidance Note (5th draft) on ecosystem condition accounts by Eurostat[1]. Statistics Estonia has in previous grant project tested the compilation of condition account for selected condition indicators: green areas in cities and adjacent towns and suburbs (% of total area), concentration of particulate matter (PM) with a diameter up to 2.5 μm (annual average μg/m3), soil organic carbon stock in topsoil (kg C/ha) of grasslands and croplands, common farmland birds index, deadwood (m3/ha), tree cover density (%), share of artificial impervious area cover (% of total area) in coastal areas.[2] For the compilation of condition account for the year 2022, the same methodologies for calculating mandatory indicators were used as in the previous grant with some minor differences. The description of the work is presented in chapter 2.

An additional goal was to evaluate the feasibility of assessing extra condition indicators, aiming to provide a broader ecological perspective for the condition account. Currently the final available guidance note includes the mandatory indicators and the section on voluntary indicators from a previous Guidance Note (4th draft) [3] has been removed as the alignment with the indicators in the Nature Restoration Law was seen as an necessary step before continuing.

There are several relevant ongoing international processes regarding the monitoring of ecosystem condition: the Nature Restoration Law and Forest Monitoring Law in Europe, The Kunming-Montreal Global Biodiversity Conservation Framework. These monitoring frameworks are in development and the methodologies for monitoring the indicators included in the frameworks are also being developed. However, in principle, several of the proposed indicators for monitoring the condition of habitats could be associated with ecosystem accounts, especially regarding condition account when it includes mandatory and voluntary condition indicators. These indicators include, for example, the area of urban green space and the coverage of tree canopies in cities, grassland butterfly index, organic carbon stock of mineral soils of agricultural lands, share of agricultural land with diverse landscape elements, farmland bird index, forest tree cover density, dead wood, age structure of forests, coherence of forests, forest bird index, etc. International institutions and national stakeholders have addressed the need to harmonize definitions and production when the same indicators are used in multiple reports.

In the light of this, at the beginning of the project experts and local stakeholders in Estonia (Ministry of Climate, Estonian Environment Agency, Ministry of Economic Affairs and Communications; Ministry of Finance; Ministry of Regional Affairs and Agriculture, The Centre of Estonian Rural Research and Knowledge) decided on a set of additional indicators that could be included in Estonia's ecosystem accounts, alongside the mandatory indicators set by the regulation (see ANNEX 1).

In case of forest bird index, the indicator was first proposed to be added as a voluntary indicator, but later added to the regulation as a mandatory indicator.

The proposed extra indicators by local stakeholders were:

- Forest bird index (Forest and woodland)
- Forest connectivity (Forest and woodland)
- Share of forests with uneven-aged structure (Forest and woodland)

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[1] Eurostat – Unit E2. Doc. ENV/EA/TF/2023_3/4. Ecosystem condition accounts – guidance note. Fifth draft. (November 2023) https://circabc.europa.eu/ui/group/922b4700-1c83-4099-b550-763badab3ec0/library/73788ea5-35fb-4e3e-be1c-c154b46dc285/details

[2] Statistics Estonia, 2020. Development of the forestry, environmental subsidies and ecosystem accounts" (Eurostat Grant Agreement no NUMBER – 101113157 - 2022-EE-EDG) https://www.stat.ee/sites/default/files/2023-09/D1_8_%20Description%20of%20the%20methodology%20for%20advancing%20ecosystem%20accounts%2C%20methodology%20_101022852_2020-EE-ENVACC_k%C3%BClj.pdf

[3] Eurostat – Unit E2. Doc. ENV/EA/TF/2023_3/4. Ecosystem condition accounts – guidance note. Fourth draft. (October 2023) https://circabc.europa.eu/ui/group/922b4700-1c83-4099-b550-763badab3ec0/library/73788ea5-35fb-4e3e-be1c-c154b46dc285/details

- Butterfly index (Grassland)
- Share of croplands with high diversity landscape features (Cropland)
- Share of inland wetlands area influenced by drainage (Wetlands)
- Wetland bird populations (Wetland)
- Standing deadwood (Forest and woodland)
- Lying deadwood (Forest and woodland)
- The area of maintained heritage meadows (Grassland)
- Share of organic farming (Cropland)

Share of forests with uneven-aged structure and wetland bird populations (index) are indicators that are not produced currently. These were considered to be important condition indicators, however due to the lack of resources the work was not carried out in the project.

For forest bird index, forest connectivity, butterfly index and share of inland wetlands area influenced by drainage the work was carried out in collaboration with Estonian Environment Agency and the developed methodologies are introduced in the respective chapters.

The remaining indicators were obtained from existing databases or calculated in-house. The details are further described in chapter 7.

## Compilation of the ecosystem condition account regarding mandatory ecosystem condition indicators

Ecosystem condition indicators for mandatory reporting in the proposed amendment of EU regulation 691/2011 are:

1. 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 $\mu g/m^3$ as a national average for the reporting period.
2. For cropland:
   - soil organic carbon stock in topsoil shall be reported in tonne/ha, as a national average for the reporting period.
3. For grassland:
   - soil organic carbon stock in topsoil shall be reported in tonne/ha, as a national average for the reporting period.
4. For cropland and grassland together:
   - common farmland bird index shall be reported as a national aggregate index for the reporting period.
5. For forest and woodland:
   - dead wood shall be reported in $m^3$/ha, as a national average for the reporting period;
   - tree cover density shall be reported in %, as a national average for the reporting period.
   - common forest bird index; the forest bird indicator index 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.

6. 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.

The condition account was compiled for the year 2022 where possible. Table 1 gives an overview of ecosystem condition indicators and their values which represent the national average.

Detailed description of the methodology and alternative approaches are given in the respective subchapters. [4]

**Table 1. Mandatory ecosystem condition indicators in ecosystem condition account. Values represent the national average. Reference year shows the year account was compiled for.**

| Ecosystem | Indicator | Reference year | Unit | Value |
|---|---|---|---|---|
| Settlements and other artificial areas | Green areas in cities and adjacent towns and suburbs | 2020* | % | 44 – 60 |
| Settlements and other artificial areas | Concentration of Particulate Matter (PM) with a diameter up to 2.5 µm | 2022 | µg/m$^3$ | 6.63 |
| Cropland | Soil organic carbon stock in topsoil | 2022 | tonne/ha | 668.0 |
| Grassland | Soil organic carbon stock in topsoil | 2022 | tonne/ha | 841.0 |
| Cropland & Grassland | Common farmland birds index | 2022 | index | 54.3 |
| Forest and woodland | Deadwood | 2022 | m$^3$/ha | 15.8 |
| Forest and woodland | Tree cover density | 2022* | % | 70.4 |
| Forest and woodland | Common forest bird index | 2022 | index | 85.9 |
| Coastal beaches, dunes and wetlands | Share of artificial impervious area cover | 2020* | % | 9 – 16 |

*Results were calculated in project 101022852 — 2020-EE-ENVACC.

Data availability and analysis for regular production of the mandatory condition indicators were conducted as part of the work.

**Green areas in cities and adjacent towns and suburbs**

There are two approaches described in the Guidance Note (5th draft) on ecosystem condition accounts by Eurostat[5] for the calculation of green areas in cities. In option 1 the delineation of urban areas as the reference area for the share of green areas is based on LAU and in option 2 the delineation is based on the ecosystem type 'Settlement and other artificial areas'. The calculation for 2022 condition account of green areas in cities was done based on option 1 because it is better aligned with the definition of condition indicator and it is simple to calculate. Relevant LAUs in Estonia are Tallinn, Tartu, Narva and their administrative borders were used for the calculations. Classes that can be considered as urban green were identified from ecosystem extent map (urban blue was excluded) and then their share from each LAU was calculated, which was then averaged over national territory. Following the described approach, then the input data is available based on the availability of ecosystem extent map. More details on the methodology and alternative approaches are described in respective subchapter.

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[4] Some of text of this chapter copies the methodological descriptions given already in the following grant: Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC, Development of environmental accounts; Activity "Developing and refining ecosystem accounts", D1.8 Description of the methodology for advancing ecosystem accounts" Authors of the text are the same. The reasons to copy also the basic descriptions are:
- These methodological descriptions were well-developed during the previous grant work,,
- Full methodological description is needed to provide the reader with comprehensive approach in single stand-alone document instead of references to other documents

[5] Eurostat – Unit E2. Doc. ENV/EA/TF/2023_3/4. Ecosystem condition accounts – guidance note. Fifth draft. (November 2023) https://circabc.europa.eu/ui/group/922b4700-1c83-4099-b550-763badab3ec0/library/73788ea5-35fb-4e3e-be1c-c154b46dc285/details

**Concentration of PM2.5 in cities**

Concentration of PM2.5 in cities is calculated based on the map of average annual PM2.5 concentrations, which is calculated based on national emissions and meteorological data in Airviro modelling system, by Estonian Environmental Research Centre (EKUK), which is also used as an input for the air filtration, and ecosystem extent map, where the ecosystem type 'Settlements and other artificial areas' in LAUs considered as cities (Tallinn, Tartu, Narva) are delineated to calculate the average. More details on the methodology and alternative approaches are described in respective subchapter. The input data is foreseen to be obtained as part of the work on air filtration service which is made by Environmental Research Centre (EKUK) per contract. The input data of PM2.5 concentrations is available T-15, where T is reference year.

**Soil organic carbon stock in topsoil in croplands and grasslands**

Soil organic carbon stock was calculated using the soil carbon map created during ELME2[6] project based on national soil map and literature with the assumption that in croplands and grasslands the whole stock describes the stock in topsoil because of its natural depth which rarely falls under 30 cm. For the delineation of cropland and grasslands, the map of ecosystem extent was used. More details on the methodology are described in respective subchapter. There is consistency between the condition indicator and the organic carbon stock accounted in the global climate regulation service as the used input data is the same. The used soil carbon map is foreseen to be updated regularly in the future by Estonian Environment Agency, but specifics are not yet clear. It is also a possibility that more relevant data is compiled during currently ongoing projects, for example project "Land and Soil Use Management System for Effective and Sustainable Use of Soil Services, Biodiversity Protection, and Climate Impact Reduction"[7] which is led by the Ministry of Climate (completion by 2027).

**Common farmland bird index**

Farmland Bird Index (FBI) is a composite index that measures the rate of change in the relative abundance of common farmland bird species at selected sites. It is reported yearly to OECD and the Statistical Office of the European Commission (Eurostat). The input data is collected and the index is calculated yearly in Estonian Environment Agency. Calculated indices become available T-2 via Estonian Environment Agency. In the project additional analysis was done, which is described in chapter 3.

**Deadwood in forests**

The estimates of deadwood volume are based on data measured in the process of the National Forest Inventory (NFI) conducted by Estonian Environment Agency. All NFI basic estimates are compiled from the measurements of the 5 most recent years and attributed to the latest year of measurement. Data is available T-6 – T-10 via Estonian Environment Agency. More details on the methodology are described in respective subchapter.

**Forest tree cover density**

Forest tree cover density was calculated by an expert per contract in 2022 using the latest available data (2019 - 2022). In the current condition account results from the previous project is used. ALS measurements (carried out yearly by the Estonian Land Board, the whole country is covered over 4-year cycle) made in summertime were used for canopy cover estimation. More details on the methodology are described in respective subchapter. Input data is available during the reference year (T) However, the calculations are resource consuming and currently the data is not produced for other uses. Therefore, it was suggested that, unless the reporting is due, the indicator were calculated following the 4-year cycle during which the data for the whole country is updated. The indicator may become relevant in the future, e.g. regarding Forest Monitoring Law in Future.

**Common forest bird index**

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[6] Estonian MAES project, Countrywide Socioeconomic Assessment of Ecosystem Services
https://loodusveeb.ee/en/countrywide-MAES-EE-socioeconomic-terrestrial
[7] https://kliimaministeerium.ee/uudised/kliimaministeeriumi-eestvottel-valmib-kaasaegne-mullastikukaart

indices become available T-2 via Estonian Environment Agency. In the project additional analysis was done, which is described in chapter 3.

**The share of artificial impervious area covering coastal areas**

After the delineation of the coastal area and defining the classes that can be considered as artificial in ecosystem extent map, the total share of the artificial area was calculated. More details on the methodology and alternative approaches are described in respective subchapter.

## Green areas in cities and adjacent towns and suburbs

For settlements and other artificial areas the condition indicator would be: green areas in cities and adjacent towns and suburbs that 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.

The guidance note also suggests: 'Urban green space' is the proportion of existing green areas in an urban area. Green areas can be defined as the ensemble of the following categories of the CLC Classification: 'green urban areas', 'broad-leaved forests', 'coniferous forests', 'mixed forests', 'natural grasslands', 'moors and heathlands', 'transitional woodland-shrubs' and 'sparsely vegetated areas'.

According to the guidance note, for the spatial delineation of urban areas, cities, and their adjacent towns and suburbs are considered local administrative units, categorized according to the degree of urbanization typology set out under Regulation (EU) 2017/2391. Relevant LAUs in Estonia are the following cities: Tallinn, Tartu, and Narva. Administrative borders[8] of these cities were used.

As suggested in the guidance note, Copernicus Urban Atlas data (corresponding roughly to the ecosystem extent account level 2) to define green areas were used (2018)[9]. In addition to this, Estonian Topographic Database data (2023)[10] were tested.

Classes that can be considered as urban green in these two datasets[11] were chosen to calculate the indicator. Then, national average share of urban green areas and the share in different cities was calculated using standard GIS-programs (ArcGIS, MapInfo).

It could be argued how to define urban area. In this case, the analysis was carried through within the local administrative units (LAUs) in DEGURBA level 1 administrative units that are Tartu, Tallinn, and Narva. It would be more appropriate of urban areas were spatially delineated according to areas functioning as urban ecosystems. We are proposing an approach for delineating urban areas that has been worked out during Estonian MAES project ELME (methodology enclosed in separate document). One of several possibilities has been presented here: ETAK (ETD) green areas within ELME urban areas within administrative borders. According to this approach, the share of the green areas was the lowest. It might be useful to also present the share of the green areas within the whole ELME urban (functionally whole) area, i.e., without delimiting it with the LAU level 1 unit's administrative borders.

Different approaches gave different results (Table 2). More detailed results are provided in attached tables and layers.

[8] Borders of cities: Estonian Land Board, https://geoportaal.maaamet.ee/eng/Spatial-Data/Administrative-and-Settlement-Division-p312.html. Validity date 5.04.2023.
[9] https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018?tab=download
[10] https://geoportaal.maaamet.ee/eng/Spatial-Data/Estonian-Topographic-Database-p305.html
[11] Classes defined as urban green in this analysis, are listed in respective attached tables and layers.

**Table 2. Urban green – % of the area of the administrative unit according to two different data sets (Estonian Topographic Database and Urban Atlas). In addition, areas functioning as whole urban ecosystems were selected inside administrative borders of the cities to assess the share of (ETAK) green areas.**

| | ETAK (Estonian Topographic Database) green (%) within city administrative borders | | Urban Atlas green (%) within city administrative borders | | | ETAK urban green (%) within ELME urban area (within city administrative borders) |
|---|---|---|---|---|---|---|
| | non-artificial in total | without waterbodies | non-artificial in total (incl. arable land with annual crops) | without arable land (annual crops); waterbodies included | without arable land and waterbodies | |
| Tallinn | 45 | 37 | 43 | 42 | 34 | 25 |
| Tartu | 47 | 45 | 78 | 57 | 55 | 31 |
| Narva | 57 | 49 | 58 | 58 | 52 | 33 |
| NATIONAL AVERAGE | 50 | 44 | 60 | 53 | 47 | 30 |

In conclusion, national average share of urban green areas varies from 44 to 60% depending on the used dataset and classes included as urban green.

## Concentration of particulate matter, with a diameter up to 2.5 µm in cities

The ecosystem condition characteristic is defined in the proposal for legal text as concentration of particulate matter, with a diameter up to 2.5 µm in cities, shall be reported in µg/m3 as a national average for the reporting period.

For assessing the indicator annual air quality statistics for 2020 was used. Estonian Environmental Research Centre (EKUK) has produced a map of PM2.5 concentrations in resolution of 1000x1000m based on national emissions and meteorological data in Airviro modeling system. The same data was used as an input for the air filtration ecosystem service. For the PM concentration (PM2.5) emissions assessments and modelling were carried out for fine particles (PM2.5) from all anthropogenic sources, like traffic, residential wood combustion, energy and industrial sector, agriculture.

National emissions data (2020) was used as input for the emissions, which were validated with air quality monitoring results.

The emission dataset was imported into the Airviro modelling system and emission sources were identified as grid sources. The modeling utilized meteorological observation data from the year 2020. The Eulerian grid dispersion model was used. For the modeling of the entire Estonia, the size of the modeling grid cell of 1000x1000 m was used. Hourly results from the dispersion model were aggregated into annual average value, where each grid cell in the modeling grid corresponded to the arithmetic mean of the calculated hourly average values for that grid cell. The modeling results (Figure 11) were compared to monitoring data at monitoring points. The model was considered reliable if sufficient agreement was obtained at all monitoring points.

For delineating cities, two different approaches were tested:

1) local administrative units, categorised as cities according to the degree of urbanisation typology set out under Regulation (EU) 2017/2391[12] was the proposed approach in the guidance note. It includes three major cities in Estonia: Tallinn, Tartu, Narva within their administrative borders (Estonian Land Board, 2023).
2) Urban areas on ecosystem extent map (year 2020). This approach includes all urban areas with dense infrastructure and population.

[12] https://ec.europa.eu/eurostat/web/degree-of-urbanisation/background

PM2.5 map was combined with the different data used for delineating cities and the (spatial) average concentration of PM2.5 was found.

## Soil organic carbon stock in topsoil in grasslands and croplands

The ecosystem condition characteristic is defined in the proposal for the legal text as soil organic carbon stock in topsoil shall be reported in tonne/ha, as a national average for the reporting period.

The soil carbon map was created during ELME project based on national soil map with high spatial resolution (Estonian Land Board) and literature. The data is described as follows[13]:

> *The soil carbon reserve is a rather stable indicator over time, therefore based on the soil texture and the name of the soil derived from soil map an approximate estimation of the soil carbon reserve can be made, which has also been confirmed by the soil science professor of The Estonian University of Life Sciences (EMÜ) A. Astover. Also, the approximate soil carbon reserves of forests by habitat type have been published by EMÜ scientists (Lutter et al., 2019) and by scientists of the University of Tartu (UT) Geography Department (Kmoch et al., 2021) to estimate carbon reserves, a model using a soil map as a basis has been created, which covers all ecosystems throughout Estonia.*

The soil carbon map includes all carbon stock with no depth limit. It was discussed and an assumption was made that in croplands and grasslands the whole stock describes the stock in top layer of the soil because of its natural depth which rarely falls under 30 cm. The issue could rise on crop- or grasslands on deep peat soils. It was also noted that even when the top layer limit is applied, the whole supply is ecologically important.

For the spatial delineation cropland and grasslands as defined in the ecosystem extent account was used.

## Deadwood

The estimates of deadwood volume are based on data measured in the process of the National Forest Inventory (NFI).

Design of the Estonian NFI is a systematic sample without pre-stratification. The network of sample plots covers the whole country and is planned as a five-year cycle. The sampling intensity is the same throughout the whole country. The sample (cluster) distribution is based on a national 5-km x 5-km quadrangle grid, determined by the L-EST co-ordinates system. Sample plots are concentrated into clusters to increase the efficiency of the survey. Approximately 370 clusters (ca 5 500 sample plots) measured each year i.e. the permanent plots will be re-measured in every 5 years.

An observation unit is an individual field plot that is the centre of sample circles with defined radii. The method of sampling with partial replacement is used. Plots are divided into permanent clusters and temporary clusters that form 800 x 800 metre squares. The sample plot radius depends on the assessed variables, as well as their values (e.g., tree diameter). In addition to plots with the main radii of 10 m and 7 m, where the land-use category is determined, plots of other radii are also used. All population units have an equal probability of being selected into the sample. The result is point estimates of multiple population parameters based on the measurement data. Although all NFI estimates are

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[13] „The nation wide assessment and mapping of ecosystem services“. Project "Establishment of tools for integrating socioeconomic and climate change data into assessing and forecasting biodiversity status, and ensuring data availability" (ELME) http://www.keskkonnaagentuur.ee/elme
Lutter, R., Kõlli, R., Tullus, A., Tullus, H. (2019). Ecosystem carbon stocks of Estonian pre-mature and mature managed forests: effects of site conditions and overstorey tree species. European Journal of Forest Research, 138, 125–142.10.1007/s10342-018-1158-4
Kmoch, A., Kanal, A., Astover, A., Kull, A., Virro, H., Helm, A., Pärtel, M., Ostonen, I., Uuemaa, E. (2021). ESSDD - EstSoil-EH v1.0: An eco-hydrological modelling parameters dataset derived from the Soil Map of Estonia, Earth System Science Data, 13, 83–97, 2021. https://doi.org/10.5194/essd-13-83-2021. https://essd.copernicus.org/articles/13/83/2021/

based on sampling, they are not absolute. Therefore, each estimate of a general parameter is always accompanied with a sampling error. The sampling scheme and design are described in more detail by Adermann (2010)[14].

NFI forest estimates are the basis for national[15] and international statistical reporting: e.g. United Nations/FAO Forest Resources Assessment[16], the Ministerial Conference on the Protection of Forests in Europe (Forest Europe aka MCPFE[17]), information on forest carbon pools and changes for the LULUCF sector in the GHG inventory[18].

NFI provides deadwood volume estimates about standing and lying deadwood of stemwood:

- with utilisation value (at least for fuelwood) and
- without utilisation value (at least for fuelwood) i.e. decaying wood or snags and notches.

In Estonia, usually the standing and lying deadwood with utilization value (at least for fuelwood) is being reported. Same approach is valid in case of Pan-European reporting: Forest Europe process defines deadwood as *non-living woody biomass either standing or lying on the ground, exceeding specified thresholds*. UNFAO 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 CO2 eq) the stem wood volume is expanded with biomass expansion factors to include the non-stemwood and below-ground deadwood.

NFI is able to provide all mentioned estimates for forest land according to Estonian or international (FRA) forest definition. NFI yearly estimates are available since 1999. Data for the previous year become available in June of the next year. Note that all NFI basic estimates are compiled from the measurements of the 5 most recent years and attributed to the latest year of measurement.

## Forest tree cover density

The estimates of canopy cover are based on airborne laser scanning (ALS) data. The data is collected from airplanes, using a laser scanner which operates in near infra-red (NIR) wavelength. The pulses emitted by the scanner are timed and the position of the reflection (echo) is calculated through the aircrafts GNSS (global navigation satellite system), inertial measurement unit (IMU) and scan angle. The end result is a three-dimensional pointcloud which can be used to describe the whole vertical structure of a forest and the ground beneath. The point cloud formed by the ground reflections is an elevation dataset that allows topographic, hydrological, etc. analyses.

ALS data is processed to distinguish the ground from the pointcloud and canopy cover is then calculated as the ratio of echoes above 1.3 m to all echoes. Those points are considered to represent the crown coverage of woody vegetation. Average forest tree crown coverage is calculated for every pixel of 10x10m of scanned area. To obtain the tree cover density of forest land only those pixels have to be considered which remain inside the perimeter of the designated forest land area. According to the tree cover estimates of the pixels remaining on forest land the average forest tree cover density estimate is then calculated.

The ALS data were processed using FUSION/LDV freeware. The raster maps were processed with QGis and zone statistics using forest land mask of Estonian Topographic Database (ETAK). According to the described method the estimate of tree cover density for 2022 is 70.4%. ALS data is from years 2019-2022, forest land mask of ETAK is as published current status by Estonian Land Board.

Similar method can be used with other types of remote sensing data (e.g. satellite images). ALS method was chosen by remote sensing experts as most accurate and handy available method at present in Estonia. The detailed general description of the methodological approach by Tauri Arumäe and Mait Lang is available in article "Estimation of canopy cover in dense mixed-species forests using airborne lidar data"[19].

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[14] Adermann, V. (2010). Estonia. *In*: Tomppo, E., Gschwantner, T., Lawrence, M., McRoberts, R. (eds). National forest inventories: Pathways for common reporting. Dordrecht: Springer, pp. 171–184.
[15] https://keskkonnaportaal.ee/sites/default/files/Teemad/Mets/Mets2020.pdf
[16] https://www.fao.org/forest-resources-assessment/en/
[17] https://foresteurope.org/state-of-europes-forests/
[18] https://unfccc.int/documents/461808
[19] Available at: https://www.tandfonline.com/doi/full/10.1080/22797254.2017.1411169

"EU-wide methodology to map and assess ecosystem condition[20]" defines tree cover density as follows: "*Tree cover density is defined as the 'vertical projection of tree crowns to a horizontal earth's surface*". Forest tree cover density is mostly used in describing the bushlands in stand-wise forest inventory. Number of trees per ha in case of reforestation areas/young stands and stocking level in case of other stands are used to describe the use of habitat space by woody vegetation on forest land. There is no everyday use of forest tree cover estimates in forestry.

ALS measurements are carried out yearly by the Estonian Land Board. Data[21] from flights made in summertime (so-called summer flights or forestry mapping flights) were used for canopy cover estimation. The data for the whole country was gathered from 2019 to 2022. Forest land data from the Estonian Topographic Database (ETAK) by Estonian land Board is used as the basis of the forest land.

LiDAR elevation data from forestry mapping by the Estonian Land Board is publicly available at: https://geoportaal.maaamet.ee/est/Ruumiandmed/Korgusandmed/Aerolaserskaneerimise-korguspunktid/ALS-IV-ring-2021-2024-p855.html (in Estonian); https://geoportaal.maaamet.ee/eng/Maps-and-Data/Topographic-Data/Elevation-data-p308.html (in English).

Forest land data from the Estonian Topographic Database (ETAK) by Estonian land Board is publicly available at Board's web-site: map layer of woody vegetation (E_305) subtype „Mets", see more https://geoportaal.maaamet.ee/eng/Spatial-Data/Estonian-Topographic-Database-p305.html.

## Share of artificial impervious area cover in coastal areas

For coastal areas, the share of artificial impervious area cover (% as a national average) is planned to be reported as an indicator describing the condition of coastal ecosystems.

According to the guidance note, original (semi-) natural land cover or water surface in coastal areas with an artificial, impervious cover is considered as an indicator for ecosystem condition degradation.

According to the guidance note, coastal areas are the local administrative units (LAUs) that are bordering or close to the coastline (at least 50% of their surface area within a distance of 10 km from the coastline). A total of 25 municipalities are considered as coastal according to this approach in Estonia. However, two more municipalities having less than 50% of their area within the 10 km zone (Lüganuse and Lääne-Nigula) were also included in the analysis because they are located on the coast. A total of 27 municipalities[22] were thus involved.

Three data sets were tested to calculate the indicator: Corine Land Cover (CLC; 2018[23]; suggested in the guidance note), Estonian Topographic Database (ETD; 2023[24]), and Copernicus imperviousness layer (2019, based on 2018 data[25]). The first two are the so-called pre-classified datasets.

After the delineation of the coastal area (choosing the municipalities) and defining the classes that can be considered as artificial in ETD and CLC datasets[26], the total share of the artificial area (national average) and the share in different municipalities was calculated using standard GIS-programs (ArcGIS, MapInfo). Overlapping phenomena in the ETD dataset were combined before calculations.

All these three datasets gave different results (Figure 1). According to the ETD, the average share of the artificial area in the 27 municipalities is 9%. ETD is the most accurate regarding the topology of the phenomena and the dataset we used was the most up to date, but the dataset is updated irregularly. The result from CLC data was 16% which is much

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[20] Available at: file://sise.envir.ee/Kasutajad$/KAUR/37109292732/Downloads/eu-wide%20methodology%20to%20map%20and%20assess%20ecosystem%20condition-KJNA31226ENN.pdf

[21] LiDAR data with average pulse density 0.8 p/m$^2$, distance between pulses 1.64 m,

[22] Borders of local municipalities: Estonian Land Board, https://geoportaal.maaamet.ee/eng/Spatial-Data/Administrative-and-Settlement-Division-p312.html. Validity date 5.04.2023.

[23] https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

[24] https://geoportaal.maaamet.ee/eng/Spatial-Data/Estonian-Topographic-Database-p305.html

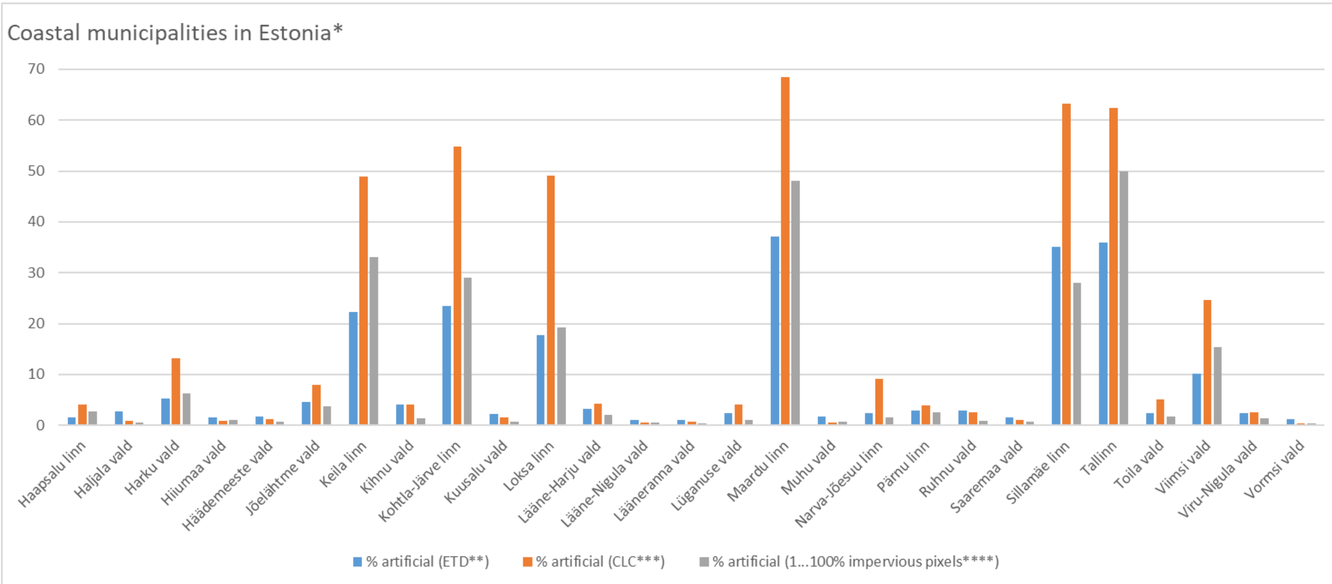
[25] Imperviousness Density 2018 — Copernicus Land Monitoring Service (https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/status-maps/imperviousness-density-2018?tab=metadata)

[26] Classes that were considered artificial in this analysis, are listed in respective attached tables and layers.

higher value, but it is well known that CLC tends to smooth smaller patches of habitats and other phenomena, including green areas in settlements which are together defined as continuous or discontinuous urban areas in CLC. Thus, CLC tends to overestimate the share of artificial areas compared to the other datasets we used. We also tested the high resolution (10 m) imperviousness layer[4] suggested by European Environment Agency[27] and describing soil sealing and how impervious the surfaces are. According to this data set, the average sealed area (we considered all pixels with an imperviousness value of 1% to 100% as sealed) in these 27 municipalities is 9% that is the same as in the case of ETD data. If the imperviousness data were more up to date, it could possibly be considered the most accurate in terms of assessing the share of impervious land cover, while pre-classified layers like CLC of ETD don't give the full information of how impervious the objects are (e.g., the class comprising sport fields might comprise objects with very variable imperviousness).

It might be useful to test the NDVI-based indices. Copernicus imperviousness layer is also NDVI-based, but the input data is a bit outdated and newer information would be useful. The imperviousness layer enables a methodological comparison with CLC while the datasets are based on the satellite data from the same year (2018).

**Figure 1. The share (%) of artificial and impervious areas in 27 coastal municipalities in Estonia.**




** According to the current definition in the guidance note*
*** ETD – Estonian Topographic Database*
**** CLC – Corine Land Cover*
***** Copernicus imperviousness data*

It should be decided how to define the coastal area. It can be argued whether the current definition of coastal areas is adequate (50% of the municipality within 10 km from the coastline).

We also used 200 m buffer from coastline as a coastal area for comparison. In this case, 25 municipalities are comprised (the cities of Kohtla-Järve and Keila are excluded while they are located further inland) with their 200 m shoreline buffer. According to the Copernicus imperviousness layer 3% of the 200 m wide coastal zone is covered with impervious areas in Estonia. This is significantly less than in the case of the zone defined in the guidance note. The result seems sound while 200 m is generally (but with possibilities for exceptions) the width of the shore building exclusion zone on the seacoast. For comparison, ETD artificial areas cover 11% of the 200 m zone of the coastal 25 municipalities. It should be further analysed (by combining different data sets) why the difference in ETD data and imperviousness data is so large here. It might be the case that the ETD data we used are newer but other reasons should also be investigated in further testing with ancillary data and combined datasets. We did not calculate the areas of the artificial CLC classes in the 200 m zone because of the low possible relevance (the coarseness of the dataset).

[27] https://www.eea.europa.eu/publications/soil-monitoring-in-europe

Similar calculations can be provided for 100 m (as being currently discussed in EUROSTAT task force) and 500 m buffers (as has been done before in Estonia, in the case of marine ecosystem services mapping process).

In conclusion, national average share of artificial areas on the coast varies from 9 to 16% if the whole area of the coastal municipalities is included in the analysis, and from 3 to 11% in the 200 m wide coastal zone.

## Farmland and Forest bird indices

### Introduction

Multi-species indices (MSI) are complex ecological indicators that are used to combine relative abundance estimates of a set of species. The objective of a multi-species index is to summarise the status and trends of the set of species. The choice of species is often motivated by the demand to inform different environmental policies. Farmland bird index (kultuurmaastiku haudelinnustiku indeks) and forest bird index (metsamaastiku haudelinnustiku indeks) are two most widely used multi-species indices that are used to summarise the status of birds that breed in farmlands and forests.

### Methods

Multi-species indices are usually estimated by calculating geometric mean of species relative abundance estimates, known as population indices. Population index is a time-series that presents the abundance of a species, relative to a base year (e.g. abundance in 1984 equals 100%). The indices of other years are expressed as percentage of abundance of base year. Population indices and standard errors are calculated using a tailor-made implementation of loglinear regression models known as TRIM (TRends and Indices for Monitoring) software (Pannekoek and Van Strien, 2005). For estimating multi-species indices and confidence intervals, an algorithm using Monte Carlo simulation is used (Soldaat *et al*. 2017).

Species choice for farmland bird index (**FBI**) is based on 39 species listed in PECBMS species lists (PECBMS, 2024). From the 39 species, 23 of them breed in Estonia and for about 15 species there is sufficient data for estimating population indices. Species choice for forest bird index (**FoBI**) is based on 34 species listed in PECBMS species lists (PECBMS, 2024). From the 34 species, 26 of them breed in Estonia. It should be noted that this list does not include some abundant forest species for Estonia (e.g. willow warbler *Phylloscopus trochilus*). Species list of Estonian forest bird index (**EST-FoBI**) is based on expert choice and includes almost all abundant forest specialists (53 species). In June 2022, the proposal for Nature Restoration Law was introduced by European Commission (DG Environment, 2022). The proposal includes also species lists to assess the status of farmland birds in different member states. For Estonia, this list contains 14 species. This new index is referred as common farmland bird index or in short **LPI** (levinud põllulindude indeks).

### Results

In the calculation of the Estonian FBI, it was possible to use the data of 16 species in 2023 (skylark, meadow pipit, white stork, rook, yellowhammer, common kestrel, barn swallow, red-backed shrike, common linnet, yellow wagtail, tree sparrow, whinchat, turtle dove, common starling, common whitethroat, Northern lapwing), because for 7 species (tawny pipit, ortolan bunting, crested lark, black-tailed godwit, grey partridge, European serin, hoopoe) the common bird monitoring scheme does not receive enough representative data or they have too much variability, which is why the MSI algorithm removes them. Of the 16 species that make up the multi-species index, 6 has declining, 4 stable, and 2 increasing population trends.

In the calculation of the Estonian FoBI, it was possible to use the data of 24 species in 2023 (sparrowhawk, tree pipit, hazel grouse, treecreeper, hawfinch, stock dove, lesser-spotted woodpecker, black woodpecker, pied flycatcher, jay, crested tit, spotted nutcracker, common redstart, chiffchaff, wood warbler, grey-headed woodpecker, willow tit, marsh tit, bullfinch, goldcrest, nuthatch, siskin, green sandpiper, mistle trush), because for 2 species (middle-spotted woodpecker, coal tit) the common bird monitoring scheme does not receive enough representative data or they have too much variability, which is why the MSI algorithm removes them. Of the 24 species that make up the multi-species index, 7 has declining, 9 stable, and 1 increasing population trends. The results are given in Table 3.

**Table 3. Common farmland and forest bird indeces: LPI - the common farmland bird index, FBI (the farmland bird index), FoBI (forest bird index), EST-FoBI (Estonian forest bird index) and their upper and lower confidence levels.**

| Year | LPI | Lower CL LPI | Upper CL LPI | FBI | Lower CL FBI | Upper CL FBI | FoBI | Lower CL FoBI | Upper CL FoBI | EST-FoBI | Lower CL EST-FoBI | Upper CL EST-FoBI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 53.5 | 40.7 | 70.3 | 65.1 | 49.9 | 85.0 | 87.2 | 65.9 | 115.2 | 88.4 | 74.8 | 104.4 |
| 2021 | 60.0 | 45.8 | 78.6 | 72.3 | 55.7 | 93.9 | 81.6 | 61.5 | 108.4 | 84.2 | 71.2 | 99.5 |
| 2022 | 54.3 | 41.2 | 71.7 | 65.6 | 50.2 | 85.8 | 85.9 | 64.3 | 114.5 | 85.0 | 71.0 | 101.8 |
| 2023 | 52.9 | 40.2 | 69.8 | 65.8 | 50.4 | 85.9 | 84.7 | 63.5 | 112.8 | 85.8 | 72.3 | 101.8 |

## References

Directorate-General for Environment. 2022. Proposal for a Nature Restoration Law. https://environment.ec.europa.eu/publications/nature-restoration-law_en

Pannekoek, J., van Strien, A.J., 2005. TRIM 3 manual. TRends and Indices for Monitoring data. Research paper no. 0102. Voorburg, The Netherlands. Available freely at: https://www.cbs.nl/en-gb/society/nature-and-environment/indices-and-trends-trim

Pan-European Common Bird Monitoring Scheme. 2024. What species is habitat classification used for PECBMS data? https://pecbms.info/methods/questions-and-answers/question-4-1

Soldaat, L.L., Pannekoek, J., Verweij, R.J.T., van Turnhout, C.A.M., van Strien, A.J. 2017. A Monte Carlo method to account sampling error in multi-species indicators. Ecological Indicators. 81, 340-347. https://doi.org/10.1016/j.ecolind.2017.05.033

# Forest connectivity

## Data and definitions

Different estimates of forest connectivity are based on data aggregated, integrated, and modelled in the Estonian MAES project, Countrywide Socioeconomic Assessment of Ecosystem Services[28] (ELME2). Major outcomes relevant to the forest connectivity indicator include:

1. A basemap depicting the spatial distribution and extent of ecosystem types.
2. Ecosystem condition maps at different scales.

The base year for these maps is 2022, although some input data may be older. The underlying data for delineating forest ecosystems originates from the Register of Forest Resources (Forest Register) and LiDAR-based canopy height data. These were combined with an updated digital soil map[29] and drainage network to create different ecosystem types. Additionally, multiple map layers were used to exclude forest stands that should no longer be classified as forest ecosystems.[30]

Various forest properties were combined in evaluating the condition of forest ecosystems. These included protection status, data availability, conservation value, continuity of forest land, logging activities, drainage, stand composition, deadwood amount, stand age, and soil type. These attributes were combined to create a hierarchical decision sequence assigning condition classes (A-F) to forest ecosystem types[31].

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[28] https://loodusveeb.ee/en/countrywide-MAES-EE-socioeconomic-terrestrial
[29] Kmoch, A., Kanal, A., Astover, A., Kull, A., Virro, H., Helm, A., Pärtel, M., Ostonen, I., & Uuemaa, E. (2021). EstSoilEH: a high-resolution eco-hydrological modelling parameters dataset for Estonia. Earth System Science Data, 13(1), pp. 83–97.
[30] https://loodusveeb.ee/sites/default/files/inline-files/ELME2_LOPPARUANNE_fin_151123.pdf, p. 27
[31] Ibid, pp. 65–72.

The forest ecosystem, in this analysis, is defined as areas inventoried in the Forest Register. For areas outside the Forest Register, it includes LiDAR-detected regions with a canopy height greater than 5 meters and a minimum area of 0.05 hectares. This includes young stands, undergrowth, and shrubs in inventoried areas.

## Method

The method of calculating forest connectivity was adapted from the European Environment Agency's (EEA) Forest Connectivity in Europe analysis. The indicator measures forest connectivity from 0% (no connectivity) to 100% (full connectivity) within a local neighbourhood area of 10 hectares, calculated as the per-pixel average of local forest area density.[32]

Different versions of the forest connectivity indicator were tested for the pilot area, Ida-Virumaa County, chosen for its variable forest ecosystem and shorter calculation time. Parameters tested included spatial resolution of the data layer, kernel shape and size, and forest condition considered in the connectivity calculation. Main conclusions from testing:

1. Gains from 5-meter resolution compared to 10-meter resolution are insignificant relative to increased computation time.
2. The difference between circular and square kernels is insignificant. There are examples of square[33] and circular[34] kernels in scientific literature. Circular kernels were used for countrywide calculations following the ELME2 methodology.
3. Kernel size affects statistical values and spatial distribution of forest connectivity indicator values. A 1 km radius circular kernel (~314 ha) better describes forest connectivity needs for large mammal movement within green infrastructure.[35]
4. As expected, considering the entire forest ecosystem without factoring in forest condition results in higher average connectivity values compared to calculations considering only forests in good and moderate condition.

For countrywide calculations, a 10-ha circular kernel was used due to its uniform distance from the center point. All terrestrial ecosystems were included in the connectivity calculations. Forest connectivity was classified as low-medium (0-50%), medium-high (51-75%), and high (76-100%). Additionally, the average connectivity value was calculated. Connectivity values depend largely on kernel size, so additional versions were calculated using a 314-ha (1 km radius) circular kernel. Different measures of forest connectivity are presented in Table 4.

[32] https://www.eea.europa.eu/en/analysis/indicators/forest-connectivity-in-europe?activeAccordion=309c5ef9-de09-4759-bc02-802370dfa366
[33] Maes, J., Bruzón, A.G., Barredo, J.I. et al. Accounting for forest condition in Europe based on an international statistical standard. Nat Commun 14, 3723 (2023). https://doi.org/10.1038/s41467-023-39434-0
[34] Belote, R.T., Barnett, K., Zeller, K. *et al.* Examining local and regional ecological connectivity throughout North America. *Landsc Ecol* **37**, 2977–2990 (2022). https://doi.org/10.1007/s10980-022-01530-9
[35] https://keskkonnaportaal.ee/et/rohevorgustik-uldplaneeringute-analuus-ja-planeerimise-juhend

**Table 4. Distribution and average forest connectivity across the country depend on forest condition and scale used in the calculation.**

| Forest ecosystem condition considered in the calculation | 10 ha circular neighbourhood | | | |
|---|---|---|---|---|
| | Low-medium (0-50%) | Medium-High (51-75%) | High (76-100%) | Average forest connectivity across the country |
| Connectivity of forests in good condition | 85% | 9% | 6% | 21% |
| Connectivity of forests in good and moderate condition | 33% | 30% | 37% | 62% |
| Connectivity of the entire forest ecosystem | 7% | 15% | 78% | 87% |
| **Forest ecosystem condition considered in the calculation** | **314 ha circular neighbourhood** | | | |
| | **Low-medium (0-50%)** | **Medium-High (51-75%)** | **High (76-100%)** | **Average forest connectivity across the country** |
| Connectivity of forests in good condition | 95% | 4% | 1% | 17% |
| Connectivity of forests in good and moderate condition | 44% | 43% | 13% | 52% |
| Connectivity of the entire forest ecosystem | 16% | 31% | 53% | 73% |

Forest connectivity values depend strongly on the kernel's size (neighbourhood used in calculations), the definition of ecologically connected forests, and the level of connectivity considered good. Generally, the forest connectivity index is higher at finer scales and when considering the entire forest ecosystem.

Different scales and definitions of ecologically connected forests serve various objectives. Finer scales highlight small forest patches as stepping stones, while coarser scales emphasize intact and edge forests, viewing stepping stones as less connected. The different definitions of ecologically connected forests in this analysis are useful for highlighting either all forests (including human-impacted) or more natural forests in better ecological condition.

Countrywide figures for different parameters are presented at the end of this document.

## Data availability and periodicity

The ELME2 ecosystem basemap and condition maps are scheduled for an update next year for the base year 2024. This means ecosystem maps will be available for the base years 2019, 2022, and 2024, though the 2019 maps are not directly comparable to later editions. The exact future data update interval has not yet been determined.

## Discussion

In the future, it is possible to compare forest connectivity calculated from different datasets. These datasets include the Estonian Topographic Database[36] (ETD), Statistics Estonia's Ecosystem Extent by Ownership Category and Ecosystem Type Map[37], and future projects combining ETD, the National Forest Inventory (NFI), the Forest Register, LiDAR, and other remote sensing data. The ELME2 methodology has already combined the Forest Register, LiDAR, and, to a lesser extent, ETD in assessing forest ecosystems.

Defining forest extent, spatial distribution, and forest ecosystem condition is crucial. Forest ecosystems can be assessed from various aspects and evaluated differently. Condition assessments could focus on ecological health or the provision of services such as water, food, wood, and other materials. Forest connectivity values depend on both spatial definition and forest ecosystem condition. ELME2 has evaluated the condition of the main natural terrestrial ecosystems, which is a significant advantage compared to other datasets.

It is possible to combine different scales into one aggregated measure of forest connectivity. If the focus is on the connectivity of specific forest patches, the average connectivity can be calculated for patches of interest.[38]

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[36] https://geoportaal.maaamet.ee/eng/spatial-data/estonian-topographic-database-p305.html
[37] https://www.stat.ee/en/find-statistics/methodology-and-quality/esms-metadata/10305
[38] https://ies-ows.jrc.ec.europa.eu/gtb/GTB/psheets/GTB-Fragmentation-FADFOS.pdf

## Related figures by Estonian Environment Agency

**Figure 2. A finer scale highlights stepping stones as important patches for forest connectivity. Not considering forest condition includes more forests or forest land with human activity in the forest connectivity indicator.**

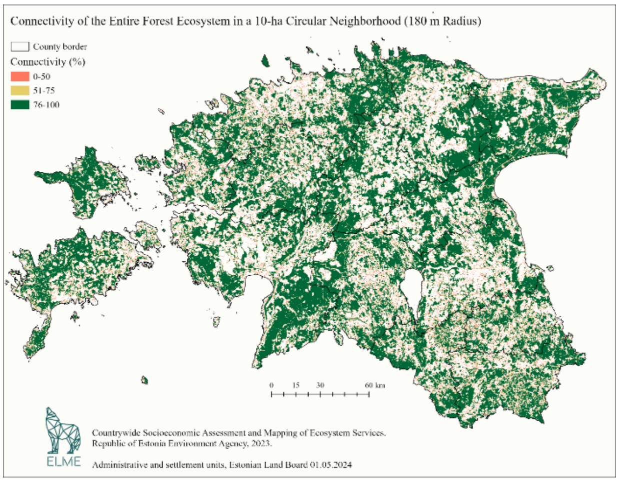



**Figure 3. A coarser scale emphasizes core areas over stepping stones, resulting in a lower countrywide forest connectivity indicator.**

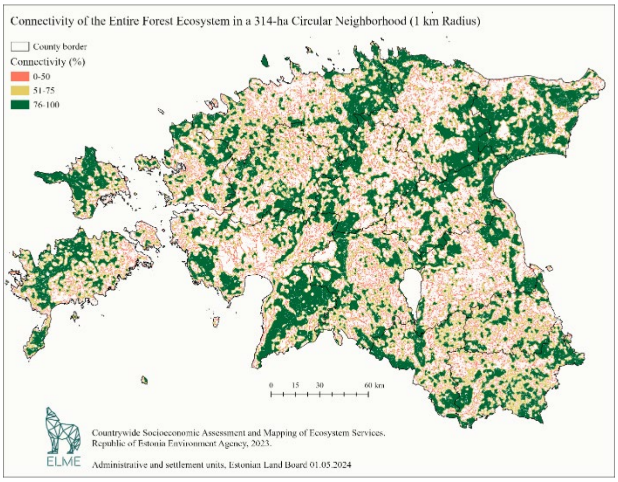



**Figure 4. Considering forests in good and moderate condition results in a more heterogeneous spatial distribution of forest connectivity values. Low connectivity areas are fragmented with high connectivity areas. This approach yields a more lenient connectivity measure compared to considering only forests in good condition. Moderate condition forests are important for habitat connectivity.**

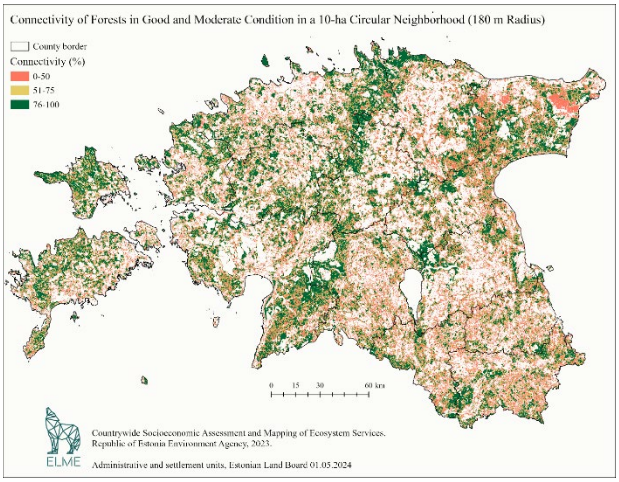



**Figure 5. More edge forests and fewer core areas are apparent compared to map calculated using entire forest ecosystem.**

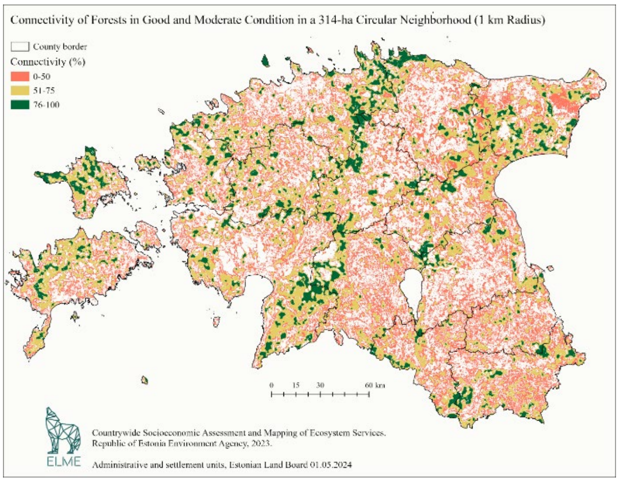


**Figure 6. Overall, there are few intact areas with forests in good or very good condition (A or B). Forest patches are fragmented, and connectivity is mostly below 50%.**

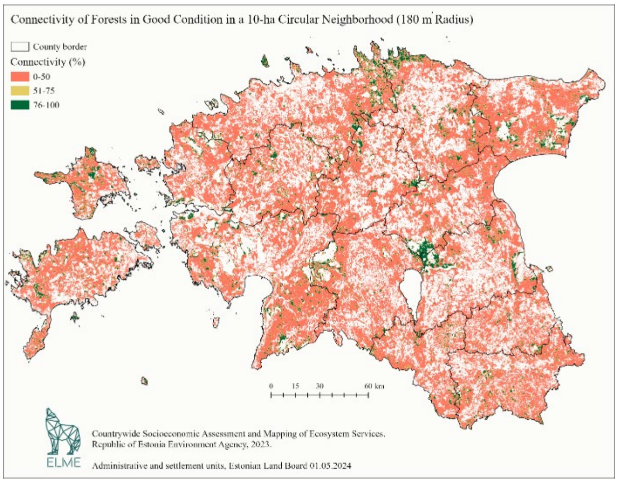
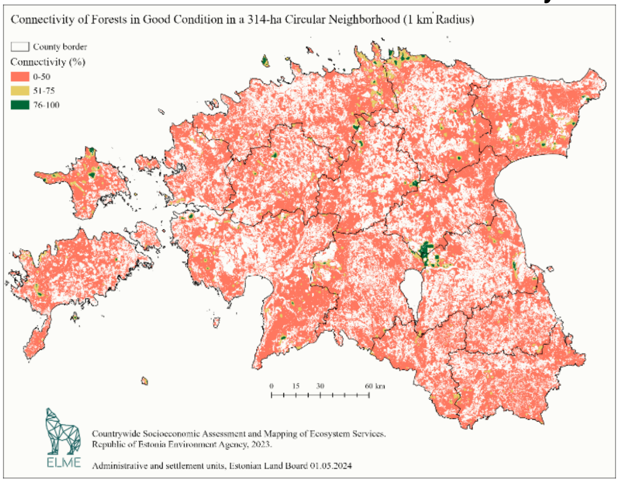



**Figure 7. A coarser scale emphasizes core forests in good or very good condition and edge forests, which are more affected by human activity or fragmented by other ecosystems.**



# Grassland butterfly index

## Introduction

Multi-species indices (MSI) are complex ecological indicators that are used to combine relative abundance estimates of a set of species. The objective of a multi-species index is to summarise the status and trends of the set of species. The choice of species is often motivated by the demand to inform different environmental policies. In the European Union, pollinators have dramatically declined in recent decades, including grassland butterflies. EU grassland butterfly index is one of the EU-level prototypes that summarises the status on butterfly assemblages of grasslands. In the directive of nature restoration (Council of the European Union, 2024), member states are obliged to achieve an increasing trend in national level for several indicators that indicate the diversity of agricultural ecosystems. One of these indicators is the grassland butterfly index. Within this work, we explored possibilities to produce a prototype indicator for grassland butterflies of Estonia.

## Methods

Multi-species indices are usually estimated by calculating geometric mean of species relative abundance estimates, known as population indices. Population index is a time-series that presents the abundance of a species, relative to a base year (e.g. abundance in 2004 equals 100%). The indices of other years are expressed as percentage of abundance of base year. Population indices and standard errors are calculated using a tailor-made implementation of loglinear regression models known as TRIM (TRends and Indices for Monitoring) software (Pannekoek and Van Strien, 2005). For estimating multi-species indices and confidence intervals, an algorithm using Monte Carlo simulation is used (Soldaat *et al*. 2017).

Species choice for grassland butterfly index (RPlibI) is based on 10 species which 5 are listed in EU grassland butterfly index species list (European Environment Agency, 2024). Additional 4 species were included to improve the representativity of common grassland butterflies in the assemblage.

## Results

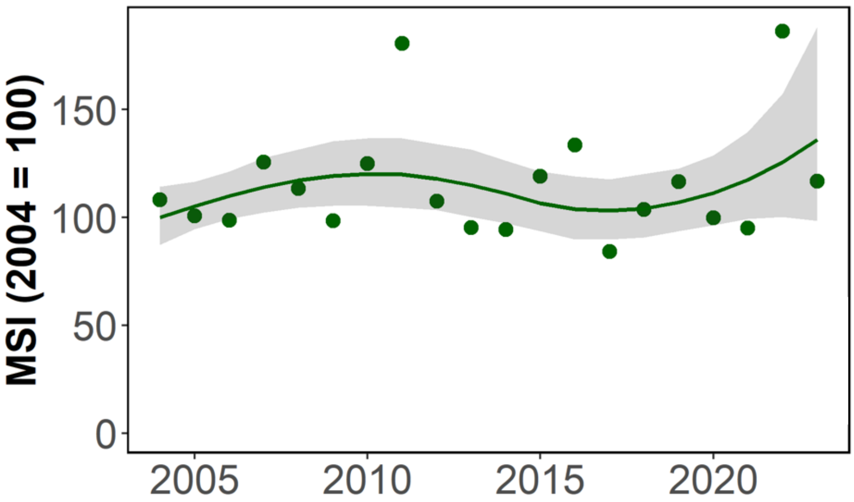
In the calculation of the Estonian indicator, it was possible to use the data of 9 species in 2023, for 1 species, the butterfly monitoring scheme does not receive enough representative data or there is too much variability, which is why the MSI algorithm removed it. Of the 9 species that make up the multi-species index, 1 has declining, 6 stable, and 1 increasing population trends. Overall population trend in grassland butterfly index was estimated as stable (+0.4%/year). The results are given in Table 5.

Several issues were identified with the sampling and monitoring intervals, which give concerns that the indicator lacks representativity in national level. Since year 2000, annual monitoring at sites was replaced with interval monitoring. This likely causes uncertainty in population models and index estimates of species. The second major concern is the spatial arrangement of the sampling sites. The sampling sites originate mostly from the beginning (2004) of the monitoring and are probably a choice that was motivated by the home range of monitoring experts. To conclude the findings, we point out that to produce a reliable and representative indicator, a completely new network of sampling sites is required.

**Table 5. Grassland butterfly index (RPlibl) and their upper and lower confidence levels.**

| year | RPlibl | lower_CL_ RPlibl | upper_CL_ RPlibl |
|---|---|---|---|
| 2020 | 99.68 | 62.9 | 157.98 |
| 2021 | 94.95 | 64.72 | 139.3 |
| 2022 | 186.35 | 123.26 | 281.72 |
| 2023 | 116.79 | 73.39 | 185.84 |

**Figure 8. Grassland butterfly index: Anthocharis cardamines, Aphantopus hyperantus, Coenonympha glycerion, Lycaena phlaeas, Lycaena tityrus, Lycaena virgaureae, Maniola jurtina, Ochlodes sylvanus, Thymelicus lineola. The gray area in the figure represents the 95% confidence intervals.**

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Pannekoek, J., van Strien, A.J., 2005. TRIM 3 manual. TRends and Indices for Monitoring data. Research paper no. 0102. Voorburg, The Netherlands. Available freely at: https://www.cbs.nl/en-gb/society/nature-and-environment/indices-and-trends-trim

Soldaat, L.L., Pannekoek, J., Verweij, R.J.T., van Turnhout, C.A.M., van Strien, A.J. 2017. A Monte Carlo method to account sampling error in multi-species indicators. Ecological Indicators. 81, 340-347. https://doi.org/10.1016/j.ecolind.2017.05.033

# Wetlands influenced by drainage

## Introduction

Changing the hydrological regime, i.e., mainly draining is the most important pressure affecting the state and hence the provision of the essential ecosystem services (incl. climate regulation) of terrestrial wetlands.

Therefore, the following indicators are proposed as suitable to describe the condition of the terrestrial wetlands:

- the area of wetlands affected by drainage (ha),
- the proportion of wetlands affected by drainage (% of the total area of wetlands).

## Methodological background, definitions, and data

To give an insight to the possible approach, the methodology used in the national MAES project ELME[39] is introduced.

In ELME, when assessing and mapping the condition of ecosystems, the main criterion for terrestrial wetlands was the distance to the nearest drainage system.

The following distance zones were used:

- wetlands in natural state – nearest drainage >250 m (condition class 'A' in ELME);
- wetlands slightly influenced by drainage – nearest drainage 100–250 m (condition class 'B');
- wetlands influenced by drainage – nearest drainage <100 m (condition class 'C');
- intensively managed or intensively drained wetlands, wetlands with functioning drainage network, peat extraction sites, cut-over peatlands, residual bogs (condition classes 'D' and 'E').

The widths of the zones are based on the scientific research, including Kull (2016) and Paal *et al*. (2016).

In this case, terrestrial wetland ecosystems comprise mires that are actively accumulating peat and having thickness of the soil surface organic layer greater than 30 cm, but also other peatlands that are no longer accumulating and do not support the principal peat forming plants (e.g. *Sphagnum* spp.), including former and current peat extraction sites.

The map layer of the wetlands was created by aggregating the data from the Estonian 1:10 000 digital soil map (data source: Estonian Land Board, adaptations by University of Tartu and Centre of Estonian Rural Research and Knowledge), Estonian Topographic Database (Estonian Land Board), LiDAR-based canopy height model (raw data: Estonian Land Board, adapted by ELME team), Estonian Nature Infosystem (Estonian Environment Agency), Estonian mires inventory data (Estonian Fund for Nature), and data layers of residual bogs (data from State Forest Management Centre, Estonian Fund for Nature, University of Tartu). Then, grasslands, agricultural ecosystems, and forests were excluded from the wetland layer during the overlay analysis of consolidating all ecosystems into one base map, using the corresponding relevant data layers. Drainage network data was gained from the Estonian Topographic Database (Estonian Land Board) and the melioration infosystem (data source: Agriculture and Food Board). The base year of compiling the base map and the condition map was 2022, although some input data may be older. More methodological details are given in ELME report (Helm *et al.* 2023).

## Results and discussion

According to ELME, 53% (139 836 ha) of the wetlands are in natural state in Estonia. The rest are more or less affected by drainage. 17% (43 688 ha) are slightly influenced, 13% (34 509 ha) are impacted by drainage that is closer than 100 m, and 17% (43 228 ha) are strongly affected wetlands. 1% of the wetlands has no data on their condition.

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[39] „Establishment of tools for integrating socioeconomic and climate change data into assessing and forecasting biodiversity status, and ensuring data availability", https://loodusveeb.ee/en/countrywide-MAES-EE

**Table 6. Wetlands influenced by drainage, area and share from the total area of wetlands**

| | Area (ha) | Share (%) |
|---|---|---|
| Wetlands influenced by drainage | 121425 | 47 |
| Wetlands slightly influenced by drainage | 43 688 | 17 |
| Wetlands influenced by drainage | 34 509 | 13 |
| Wetlands strongly influenced by drainage | 43 228 | 17 |
| Wetlands not influenced by drainage | 139 836 | 53 |

According to the International Peatland Society[40], about 84% of the world's peatlands are considered to be in natural or near-natural state. Drained peatlands make up about 16% of the world's peatlands, or 0.5% of the Earth's terrestrial surface. For comparison, according to ELME, if the classes 'A'–'C' are summed, the proportions are similar – Estonian wetlands that are in natural state or are affected but not having the drainage system right on site, comprise 83% of the terrestrial wetland area.

More research might be needed to determine how to classify transitional communities, especially the transitions between forest ecosystems and wetlands – from treeless to wooded to forested peatlands. An agreement should also be reached regarding the thickness of the organic layer and the content of organic matter to define organic soils and hence peatlands. The present distribution of organic soils needs to be mapped and the real status in (former) peat extraction sites should be specified.

## Data availability and periodicity

All used input data are freely available and mostly systematically updated. In the next years, updating the soil map, being the main data source in this case, upgrading the infosystems of the drainage networks, and consolidating different data sources is foreseen.

The calculations are based on the ELME map layers that are available here: https://arcg.is/WuW9

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[40] What are peatlands? - International Peatland Society

## Other condition indicators

Additional ecosystem condition indicators of national interest were:

For cropland:

- Share of croplands with high diversity landscape features (%),
- Share of organic farming (%)

For grassland:

- The area of maintained heritage meadows (ha),

For forest and woodland:

- Standing and lying deadwood ($m^3$/ha)

Existing requirements of other environmental data reporting frameworks were considered in several cases when stakeholders were proposing additional condition indicators. Therefore the remaining indicators were obtained from existing databases, via simple query to data holders or calculated in-house.

### Share of croplands with high diversity landscape features

In 2023 a support scheme for croplands for the preservation of ecosystem services[41] was implemented. The support scheme is intended to support diverse agricultural landscapes, the preservation of landscape elements, and natural areas with the aim of ensuring natural enemies of agricultural pests (ecosystem service) in cropland. The support is provided for agricultural land that is covered by at least 60% or at least 90% of landscape elements and natural areas that enable ecosystem services. The owner of the data is The Agricultural Registers and Information Board (ARIB). Per query to ARIB the data was obtained and it is currently available for year 2023. The results are presented in Table 7.

**Table 7. Cropland covered by landscape elements and natural areas that enable ecosystem services, 2023**

| | Area (ha) | Share (%) |
|---|---|---|
| Cropland covered by at least 60% of landscape elements and natural areas that enable ecosystem services | 65 666.85 | 6.7 |
| Cropland covered by at least 90% of landscape elements and natural areas that enable ecosystem services | 17 072.32 | 1.7 |

### Share of organic farming

Agricultural statistics of Statistics Estonia collects and publishes data on area and production of organic crops (PM071)[42] and agricultural land and crops by county (PM0281)[43]. Using the data, the share of the utilised agricultural area converted and under conversion to organic farming from the total area under cultivation was found. The results are presented in Table 8.

[41] https://www.pria.ee/toetused/OST-2024#baasnouded
[42] PM071: Area and production of organic crops
https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__taimekasvatussaaduste-tootmine/PM071
[43] PM0281: Agricultural land and crops by county
https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__taimekasvatussaaduste-tootmine/PM0281

**Table 8. Cropland covered by landscape elements and natural areas that enable ecosystem services, 2022**

| | Fully converted and under conversion to organic farming (ha) | Total area under cultivation (ha) | Share of total area (%) |
|---|---|---|---|
| Utilised Agricultural Area | 231.0 | 986.2 | 23.4 |
| Arable land | 135.8 | 707.3 | 19.2 |
| Permanent grassland | 92.8 | 274.3 | 33.8 |
| Permanent crops | 2.5 | 4.6 | 54.6 |

### The area of maintained heritage meadows

Heritage meadows, including semi-natural biotic communities or heritage communities, are grasslands traditionally used as pastures or meadows. These meadows are crucial for open landscapes, serving as biodiversity guardians. They offer habitat and feeding grounds for many rare species of fungi, animals, and plants, thereby preserving the biodiversity of agricultural land and enhancing landscape diversity.

The heritage meadows that are mainly common in Estonia are alvars, grasslands on mineral soil, floodplains, swampy meadows, wooded meadows, wooded pastures and coastal meadows. In order to increase the area of heritage meadows and preserve the diversity of species and traditional landscape characteristic of Estonia, the state supports the restoration and maintenance of semi-natural biotic communities. The Land Maintenance Bureau of the Environmental Board handles the processes of restoration and maintenance of heritage meadows and keeps the data on areas under support for maintenance and eligible for the support[44]. Per query to Environmental Board the data was obtained and the results are presented in Table 9.

**Table 9.** Area of maintained semi-natural grasslands (ha)

| Year | Area of maintained semi-natural grasslands (ha) |
|---|---|
| 2018 | 33 800 |
| 2019 | 35 600 |
| 2020 | 37 900 |
| 2021 | 39 500 |
| 2022 | 40 000 |
| 2023 | 40 600 |
| 2024 | 41 600 |

### Standing and lying deadwood

Standing and lying deadwood are categories within the total deadwood reported as mandatory indicator in condition account. The estimates of deadwood volume are based on data measured in the process of the National Forest Inventory (NFI) conducted by Estonian Environment Agency. Data was obtained via query from Estonian Environment Agency but is also available online from information board for National Forest Inventory.[45]

The stock for lying dead wood was 9.3 $m^3$/ha and stock for standing deadwood was 6.5 $m^3$/ha in 2022. The total stock of lying dead wood was 21 537.5 thousand $m^3$ and the total stock of standing dead wood was 15 087 thousand $m^3$.

[44] Maintenance of heritage meadows https://www.keskkonnaamet.ee/en/wildlife-nature-protection/nature-protection/maintenance-heritage-meadows
[45] https://tableau.envir.ee/views/SMI/8Enamuspuuliigiti?%3Aembed=y&%3Aiid=1&%3AisGuestRedirectFromVizportal=y

# ANNEX 1.

Kick Off seminar on the development of ecosystem accounts

October 4, 2023, Statistics Estonia

Summary

Teams meeting

Participants:

Kaia Oras, Kätlin Aun, Grete Luukas, Helen Saarmets, Argo Ronk (Statistics Estonia); Peep Siim, Madli Linder, Krisela Uussaar, Timo Torp (Estonian Environment Agency); Kadri Möller, Hedy Eeriksoo, Maris Arro, Mart Kiis, Eda Andresmaa, Kristi Loit, Ann Riisenberg, Heidi Koger, Mikk Toim (Ministry of Climate); Iiri Raa, Tiina Köster (The Centre of Estonian Rural Research and Knowledge); Karel Lember (Ministry of Economic Affairs and Communications); Nele Väits, Anne Martin (Ministry of Finance); Kadri Kask, Andres Levald, Kristi Grišakov (Ministry of Regional Affairs and Agriculture); Üllas Ehrlich (Tallinn University of Technology)

1. Introduction: Ecosystem Accounting

Kaia Oras gave a brief overview of the framework of the ecosystem accounting beginning with UN SEEA to the current state of the new proposed module of ecosystem accounting of regulation EU 691/2011. The detailed reporting requirements are now and in the coming years being discussed in the EU with the aim that the first data transmission is in 2026 on the account for year 2024.

2. Work done on ecosystem extent, condition and services (physical and financial) accounts to date

Kätlin Aun gave a brief overview that from 2018 to 2023 Statistics Estonia has worked on three grant projects to develop ecosystem accounts. The accounts consist of three major parts: ecosystem extent and the matrix of changes in the area of ecosystem types, ecosystem condition account, supply and use table of services in physical and monetary terms. The focus of the last grant work (2021-2013 July) was set by the proposed module of ecosystem accounting of regulation EU 691/2011 and therefore EU ecosystem typology, accounting for condition indicators (green areas, concentration of particulate matter, soil organic carbon stock in topsoil, common farmland bird index, dead wood, tree cover density, the share of artificial impervious area cover) and ecosystem services (crop production, crop pollination, wood production, air filtration, global climate regulation, local climate regulation, nature-based tourism services) proposed in the module were tested.

3. Plan of further activities

Regarding the beginning of grant work 101113157 — 2022-EE-EGD, it is expected to include the interests of local stakeholders regarding additional/voluntary condition indicators and more detailed aspects for ecosystem services. The main tasks include compiling accounts (extent, condition, services) for the new period and contributing to Eurostat Task Force of ecosystem accounts. In case of extent, marine areas are expected to be defined and mapped. In case of ecosystem services, the methodology for local climate regulation is still being developed.

A list of proposals made by Estonia in 2022 for consideration to the proposal of the module of ecosystem accounting of regulation EU 691/2011 but which were not included in the final document was introduced.

4. The need for collaborative discussion and primary input on the selection of indicators

The list of primary additional condition indicators and services was shared with the local shareholders to set the focus for additional tasks. It is encouraged to add new items in the list. The feedback on the importance of the proposed indicator, the reason and available data was asked for 13.10.2023.

Next seminar is on 8.11.2023. The results of feedback will be presented.

Questions:

- Ann Riisenberg asked which registry is the basis for crop and grasslands. In different registries cropland and grasslands are defined differently, therefore further insight would be useful. Kadri Kask, Iiri Raa joined in the discussion as they are beginning to assess high value grasslands.

STAT: Croplands come from PRIA and ETAK. Grasslands come from several registries: NATURA, ELF, PRIA, grasslands under support, ETAK. Comparison of definitions was not done therefore it was agreed that another meeting on the topic would be useful to compare the crosswalk tables and make the accounts coherent.

- Kadri Kask asked which are the landscape features on croplands. METK compiled biocontrol service map which includes landscape features in spring 2023 and high value grasslands in autumn 2023. ELME assessed the condition of croplands based on landscape features.

STAT: Linear landscape features of croplands are considered as one of the voluntary condition indicators but there is no methodology yet. This can be another topic to be discussed further.

- Kadri Möller asked whether methodology and data for compiling ecosystem accounts are set centrally as is the case with Nature Restoration Law or member states can apply their own data and methodology.

STAT: Methodology and definitions are developed by Eurostat but member states can improve it where possible. The methodology for voluntary condition indicators is not yet agreed upon.

Feedback and additional comments (16.10.2023):

- It is important that for similar indicators used by different EU legislation, data is collected based on the same methodology.
- It is hoped that the agreement on the trilogies of the Nature Restoration Regulation would be reached already in November.
- Indicators can be based on the mandate of the EU Council, which is available at https://www.consilium.europa.eu/media/65128/st10867-en23.pdf

- Additional information and discussion were asked about environmental subsidies of common agricultural policy (ÜPP keskkonnatoetused), which were listed in Appendix 3as voluntary services to be evaluated. At the meeting on November 8, it could be explained why these measures should be evaluated here separately and what is the benefit to the country. CAP evaluation and reporting is mandatory anyway and is done quite thoroughly. Therefore, the data is probably quite easily available, but does it make sense to add it? And we are waiting for the discussion of the concept of grasslands, it definitely needs to be discussed. There was also a question about the mandatory status indicator "carbon stock in the soil", where is the data for this indicator obtained?

Composed: 25.10.2023 by Statistics Estonia