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Final Report

Methodological report

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Introduction

This methodological report outlines the development work conducted under Activity 3 for the creation of ecosystem accounts. This work is part of the broader initiative on environmental accounts development for 2023-2024, funded by the grant "Agreement no 101113157 — 2022-EE-EGD, Development of the forestry, environmental subsidies, and ecosystem accounts." The report focuses on the methodology used, addresses problematic issues related to ecosystem accounts, and provides an overview of the work done.

At the national level, kickoff meetings were held to set goals and agree on the work to be done. These meetings included main partners in Estonia and colleagues from Statistics Netherlands. During the project, two major methodological seminars were conducted, bringing together stakeholders, statisticians, and scientists in the field of ecosystem accounting.

The goals of the project were successfully achieved, focusing on all main fields of ecosystem accounts: ecosystem extent, condition, and services accounts. The results (compiled accounts) contributed to the production of statistics in line with the planned new module on ecosystem accounts under Regulation 691/2011 on environmental economic accounting. Additionally, the work supported discussions and the compilation of methodological materials within the Eurostat Task Force on ecosystem accounts. The experience gained in Estonia can hopefully help develop logical and cost-effective methods for producing ecosystem accounts in other ESS countries. The refinement of existing methods and testing of new methodologies proposed by Eurostat were also undertaken.

Among the project's achievements, it is noteworthy to mention the expansion and automation of the ecosystem extent account compilation. Several steps in the compilation process were automated, reducing the time needed for future compilations and increasing procedural transparency. Marine areas were also added to the extent account in this round of work.

Eurostat reporting tables on ecosystem accounts were compiled, and issues of concern were listed and analyzed. Several data gaps identified in previous work were filled, such as those related to local climate regulation ecosystem services. Both physical and monetary valuation methods were explored to identify the most suitable approaches for compiling a complete account.

To validate the ecosystem accounts data and monetary valuation, collaboration with key partners in the field was enhanced. The extent compilation principles were compared with the process of creating ecosystem maps from ELME1 assessment[1]. Additionally, the approaches for evaluating and valuing ecosystem services were examined through the ELME2 project[2] ("Nationwide assessment and mapping of the economic value of the benefits (ecosystem services) of Estonian terrestrial ecosystems"). These findings were analyzed and discussed during a methodological seminar. The results are expected to benefit the development of this area of statistics in Estonia. They will contribute to future cooperation; especially as regular reporting is anticipated and the produced statistics will inform management policy decisions. Additionally, these comparisons help ensure data quality. The analyses of differences in the valuation of ecosystem services between ELME and Statistics Estonia reveal the nature of these differences based on values and methods. The main finding was that the results depend on the assumptions made, theoretical framework applied and semantics used.

For meaningful results and improved valuation of ecosystem services, work on the semantics of the ecosystem service account was continued. This included analyzing the semantics of ecosystem service valuation, discussing

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[1] Helm, A., Kull, A., Veromann, E., Remm, L., Villoslada, M., Kikas, T., Aosaar, J., Tullus, T., Prangel, E., Linder, M., Otsus, M., Külm, S., Sepp, K., 2021. Metsa-, soo-, niidu- ja põllumajanduslike ökosüsteemide seisundi ning ökosüsteemiteenuste baastasemete üleriigilise hindamise ja kaardistamise lõpparuanne. ELME projekt. Tellija: Keskkonnaagentuur (riigihange nr 198846). http://loodusveeb.ee/en/countrywide-MAES-EE-condition-and-services-terrestrial

[2] Helm, A., Kull, A., Kiisel, M., Poltimäe, H., Rosenvald, R., Veromann, E., Reitalu, T., Kmoch, A., Virro, H., Mõisja, K., Nurm, H-I., Prangel, E., Vain, K, Sepp, K., Lõhmus, A., Linder, M., Otsus, M., Uuemaa, E. (2023). Eesti maismaaökosüsteemide hüvede (ökosüsteemiteenuste) majandusliku väärtuse üleriigiline hindamine ja kaardistamine. Tehniline lõpparuanne. Riigihange "Maismaaökosüsteemiteenuste üleriigiline rahaline hindamine, sh metoodika väljatöötamine" (viitenumber 235366, Keskkonnaagentuur). Tartu Ülikool. Eesti Maaülikool. ISBN 978-9985-4-1398-2 (pdf)

the principles and methods of valuation using examples of two ecosystem services (crop and wood), and addressing trends across various services. These aspects are outlined in the chapter on valuation.

Statistics Estonia also contributed to the advancement of the SEEA EA (SEEA Ecosystem Accounting) methodology through presentations and participation in various forums, including the Ecosystem Partnership Conference, the UN London Group of Environmental Accounting, and the UNECE/OECD seminar on the implementation of environmental accounting. Additionally, Statistics Estonia contributed to the work of the Eurostat Task Force on ecosystem accounts by providing feedback to developed guidance notes and participating in voluntary testing of compiling ecosystem extent and services reporting tables, including testing the usability of INCA Tool. Presentations on the developed methods were given to Statistics Finland, Czech Statistics, Statistics Ireland, and SITRA. Cooperation with Statistics Netherlands continued during this grant work, bringing together experts from both statistical offices, as well as experts from Wageningen University and Research and Tallinn Technical University.

The supply and use tables for ecosystem services were created for the year 2022. The results of this project (compiled accounts) were made available for analysis by the main users. Publishing the ecosystem extent and services data, along with the methodological report, on a central web platform made the ecosystem accounts data accessible to the public. Additionally, the publication of the results in an interactive web interface serves as a tool for dissemination and for gathering feedback for future improvements.

The decision on the selection of services was made in light of the amendment to Regulation 691/2011, considering those that still required work and aligning with the priorities of the Estonian Ministry of Environment (renamed the Ministry of Climate in 2023). Statistics Estonia tested indicator calculation methodologies, for example, for the flood regulation ecosystem service. Additional condition indicators, which were potential subjects of the Nature Restoration Law, were also considered.

Statistics Estonia has been contributing to the creation of a partner-inclusive system from the perspective of statistics, as a responsible institution for the compilation of official statistics. For optimal results, it was and is essential to continue developing the ecosystem accounts in a coordinated manner.

Ecosystem extent account

Overview[3]

Ecosystem extent accounts are fundamental to ecosystem accounting, serving as the foundation for compiling both ecosystem services and ecosystem condition accounts. Ecosystem extent account was compiled for the year 2022. Compilation of ecosystem extent account was based both on experience and knowledge obtained from previous projects but also closely followed Eurostat guidance note on ecosystem extent accounts (version December 2023).

Compilation of ecosystem extent account was greatly improved compared to previous years, mainly in sense of automatization of some parts of the process (see file D1.5 Description of the automatization process for ecosystem extent account for details) and by applying EU ecosystem typology to classify ecosystem assets consistently. Moreover, we also accounted marine areas which was absent from previous years extent accounts.

The report with the results will be made available on Statistics Estonia web platform.

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[3] 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.

Extent map is presented also in web interface. Interactive maps have evolved into powerful tools for data visualization. In this project, illustrative interactive maps were produced for ecosystem extent and ecosystem services. Two spatial levels were used – local municipalities and 500x500m square grids. More information is given in ANNEX 8.

Compilation of extent account

Our methods for ecosystem extent map compilation follows the proposed principal steps in iterative classification process as suggested by guidance note for ecosystem extent accounts. By defining priority orderings, it ensures that area once classified as such cannot become a something else later in the classification process, which ensures that classification will be mutually exclusive and exhaustive.

For ecosystem extent map, we used largely similar approach as in previous projects where the Estonian topographic database served as a basis for the creation ecosystem extent map. For the first step as part of compilation of ecosystem extent account, we first determined continuous and discontinuous settlement areas (EU level 2 classes) based on guidance note on ecosystem extent accounts. The continuous settlement area type is assigned when settlement structures and transport networks are dominating the surface area. At least 80% of the land surface in the ecosystem asset is covered by impermeable features such as buildings, roads and artificially surfaced areas. The discontinuous settlement area type is assigned when settlement structures and transport networks associated with vegetated areas and bare surfaces are present and occupy significant surfaces in a discontinuous spatial pattern. The impermeable features such as buildings, roads and artificially surfaced areas range from 30 to 80 % land coverage in the ecosystem asset. Therefore, whole Estonia was divided into 1ha grid cells, and we determined the share/cover of impermeable features in every grid cell. As a part of the impermeable features, we regarded: residential or community buildings, buildings under construction, greenhouses, production buildings, other buildings, ruins, production yards, bus stations, pedestrian areas, the runways, traffic areas, parking lots, sport facilities, other roads, light traffic roads, side roads, other national roads, main roads, ramps and connecting roads, the streets and support roads. Data was obtained from the Estonian topographic database. Grid cells that met for the aforementioned criteria were assigned either continuous or discontinuous settlement areas based on percentage of impermeable features cover and were not analysed further.

For the rest of Estonia, we updated basis with additional data layers where more detailed data about ecosystem assets was available. In areas where more detailed information was not available, the Estonian topographic database was only source of information which we could use. Concerning the more detailed data layers, these are both gathered/collected for different purposes and times, which creates inconsistencies in ecosystem boundaries (e.g., overlapping) but also making some records outdated. Therefore, it was questionable what the actual state of these older records is. Therefore, also in current grant we used a decision tree in order decide prioritization of the different data layers when overlaps did occur between two or more detailed data layers. We preferred and therefore gave more weight to data layers which were most up to date (data from year 2022) and likely more precisely mapped due to local inventories. Different data sources reflect their status based on access date (ANNEX 5). Concerning the terrestrial land (including inland water bodies), main different detailed data layers were overlaid as follows (starting with highest priority):

1. Agricultural land and semi-natural habitats (support bases)

Data for agricultural land and semi-natural habitats was obtained from Estonian Agricultural Registers and Information Board. As this was generally most up to date dataset, we were able to use this dataset, and this got the highest priority. In this dataset only the lands which are under support bases are mapped, therefore it is quite certain that this data is both precisely mapped and to some extent verified. Nevertheless, some overlaps between agricultural land and semi-natural habitats still occurred (as owner of the land can receive support from multiple sources and purposes for the same land), in these cases we treated these overlapped areas as semi-natural habitats in order to avoid double counting.

2. Forest registry of Estonia

This was the largest and most detailed dataset that we were able to use. Data we used is within ten years' time frame. This dataset covers most of the forested areas in Estonia (around 80% are mapped). Nevertheless, there were some overlaps within the dataset which we dealt before merging it to other datasets. In case of overlaps we randomly merged overlapped areas to neighbouring polygons within the dataset. For the remaining ca. 20% of forest, based on the soil type, the forest site type was determined or predicted using the national classification (Lõhmus, E. 1984). There are over 30 different forest site types and 71 forest soil types according to the national classification. In case when soil type corresponds to more than one forest site type the latter has been predicted based on the probability of its occurrence. This probability has been found by the model (based on the National Forest Inventory, sample size around 23 thousand plots from years 2005 to 2014). Thus, even if the type predicted for a particular area may not be always accurate, the result for a larger area (whole country) is mostly correct.

3. Wetlands

Data for wetlands was mainly obtained from Estonian Fund for Nature (ELF). This dataset uses Natura 2000 habitat types as classification units and often multiple classes were given for the same area (e.g. transition areas). In order to simplify the original classification, it was therefore decided to use information about the main class/type only. In case of overlaps which were also present, we randomly merged overlapped areas to neighbouring polygons within the dataset.

4. Semi-natural habitats

This dataset consists of spatial information about Estonia's semi-natural habitats which are eligible to support, and it was obtained from Estonian Environment Agency. Similarly, to previous datasets, most of the data is within ten years' time frame and uses Natura 2000 habitat types as classification units. The reason we decided to use this dataset as a fourth layer was because of, although these are the areas which are designated as eligible to support, these do not actually receive support, meaning these areas are likely not being maintained. It is therefore questionable, what is the actual state of these older records. Therefore, we decided that if the area was registered in aforementioned datasets (agricultural land, forest or wetland) then the former information was used. In case of overlaps we randomly merged overlapped areas to neighbouring polygons within the dataset.

5. Natura 2000 habitats

This dataset consists spatial information about Natura 2000 habitats in Estonia (around 10% of area is covered by Natura 2000 habitats in Estonia) and it was obtained from Estonian Environment Agency. Unfortunately, most of the data is older than ten years, although this dataset does receive constant updates and corrections yearly. Due to presence of these older records, we gave this dataset a lower priority in our decision tree. In case of overlaps we randomly merged overlapped areas to neighbouring polygons within the dataset.

6. Meadows

This dataset consists spatial information mainly about Estonia meadows and was obtained from the Estonian Semi-natural Community Conservation Association. This dataset was the oldest we used as all the records are older than ten years. Hence, this dataset consists of inaccuracies and is probably outdated. Due to these reasons, we gave this dataset the lowest priority in our decision tree. In case of overlaps we randomly merged overlapped areas to neighbouring polygons within the dataset.

For marine areas we used spatial data from HELCOM Underwater Biotopes (HELCOM HUB). This habitat classification is a system jointly developed by Baltic Sea countries, enabling the classification of all marine area habitats in both the water column and seabed. The HUB is a hierarchical classification system that covers the entire marine area. This classification system has six different levels, but all marine areas can be classified up to at least level 5 (based on communities). Underwater biotopes in Estonia were linked to EU ecosystem typology at level 3 of marine ecosystems.

In order to increase spatial accuracy of the ecosystem extent map it was decided that some classes: the roads, inland waters, peatlands, quarries, and private yards needed to separately overlay with combined dataset. In case of roads two different types of data was available: 1) polygon type of data (consisting of main roads in Estonia and 2) polyline type of data (consisting of smaller roads and trails). In case of polyline data, a 5-meter buffer was created around polylines to convert polyline to polygon type of data to match with other data sources. Additionally, we also delimited more linear features (artificial areas) which we converted to polygons: forest rides (2-meter buffers were created), ditches (average width per width class was used as buffers), power lines (rated power classes were used as buffers) and railroads. Forest rides and powerlines were distinguished only in forests based on the assumption that these areas in forests are treeless hence influencing ecosystem service flows in forests.

Following guidance note of ecosystem extent account it was chosen 0.1 ha as minimum mapping unit (MMU). Therefore, assets smaller than 0.1 ha were merged with neighbouring assets/polygons and not separated as individual ecosystem asset in extent map. Nevertheless, merging different data layers into one layer creates additional artifacts (sliver polygons, which are often also smaller than MMU) due to fact that different ecosystem assets borders do not coincide with each other perfectly. We separately dealt ecosystem assets which were relatively “narrow” and at the same time relatively long causing sometime remarkable polygon area (sliver polygons). Using polygon buffering tool, we decided to test most of the ecosystem assets based on formula: log (asset area+1) +5 as buffer size to capture change in area relative to ecosystem asset original area. If the change was more than 5% of the original ecosystem asset area the buffered boundaries were kept otherwise original boundaries were used. Captured narrow polygons were then subdivided into 20x20 meters grids and randomly merged to neighbouring polygons within the dataset. For the last step we excluded some assets which by its nature do meet aforementioned criteria in some extent but should not be in principle merged with neighbouring polygons. These were roads, inland waters, peatlands, quarries, private yards, forest rides, ditches, power lines and railroads. For terrestrial land (including inland water bodies), after merging and simplification of different data layers and overlying with Estonian topographic database, we were able to get more detailed information around 80% of ecosystem accounting area. For the remaining 20% of the area, Estonian Topographic Database was the only source of information we could use.

For the year 2022, final ecosystem extent map consisted of ca. 3.2 million polygons covering 130 different mapping units which were then aggregated into EU typology level 2 and level 1 classes. Altogether, area of 70 441 km2 (terrestrial and marine areas combined - whole ecosystem accounting area) was mapped (Figure 1). Marine ecosystems covered most of the ecosystem accounting area (35.5%) followed by Forest and woodlands (33.7%), Cropland (11.8%) and Grassland (6.5%). All other ecosystem types covered less than 5% each from total ecosystem accounting area (Table 1).

Figure 1. Estonian ecosystem extent map for year 2022 (EU typology level 1 classes).

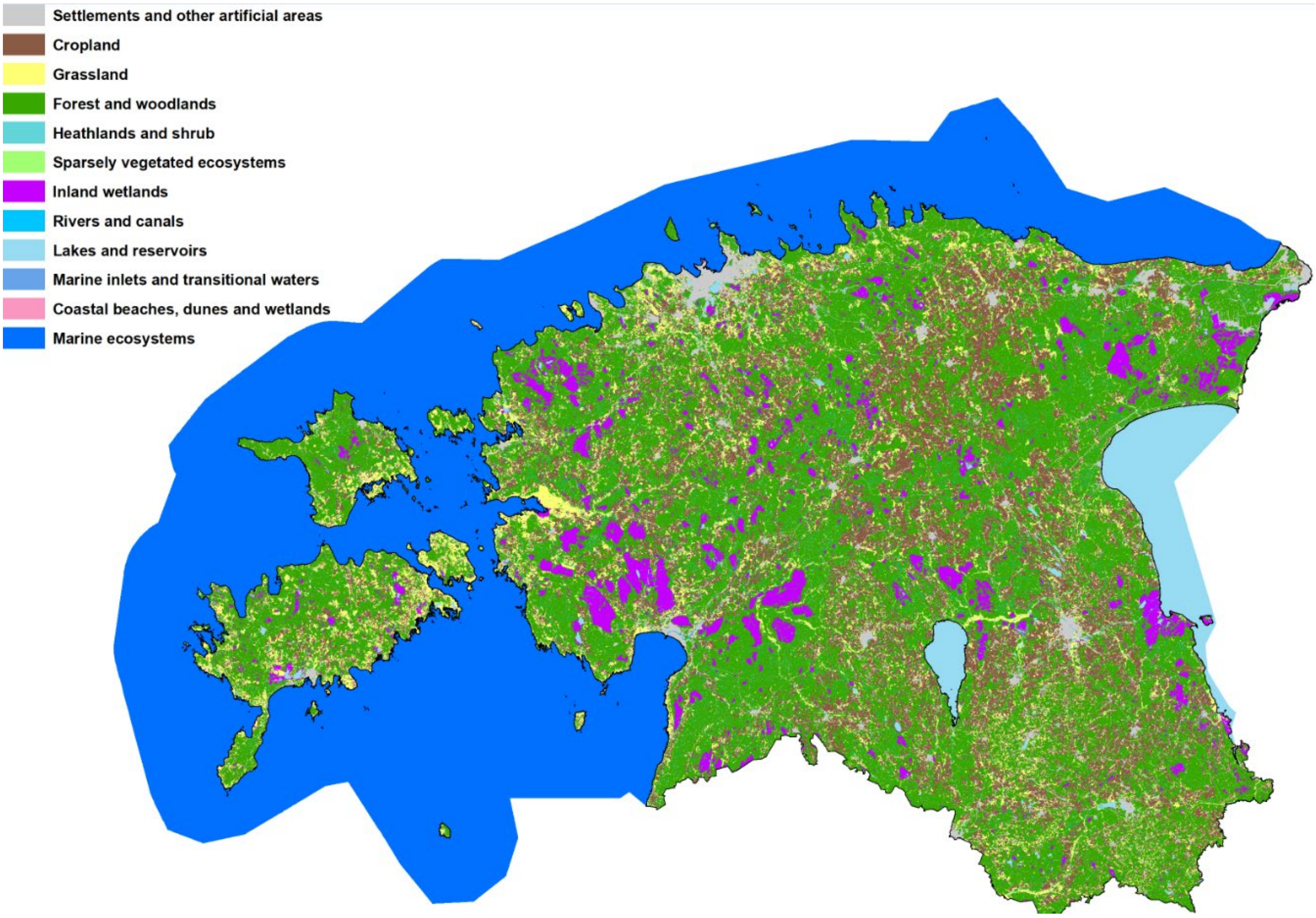

Table 1. EU ecosystem typology, level 1

Category	Name of ecosystem type	Total area (ha)	Share (%)
1.	Settlements and other artificial areas	299 266	4.2
2.	Cropland	834 602	11.8
3.	Grassland (pastures, semi-natural and natural grasslands)	458 056	6.5
4.	Forest and woodland	2 375 514	33.7
5.	Heathland and shrub	13 806	0.2
6.	Sparsely vegetated ecosystems	3 182	0.04
7.	Inland wetlands	276 199	3.92
8.	Rivers and canals	51 321	0.73
9.	Lakes and reservoirs	215 038	3.05
10.	Marine inlets and transitional waters	681	0.01
11.	Coastal beaches, dunes and wetlands	2 809	0.04
12.	Marine ecosystems (coastal waters, shelf and open ocean)	2 513 635	35.68
TOTAL		7 044 116	100

Testing of ecosystem extent account guidance note

As part of Eurostat taskforce on ecosystem accounting, we took part in the testing of ecosystem extent account guidance note, which was followed by metadata collection later on. The test itself took place from December of 2023 till end of April 2024. This was the first data collection for ecosystem accounts and a first step towards implementing the module on ecosystem accounts as part of the planned amendment of Regulation (EU) 691/2011. The objective was to fill in the questionnaire on ecosystem extent and changes matrix using EU ecosystem typology (on level 1 or

2). The results of the test reflected how well the instructions in the guidance note on ecosystem extent accounts can be applied for compiling ecosystem extent and whether ecosystem types defined in EU ecosystem typology are suitable for reporting.

Data from year 2020 as an opening extent which we had compiled in prior years using national datasets and data from 2022 as a closing extent were used for testing. As ecosystem extent had already been compiled in Estonia (for both 2020 and 2022), the main work concerned delineating ecosystem types as how they are defined in EU ecosystem typology for the year 2020.

Previously we had drawbacks on applying EU ecosystem typology on level 2 where we did not have one to one relationship between classes using different classification systems. For example, distinguishing continuous settlement areas and discontinuous settlement areas which needed some extra GIS analyses as these areas were not distinguished as such before. Similarly, class forest and woodlands needed some extra work on level 2 to classify forests into broadleaved, coniferous and mixed forest in Estonia. For this testing we have now overcome these drawbacks. At the time of the testing we still lacked data on marine areas on level 2 EU ecosystem typology but this issue has also been resolved.

Results show that marine ecosystems have the largest area in Estonia followed by forest/woodlands and cropland. This holds true both for year 2020 and 2022. Net change within class was largest in grassland class (which decreased) and smallest in marine ecosystems which basically remained the same (Table 2).

Filling out the ecosystem conversion matrix for different ecosystem types (how and if ecosystem type has changed into another ecosystem type during reference period) was relatively straightforward as reporting was needed on level 1 using EU typology (Table 3). In terms of area (ha), grasslands changed the most, which were converted into croplands (30 613 ha). In the same time 16 169 ha of cropland was also converted into grassland. No changes were detected in marine ecosystems in terms of area.

Table 2. Ecosystem extent accounts using EU ecosystem typology. Different ecosystem type areas in 2020 and 2022 with net changes during reference period

Estonia

Reference year: 2022

(Previous reference year: 2020)

EU ecosystem typology	Opening area (Extent in the previous reference year)	Standard footnotes	Explanatory footnote	Additions	Standard footnotes	Explanatory footnote	Reductions	Standard footnotes	Explanatory footnote	Closing area (Extent in the current reference year)	Standard footnotes	Explanatory footnote	Net changes (additions less reductions; +/-)	Standard footnotes	Explanatory footnote
1.1 Continuous settlement area	13.77		1 Percentage of impermeable	0.3			0.18			13.88		1 Percentage of impermeable	0.12		
1.2 Discontinuous settlement area	99.07		1 Percentage of impermeable	3.86			2.62			100.31		1 Percentage of impermeable	1.24		
1.3 Infrastructure	77.27			10.09			4.2			83.17			5.89		
1.4 Urban greenspace	15.03			0.59			1.54			14.08			-0.95		
1.5 Other artificial areas	86.36		2 Considered mapping units	6.36			8.71			84.02		2 Considered mapping units	-2.35		
1. Settlements and other artificial areas	291.5			21.2			17.25			295.46			3.95		
2.1 Annual cropland	821.13			33.71			23.8			831.04			9.91		
2.2 Rice fields	0			0			0			0			0.00		
2.3 Permanent crops	3.22			0.33			0.39			3.16			-0.06		
2.4 Agro-forestry areas	0			0			0			0			0.00		
2.5 Mixed farmland	3.32			0.34			0.5			3.16			-0.16		
2.6 Other farmland	0			0			0			0			0.00		
2. Cropland	827.67			34.38			24.69			837.36			9.69		
3.1 Sown pastures and grass (modified grasslands)	254.22			18.01			33.84			238.4			-15.83		
3.2 Natural and semi-natural grasslands	225.8			12.74			15.91			222.63			-3.17		
3. Grassland	480.02			30.75			49.75			461.03			-19.00		
4.1 Broadleaved deciduous forest	972.53	E		121.73			64.94			1029.32			56.79		
4.2 Coniferous forests	857.69	E		121.69			59.19			920.19			62.50		
4.3 Broadleaved evergreen forest	0			0			0			0			0.00		
4.4 Mixed forests	558.56	E		34.29			146.79			446.05			-112.50		
4.5 Transitional forest and woodland shrub	0			0			0			0			0.00		
4.6 Plantations	0			0			0			0			0.00		
4. Forest and woodlands	2388.78			277.71			270.92			2395.56			6.79		
5.1 Tundra	0			0			0			0			0.00		
5.2 Scrub and heathland	14.37			1.03			1.54			13.86			-0.51		
5.3 Sclerophyllous vegetation	0			0			0			0			0.00		
5. Heathlands and shrub	14.37			1.03			1.54			13.86			-0.51		
6.1 Bare rocks	0.07			0			0			0.07			0.00		
6.2 Semi-desert, desert and other sparsely vegetated areas	3.13			0.21			0.22			3.12			-0.01		
6.3 Ice sheets, glaciers and perennial snowfields	0			0			0			0			0.00		
6. Sparsely vegetated ecosystems	3.2			0.21			0.22			3.19			-0.01		
7.1 Inland marshes and other wetlands on mineral soil	50.85			2.76			3.31			50.31			-0.55		
7.2 Mires, bogs and fens	227.83			2.45			3.87			226.41			-1.42		
7. Inland wetlands	278.68			5.21			7.18			276.72			-1.97		
8.1 Rivers and streams	10.84			0.23			0.2			10.87			0.03		
8.2 Canals, ditches and drains	17.51			1.98			1.59			17.9			0.39		
8. Rivers and canals	28.35			2.21			1.79			28.77			0.42		
9.1 Lakes and ponds	207.92			0.14			0.14			207.92			0.00		
9.2 Artificial reservoirs	6.98			0.24			0.11			7.12			0.13		
9.3 Geothermal pools and wetlands (Iceland)	0			0			0			0			0.00		
9. Lakes and reservoirs	214.9			0.38			0.25			215.04			0.13		
10.1 Coastal lagoons	0.14			0.29			0.02			0.42			0.27		
10.2 Estuaries and bays	0.19			0.08			0.01			0.27			0.07		
10.3 Intertidal flats	0			0			0			0			0.00		
10. Marine inlets and transitional waters	0.33			0.37			0.03			0.69			0.34		
11.1 Artificial shorelines	0			0			0			0			0.00		
11.2 Coastal dunes, beaches and sandy and muddy shores	2.63			0.35			0.2			2.78			0.15		
11.3 Rocky shores	0.03			0			0			0.03			0.00		
11.4 Coastal saltmarshes and salines	0			0			0			0			0.00		
11. Coastal beaches, dunes and wetlands	2.66			0.35			0.2			2.81			0.15		
12.1 Marine macrophyte habitats															
12.2 Coral reefs															
12.3 Worm reefs															
12.4 Shellfish beds and reefs															
12.5 Subtidal sand beds and mud plains															
12.6 Subtidal rocky substrates															
12.7 Continental and island slopes															
12.8 Deepwater benthic and pelagic ecosystems															
12.9 Deepwater coastal inlets (fjords)															
12.10 Sea ice															
12. Marine ecosystems	2513.17			0			0			2513.17					
TOTAL	7043.63			373.8			373.82			7043.66					

Table 3. Ecosystem type conversion matrix. Ecosystem types areal changes during reference period (2020 and 2022). Changes larger than 10 ha are shown.

Estonia

Reference year: 2022

(Previous reference year: 2020)

		… TO ECOSYSTEM												
		1	2	3	4	5	6	7	8	9	10	11	12	
	FROM ECOSYSTEM…	Settlements and other artificial areas	Cropland	Grassland	Forest and woodland	Heathland and shrub	Sparsely vegetated ecosystems	Inland wetlands	Rivers and canals	Lakes and reservoirs	Marine inlets and transitional waters	Coastal beaches, dunes and wetlands	Marine ecosystems	TOTAL REDUCTIONS
1	Settlements and other artificial areas	@	1183.09	2739.15	3863.5	170.26	62.8	1519.16	396.43	96.82	112.53	96.47	0	10240.21
2	Cropland	3372.66	@	16169.01	3748.18	121.87	0	0	242.22	0	0	0	0	23653.94
3	Grassland (pastures, semi-natural and natural grasslands)	3846.44	30613.35	@	6839.84	417.33	27.62	413.96	283.53	76.27	87.72	164.9	0	42770.96
4	Forest and woodland	5903.17	1294.45	3240.33	@	263.93	65.61	2332.06	1034.14	108.91	0	59.62	0	14302.22
5	Heathland and shrub	204.98	105.9	399.32	741.63	@	0	46.45	0	0	0	0	0	1498.28
6	Sparsely vegetated ecosystems	34.67	0	34.72	80.44	0	@	31.3	0	0	25.82	0	0	206.95
7	Inland wetlands	278.4	25.36	836.14	4994.92	40.63	37.43	@	37.33	40.02	130.59	0	0	6420.82
8	Rivers and canals	437.32	161.11	188.75	678.78	0	0	61.69	@	0	0	0	0	1527.65
9	Lakes and reservoirs	68.22	0	84.21	25.53	0	0	30.93	0	@	0	0	0	208.89
10	Marine inlets and transitional waters	0	0	0	0	0	0	0	0	0	@	0	0	0
11	Coastal beaches, dunes and wetlands	78.79	0	75.62	32.69	0	0	0	0	0	0	@	0	187.1
12	Marine ecosystems (coastal waters, shelf and open ocean)	0	0	0	0	0	0	0	0	0	0	0	@	0
	TOTAL ADDITIONS	14224.65	33383.26	23767.25	21005.51	1014.02	193.46	4435.55	1993.65	322.02	356.66	320.99	0	0

Analyses of the differences between the ecosystem maps developed in Estonia

Analysis between the ecosystem extent map by Statistics Estonia and the ecosystem extent map by Estonian Environment Agency was done during the project. The primary aim was to identify the differences between two maps and understand the underlying causes for these.

Comparisons were made on two different levels: 1) comparison in most detailed map level and 2) comparison on EU typology level 1. As this work is still ongoing, ~92% of total Estonia area was covered by these analyses at the moment.

In most detailed map level, it was found that 87.6% of the total area, both maps were similar and 4.1% of the area there were differences in sense of ecosystem type. Eight percent of Estonia area still needs to be analysed although it could be expected that orders of magnitude will be similar to what was found.

On EU typology level 1, the biggest differences (in sense of area) were between Settlements and artificial area, Forest and Woodland area and inlands wetlands classes. For settlements and artificial area class, causes for differences are due to use of different methodology too determine these areas (continuous, discontinuous areas, infrastructure, urban green, other artificial areas). Area differences in forest and woodland class are multifaceted as in one hand it reflects the incompleteness of national datasets (Forest registry, topographic database) and in other hand the use of different definition of forest (what classifies as forest) between two maps and use of LIDAR data in compiling Environmental Agency ecosystem extent map. Causes of differences in inland wetlands class areas is currently in works, but likely the differences are not that big as initially found.

More details are discussed in ANNEX 3.

Ecosystem services account

Overview[4]

The main objective of the work was to compile ecosystem services account for year 2022 according to the amendment of EU regulation 691/2011 using the approaches described in guidance notes by Eurostat.

According to the amendment of Regulation (EU) 691/2011 the ecosystem services account includes the following services which the supply and use tables shall be reported in the following physical units.

- Crop provision, is defined as the ecosystem contribution to plant growth as approximated by the amount of harvested crops for different uses. This includes food and fibre production, fodder and energy, and grazed biomass, as set out under in Annex III, Table A, Sections 1.1 and Section 1.2.
- Pollination is, defined as the ecosystem contribution by wild pollinators to the production of the crops referred to in the first indent above. The contributions shall be reported in tonnes of pollinator-dependent crops that can be attributed to wild pollinators, by type of crop for the main types of pollinator-dependent crops comprising fruit trees, berries, tomatoes, oilseeds and "'other'".
- Wood provision, is defined as the ecosystem contribution to the growth of trees and other woody biomass, and shall be reported as net increment as defined in Annex VII in over-bark, in thousand m3.

[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

- Air filtration is defined as the ecosystem contribution to filtering air-borne pollutants through the deposition, uptake, fixing and storage of pollutants by ecosystem components (particularly trees). This mitigates the harmful effects of the pollutants. The contributions shall be reported in tonnes of particulate matter abdsorbed.
- Global climate regulation is defined as the ecosystem contribution to reducing concentrations of greenhouse gases in the atmosphere through the removal (net sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. The contributions shall be reported in terms of tonnes of net sequestration of carbon and tonnes of organic carbon stored in terrestrial ecosystems, including above ground and below ground stock.
- Local climate regulation is defined as the ecosystem contribution to regulating ambient atmospheric conditions in urban areas through vegetation that improves the living conditions of people and supports economic production. It shall be expressed and reported as the reduction of temperature in cities, due to the effect of urban vegetation, in degrees Celsius on days exceeding 25 degrees Celsius.
- Nature-based tourism-related services are defined as the ecosystem contribution, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in- situ, physical and experiential interactions with the environment. Those contributions shall be reported in number of overnight stays in hotels, hostels, camping grounds, etc. that can be attributed to visits to ecosystems.

In addition to the listed ecosystem services, a discussion with stakeholders was carried out in the beginning of the project, where topics of natural interest were identified (ANNEX 1). Regarding services account, there was interest in flooding mitigation, therefore it was included in the list of assessed services in the project.

- Flooding mitigation was defined as the area (ha) of ecosystems regulating water flows that protect downstream ecosystems (areas of economic significance, i.e., agricultural land and settlements and artificial areas) from flooding.

Monetary valuation of the ecosystem services was carried out. Based on the new and previous experience, the validation of the input data and monetary assessment methods for ecosystem services valuation was carried out. Regarding analyzing monetary valuation methods, one objective was to find the most suitable method among alternatives. Following chapters provide the results for the services where both physical and monetary valuation methods were tested.

For the estimation of the ecosystem services; Estonian experts’ experience was used in the calculation of services and consultations on methodological approaches. Collaboration with Statistics Netherlands was useful for determining of the methodology and validation of the results. Both national and international experts were consulted in order to integrate the knowledge generated in the area. Expert knowledge was a necessary input for the success of the project on valuation and valuation methods for ecosystem services.

The work on the quality, cooperation with partners, semantics and interpretation of ecosystem valuation methods are presented in the respective subchapters.

Supply and use tables and more detailed distribution by ecosystem types and users is given in Annex “D1.8 Dataset on ecosystem service supply-use.xlsx” (MS EXCEL file) accompanied with metainfo.

The report with the results will be made available on Statistics Estonia web platform.

The supply of services is presented also in web interface. Interactive maps have evolved into powerful tools for data visualization. Technological advances have made data presentation more readable, incorporating analytics and aggregated information. This allows users to compare, analyze, and draw conclusions based on their specific needs and interests. In this project, illustrative interactive maps were produced for ecosystem extent and ecosystem services. Two spatial levels were used – local municipalities and 500x500m square grids. More information is given in ANNEX 8.

Crop provision

According to the amendment of Regulation (EU) 691/2011, the ecosystem service crop provision is defined as the ecosystem contribution to plant growth as approximated by the amount of harvested crops for different uses. This includes food and fibre production, fodder and energy, and grazed biomass, as set out under Annex III, Table A, Section 1.1 and Section 1.2.

For physical valuation, data from MFA (material flow accounts) were used to compile the supply. Data available from agriculture statistics and national geo-spatial data on crop production areas and/or data from national registries of agricultural parcels were used for more detailed analysis.

For monetary valuation, the service was valued with rent price method.

The service is included in both physical and monetary supply and use tables. These tables and more detailed distribution by ecosystem types and users is given in Annex "D1.8 Dataset on ecosystem service supply-use.xlsx" (MS EXCEL file).

Physical account - crop provision

The supply of crop is found by using the amount of harvested crops in the MFA (material flow accounts) breakdown, sections 1.1 and 1.2. In MFA, the amount of harvested crops is recorded under characteristics 'Domestic extraction'. It is suggested in the guidance note for crop provision that when compiling the supply side of crop provision, 'Domestic extraction' of all reporting items of MFA sections 'Crops' (1.1), 'Crop residues' (1.2.1) and 'Fodder crops including biomass harvest from grassland' (1.2.2.1) is to be recorded as a supply from ecosystem type 'Cropland'. 'Domestic extraction' of MFA item 'Grazed biomass' (1.2.2.2) is to be reported as a supply from 'Grassland'. However, grassland ecosystem types include permanent grassland which also contributes to fodder production, therefore it would be more correct to attribute MF.1.2.2.1 Fodder crops (including biomass harvest from grassland) to grasslands than croplands. It is also supported by agriculture statistics (database table PM0821) data where production from permanent pastures and meadows is recorded. The results are presented in Table 1.

The use of the crop provision ecosystem service is to be attributed to intermediate consumption by industries (agriculture activity). The results are presented in Table 2.

Table 1. Supply of crop production, thousand tons, 2022

	Cropland	Grassland	Total supply
MF.1.1 Crops (excluding fodder crops)	2004		2004
MF.1.1.1 Cereals	1529		1529
MF.1.1.2 Roots, tubers	78		78
MF.1.1.3 Sugar crops	0		0
MF.1.1.4 Pulses	123		123
MF.1.1.5 Nuts	0		0
MF.1.1.6 Oil-bearing crops	219		219
MF.1.1.7 Vegetables	46		46
MF.1.1.8 Fruits	9		9
MF.1.1.9 Fibres	0		0
MF.1.1.A Other crops (excluding fodder crops) n.e.c.	0		0
MF.1.2 Crop residues (used), fodder crops and grazed biomass	1642	731	2374
MF.1.2.1 Crop residues (used)	1642		1642
MF.1.2.1.1 Straw	1352		1352
MF.1.2.1.2 Other crop residues (sugar and fodder beet leaves, etc.)	291		291
MF.1.2.2 Fodder crops and grazed biomass		731	731
MF.1.2.2.1 Fodder crops (including biomass harvest from grassland)		392	392
MF.1.2.2.2 Grazed biomass		339	339
TOTAL	3 646	731	4 377

Table 2. Use of crop production, thousand tons, 2022

	Intermediate consumption by industries	Government final consumption	Households final consumption	Gross capital formation	Exports	Total use
MF.1.1 Crops (excluding fodder crops)	2004					2004
MF.1.1.1 Cereals	1529					1529
MF.1.1.2 Roots, tubers	78					78
MF.1.1.3 Sugar crops	0					0
MF.1.1.4 Pulses	123					123
MF.1.1.5 Nuts	0					0
MF.1.1.6 Oil-bearing crops	219					219
MF.1.1.7 Vegetables	46					46
MF.1.1.8 Fruits	9					9
MF.1.1.9 Fibres	0					0
MF.1.1.A Other crops (excluding fodder crops) n.e.c.	0					0
MF.1.2 Crop residues (used), fodder crops and grazed biomass	2374					2374
MF.1.2.1 Crop residues (used)	1642					1642
MF.1.2.1.1 Straw	1352					1352
MF.1.2.1.2 Other crop residues (sugar and fodder beet leaves, etc.)	291					291
MF.1.2.2 Fodder crops and grazed biomass	731					731
MF.1.2.2.1 Fodder crops (including biomass harvest from grassland)	392					392
MF.1.2.2.2 Grazed biomass	339					339
Total	4 377					4 377

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With the aim to also find spatial distribution of crop provision ecosystems service the supply of crops was found by using agricultural statistics, which includes data on area under cultivation (ha), production area(ha), production (tons) and yield (kg(ha) divided by counties.

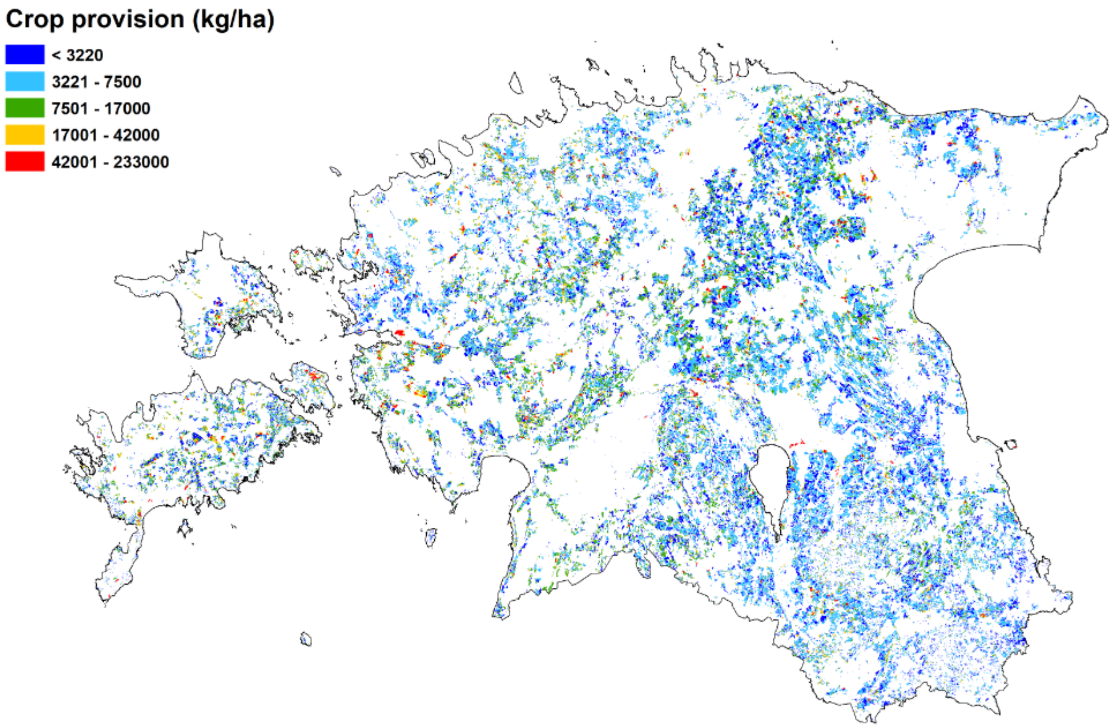
The guidance note denotes that results obtained using the advanced approaches must be aligned with MFA reporting. Data for the items of MFA section 1.1 crops can be cross walked easily. For MFA 1.2 Crop residues (used), fodder crops and grazed biomass conversions are needed:

1. Items of section 1.2.1 ‘Crop residues (used)’ represent residues of certain common crops included in section 1.1. These residues are not reported in crop statistics, but their amounts further used in the economy can be estimated and the MFA handbook suggests methods (pages 42-46).
2. Data for ‘Fodder crops’ are collected in crop statistics in EU standard humidity (i.e. 65%; see Table 3, page 14 in Annual crop statistics Handbook, 2020 edition). They need to be converted to 15% humidity.
3. For 1.2.2.2 ‘Grazed biomass’, the MFA handbook provides methods to estimate these data based on agriculture statistics and suggests conversion parameters (e.g. harvest rate, pasture yield, etc.), if these are not available nationally (see MFA handbook, pages 42-46).

Considering the possibilities of data from Agricultural Registers and Information Board which includes agricultural fields and crops grown in the field, the additional data on crop residues that is included in MFA was not included to the data from agriculture statistics.

In order to distribute crop provision on map, crop yields from agriculture statistics were combined with geospatial field data from Agricultural Registers and Information Board and additional grassland and field units from extent map. Only crops and crazed biomass was mapped (Figure 2).

Figure 2. The ecosystem service provisioning areas (croplands and grasslands) and values of crop provision (excluding crop residues). The areas coloured from blue to red represent service provisioning areas according to the physical unit value kg/ha). Areas coloured white represent areas that do not supply the ecosystem service.



Crop provision – monetary valuation

Rent price was used for monetary valuation of crop production. However there are ongoing discussions which method is the most suitable (ANNEX 6).

Rent is an expenditure user pays to the owner to use the resource. Rent payments can be related to the crop provision supplied by ecosystem as the renter is willing to pay the rent to use the service.

Data for rent price method are rent payments and area under cultivation. Rent price data were available from agricultural statistics but no distinction on land type or county is made. The average rent price of agricultural land in 2022 was 101 EUR/ha (agriculture statistics, PM59). In a separate analysis it was found that semi-natural and natural areas, whereas under agricultural land, contribute little to crop production. These areas are rented by State Forest Management Centre for the purpose of maintenance. The average rent price for semi-natural and natural grasslands, represented here by the area of ecosystem type "Grazing outside of agricultural land", was 13.3 EUR/ha in 2022. The total value of crop production ecosystem service calculated based on rent price of agricultural land was 99.6 million EUR. Table 3. The use of the crop provision ecosystem service is attributed to intermediate consumption by industries (agriculture sector).

Table 3. Monetary value of crop provision by ecosystem type, 2022, million EUR

	Area under cultivation, ha	Rent price, EUR/ha	Value of rent price, mln EUR
Utilised Agricultural Area	986 206	101	99.61
Arable land	707 319	101	71.44
Permanent grassland	274 333	101	27.71
Permanent crops	4 554	101	0.46
Natural and semi-natural grasslands	2 577	13.3	0.03

Discussion on the alternatives for valuation methods considering the differences between arable land, grassland and semi-natural communities

The provision of agricultural production is an ecosystem service where all the major problems and dilemmas in ecosystem service statistics emerge, including the conflict between environmental economics and environmental economic accounting in finding the value (or monetary equivalent) of ecosystem services. In the classification of ecosystem services, crop and fodder provision is a supply service.

The Guidance Note on Accounting for the Crop Provision Ecosystem Service [5] (version February 2023) (hereinafter Guidance Note) suggests to define crop provision as „*the ecosystem contributions to plant growth as approximated by the amount of harvested crops for different uses. This includes food and fibre production, fodder and energy, and grazed biomass*", as set out under Annex III [of Regulation (EU) 691/2011 on European environmental economic accounts.[6]

From a environmental economic accounting point of view, crop provision ES is in a better position compared to many other ecosystem regulating and welfare services, because crop and fodder provision service is expressed in agricultural production (crops and fodder), which can be accounted for in physical units that have a tradable value in the market and therefore a price. In environmental economics, the question of the monetary equivalent of crop provision ES is solved in such a way that the market price of production is taken equal to the monetary equivalent of the ecosystem service. Considering that the price of agricultural production depends largely on the type of crop grown in addition to market demand, environmental economics operates with the average market price of production.

If the goal of finding a monetary equivalent for the crop provision ecosystem service is to compare and choose different land (ecosystem) use scenarios (for example, whether to plant a forest on agricultural land or convert it into residential area), then such an approach is basically suitable.

If, for example, the goal is to compare the alternative scenario of using agricultural land as forest land, then one can compare the value of the entire agricultural production with the market value of wood during the time when the forest reaches its full age (depending on the forest, for example, 50-80 years). Such a comparison shows approximately the income from the land during the considered period. It is not particularly important what the contribution of the ecosystem is to the creation of value and how big the contribution of the economic system is. The fact that both are represented in the service of the agricultural ecosystem is not a problem from the point of view of environmental economics, which often serve as a bases for land use decisions.

From the point of view of agricultural ecosystem services statistics, the matter is more complicated as double counting should be avoided. Agricultural production is viewed as a supply service for agricultural ecosystems, but when it is obtained, the contribution or part of the economic system is very large and important. In order for agricultural production and animal feed to reach the market, all-round economic intervention is needed. The work done to obtain production, such as ploughing, sowing, fertilizing, insect control, weed control, harvesting are all economic activities and are reflected in accounting and also in agricultural statistics.

To overcome the problem, the methods used in environmental economic accounting (for example, resource rent) attribute a small part of the market price of agricultural production to the ecosystem. However, the result is the fact that the ecosystem service value found in this way is no longer suitable for deciding on alternative land use scenarios. If we take as the value of the ecosystem the monetary value of the ecosystem supply service found by the resource rent method, which is a small part of the market price of agricultural production, then the result is that each alternative use of agricultural land makes more economic sense compared to use for agricultural production.

At the same time, the question arises, is the production of agricultural ecosystems in the form of crop and fodder still a provisioning service? Let us compare agricultural ecosystems with another very important and large supply service provided by ecosystems, which is the provision of wood by forest ecosystems. Even in today's intensive forestry, the contribution of the economic system is undoubtedly important, but by no means to the same extent as in the case of agricultural ecosystems. If the agricultural ecosystem is artificial, it means that it is man-made and does not exist naturally, then the forest ecosystem is natural. Although the management system contributes to the increase in

[5] Crop Provision Ecosysten service- Guidance Note. Doc. ENV/EA/TF/2023_1/2
Item 2 of the agenda, Eurostat – Unit E2, 2023

[6] Regulation (EU) 691/2011

forest productivity, the forest is still a natural community that grows wood even without economic input. Thus, there is a fundamental difference between agricultural ecosystems and forest ecosystems. If agricultural ecosystems are more means of production, where economic and ecosystem contributions are intertwined and one cannot do without the other, then the forest ecosystem is independent, to which the economy only contributes.

In 2005 the Millennium Ecosystem Assessment (MA) defined a framework for relating ecosystem services to the larger scientific and policy communities. The MA divided ecosystem services into four understandable categories- supporting services, regulating services, provisioning services and cultural services. The MA delivered a broad definition of ecosystem services as “the benefits humans obtain from ecosystems”[7].

There is no supporting service in the currently used classification of ecosystem services. But looking at the great essential difference between the forest ecosystem and agricultural ecosystems, supporting service would probably be more suitable for the provisioning service of agricultural ecosystems than provisioning service.

But regardless of where we classify the crop and fodder provision of agricultural ecosystems, the question still remains as to which of the currently used methods is the best for finding the value of the provisioning service of agricultural ecosystems. Whereas the "best" criteria are taking into account the contribution of the ecosystem as truthfully as possible and at the same time fitting into the SEEA-EA framework.

In the Statistics Estonia’s report, rent price, resource rent, market price-agriculture, market price-MFA and hybrid methods were used for the financial evaluation of the supply service of agricultural ecosystems.

The rent price method is based on the assumption that the rent of cropland or grassland is attributable to the ecosystem as it is a market-based agreement between the owner and the renter that shows the willingness to pay to use the service Table 1 below provides an overview of the methods used and their ratio to the market price of agricultural production.

The resource rent method is based on data from national accounts. This method is used for calculation of ecosystem service value by subtracting all costs for capital and labor from the total revenue.

Implementation of the market price approach for calculating ecosystem fodder production service value, two different databases were used: (1) agricultural statistics, and (2) material flow accounts. Using the market price method and data from agricultural statistics the value of fodder production ecosystem service was calculated.

The hybrid approach that is a combination of resource rent and market price method was also used. The difference between hybrid method and resource rent is that crop output is calculated using the market price and the variables of resource rent is calculated using the structure of expenditures from the national accounts.

A comparison of the results obtained with different methods regarding fodder as a provisioning service for agricultural ecosystems is presented in table below regarding year 2018 (the year data for analyses were available at the start of the analyses).

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[7] Kumar, P., Wood, M.D. Valuation of Regulating Services of Ecosystems. Methodology and Applications. Routledge, 2010.

Table 4 Values of fodder supply ecosystem service and ecosystem contribution by estimation approaches, million EUR, 2018 and their relative volume[8].

Valuation method	Value of the fodder production service	Value of ecosystem contribution	% of the market price-agriculture	% of the rent price evaluation method
Rent price		26.0	37.2	100
Resource rent		4.7	6.7	18.1
Market price - agriculture	69.8	9.1	13.0	35
Market price - MFA	39.3	5.1	7.3	19.6
Hybrid	69.8	5.3	7.6	20.4

As can be seen from the data presented in the table, the value of ecosystem fodder production obtained by all the methods used, the value of the provisioning service of fodder ecosystems is only a part of the value of fodder production[9]. In the current work, the rent price evaluation method is considered to be the most suitable, because, according to the authors, it reflects the price paid for renting the ecosystem as a means of production and, in addition, it accounts for a larger part (37%) of the market value of the production compared to other methods. In addition, the Dutch researchers have also considered the rent price method to be the most suitable for the evaluation of the provisioning service of agricultural ecosystems. Indeed, the rental price method has advantages compared to the other methods used (and presented in the table). It is not directly related to the price of agricultural production and is relatively separate from the corresponding statistics, the rent is indeed paid for the ecosystem's potential to produce, so the rent price would be an expression of the ecosystem's potential to produce, which can be attributed to the ecosystem one hundred percent.

Despite its many advantages, the rental price method does not address the total value of agricultural ecosystem services.

It is clear that without agricultural ecosystems there would be no agricultural production. Therefore, the aforementioned methods alone, despite their consistency with the principles of statistics, are not suitable for evaluating alternative land use scenarios. In other words, if we convert an agricultural ecosystem into something else (e.g. residential land), we lose 100% of the agricultural production from that land. Consequently, the crop provision financial evaluation methods used in crop statistics are underestimated in the context of comparison of land use scenarios and unsuitable for assessing the real contribution of agricultural ecosystems. It can be said that the agricultural production is not 100% thanks to the agricultural ecosystem, but without the agricultural ecosystem we lose all the production. Of course, the same can be said about the contribution of the economic system.

Thus, it can be said that although treating the price of the entire production as the value of the supply service of agricultural ecosystems is not correct considering the rules of statistics, the alternative method used leads to an underestimation of the real value of the service. A possible solution to the problem is proposed in the latest London Group article [10]: "…it seems that in order to overcome the economic invisibility of ecosystems, the better we can do is to declare the full value of goods, services and assets that depend from ES, and the whole range of values that may emerge disappear or else change in case of ES changes, rather than look for a single, partial, separable, value of ES contribution to economic value".

[8] Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC. Development of environmental accounts
Activity 2. Developing and refining ecosystem accounts D1.8.Description of the methodology for advancing ecosystem accounts, methodology. Methodological report.
[9] Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC chapter 4.2 gives a comprehensive overview of the methods used in the evaluation of the supply service of agricultural ecosystems.
[10] Issue paper: Monetary values connected to ecosystem services. UN London Group on Environmental Accounting, 2024. A. Femia, I. Grammatikopoulou, K. Oras, Ü. Ehrlich, A. Kadulin, S. Schürz, A. Capriolo, M. Udugama.
https://seea.un.org/sites/seea.un.org/files/session_5_issue_paper_connected_values.docx

Such an approach makes it possible to overcome the limitation of the possibilities of existing statistics by considering the total value of ecosystem services and to make statistics usable as a basis for strategic resource and lane use decisions.

There are other services associated with agricultural ecosystems that are viewed as independent ecosystem services. In addition to human input, such services include soil fertility and pollination. If soil is rather classified as a resource, then pollination is undoubtedly a service that has a significant impact on the volume of agricultural production. Without pollination, the yield is significantly reduced, or, in some crops, there is no harvest at all. An important methodological question for such services is whether the total amount of services can exceed what is produced by or using them. In other words, can the sum of the values of other services affecting yield exceed the cost of production? If we recognize these services as an inevitable prerequisite for the ecosystem to be able to provide a supply service, then it is probably possible. This also corresponds to the position expressed in the above LG article.

Both cropland, grassland and semi-natural grassland are ecosystems that provide provisioning services in the form of agricultural production. However, these ecosystems differ largely. While cropland and (arable land) and cultivated grassland are artificial ecosystems created by man with the aim of providing agricultural production and fodder, semi-natural grasslands so called heritage communities which purpose has changed over time. Until the domination of machine production in agriculture, the semi-natural grasslands were the main provider of fodder. Currently, the purpose of semi-natural grasslands has changed and the services it provides are mainly recreational services and habitat services. Semi-natural grasslands also provide animal fodder, but this is more of a by-product of maintaining the community, which occurs during the mowing and grazing of semi-natural grassland. Within the common agricultural policy of the European Union, semi-natural grassland cannot compete with cultivated grassland and its maintenance requires additional financing. Thus, today semi-natural grasslands are primarily ecosystems in need of protection, the purpose of which is not fodder production and their preservation is not guaranteed by the market economy.

The same methods are not well suited for assessing semi-natural grassland ecosystem services as for agricultural ecosystems. Semi-natural grasslands primarily provide habitat services and welfare services, which are non-market services by nature. Therefore, non-market ecosystem services valuation methods, such as the contingent valuation method (CVM) belonging to the group of stated preferences methods, are suitable for the evaluation of these services. In Estonia, there is a decades-long tradition of evaluating the ecosystem services of semi-natural grasslands[11], the contingent valuation method has mainly been used, which shows well the quantifiable welfare impact of semi-natural grassland ecosystems and its monetary equivalent.

For evaluation of ecosystem services in agricultural ecosystems, whose main purpose is to provide production (crops and fodder) the methods, based on real markets and transactions might be more suitable.

Wood provision

According to the amendment of Regulation (EU) 691/2011, the ecosystem service wood provision is defined as the ecosystem contribution to the growth of trees and other woody biomass, shall be reported as net increment as defined in Annex VII in over-bark, in thousand m3. Annex VII references to the forest accounts in the same proposal for the amendment of Regulation (EU) 691/2011 where it defines net increment as follows: “Net annual increment of timber is defined as the average annual volume growth of live trees, calculated from the stock of live trees (growing stock) available at the start of the year less the average annual mortality“. It is noted that wood provision data in ecosystem accounts and forest accounts should be coherent, and the latter could be the input for the previous.

For monetary valuation, the service was valued with stumpage prices calculated over increment and removals (harvested wood). The first is combined better with the physical indicator and was thus included in the final SUT tabele but the latter shows the real flow that enters economy better.

These tables and more detailed distribution by ecosystem types and users is given in Annex “D1.8 Dataset on ecosystem service supply-use.xlsx” (MS EXCEL file).

[11] Ehrlich, Ü. (1999). Ecological Economics of Coastal and Riparian Seminatural Grasslands (A Case Study of Estonia). In: Proceedings of Medcoast 99 - Emecs 99 Joint Conference, Turkey, Antalya. (1163–1174). Ankara: MEDCOAST.

Wood provision – physical account

Data on increment and removals was obtained from Estonian Environment Agency as part of the work on development of forest account, which is also ongoing parallel process. Similarly to forest accounts, a distinction is made between forest available for wood supply (FAWS) and forest not available for wood supply (FNAWS). Data on increment or removals from other land available for wood supply (AWS) or other land not available for wood supply (NAWS) was found not available during the development of forest accounts (Table 5).

To obtain the spatial distribution of increment data, which was approximated by forest stock change, data from the Forest Registry (as of January 2023) was used as primary data source. The increment was found for each forest stand compartment based on a simplified methodology using age, height, normal stand density and site quality class according to the formulas given in Annex 12 "Calculation of the increment of growing stock " in the Regulation of the Minister of the Environment "Forest Survey Guidelines" (RT I, 31.08.2018, 8). In case of forest land, for which data were not available in the register, an average annual increment of growing stock was assigned using the weighted averages of the majority tree species and site type allocations according to the available data in the forest register. Thus, nearly 400 tree species / forest site type groups were formed, the averages of which were generalized to forest areas with incomplete data on the basis of forest site type and main tree species. The output was then combined with ecosystem extent map. The result is shown in Figure 3.

All use of wood provision from FAWS is attributed to 'Intermediate consumption by industries' (forestry activity). The results of the supply and use of wood provision service is presented respectively in Table 6 and Table 7.

Figure 3. Wood provisioning (based on net increment) areas and values. The areas coloured from blue to red represent service provisioning areas according to the physical unit value m3/ha). Areas coloured white represent areas that do not supply the ecosystem service.

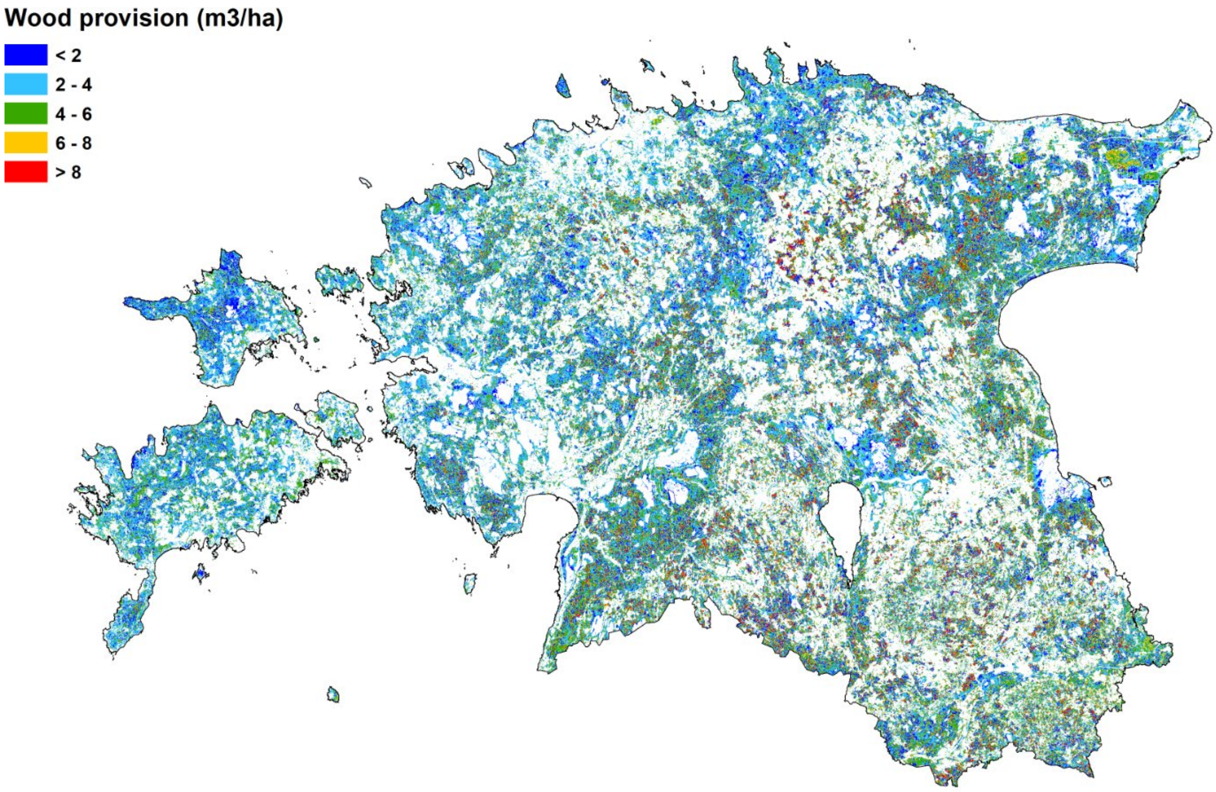

Table 5. Wood increment and removals (harvested wood) in land available for wood supply (AWS, FAWS- forest available for wood supply) and land not available for wood supply (NAWS, FNAWS- forest not available for wood supply), 1000 m3 overbark, 2022

	Total supply
Wood provision - increment in FAWS	8 100
Wood provision - increment in FNAWS	1 100
Wood provision – increment in other land AWS	n.a
Removals from FAWS	12 077
Removals from FNAWS	n.a
Removals from other land NAWS	n.a

Table 6. Wood provision – supply table (1000 m3 overbark), 2022

	Settlements and other artificial areas	Forest and woodland	Total supply
Wood provision - increment in FAWS	11.3	8 088.7	8 100
Wood provision – increment in other land AWS	n.a	n.a	n.a
Removals from FNAWS	n.a	n.a	n.a
Removals from other land NAWS	n.a	n.a	n.a

Table 7. Wood provision – use table (1000 m3 overbark), 2022

	Intermediate consumption by industries	Government final consumption	Households final consumption	Gross capital formation	Exports	Total use
Wood provision (increment in FAWS)	8 100					8 100
Wood provision – increment in other land AWS						
Removals from FNAWS						
Removals from other land NAWS						

Wood provision – monetary valuation

Wood increment and harvested timber is also included in national accounts calculations and is a SNA value. Managed and economically restricted forest lands are taken into account, strictly protected forest is excluded.

Standing timber that is considered under inventories of work- in-progress in national accounts and is part of output value in SNA. According to the methodology used in national accounts to obtain the value of standing timber, first, the net increment has to be calculated from wood increment, and thereafter, multiplied by stumpage prices. The calculations are made for each tree species and timber assortment both for State Forest Management Centre and other owners. First, the total volume lost due to natural death of trees is deducted from wood increment. Therefore, the increment of every tree species is reduced by the share of this approximation from the volume of increment.

In order to calculate monetary value of wood provision service, the stumpage prices were multiplied with the increment or removals (harvested wood). Calculations were done separately for increment and harvested wood but using the same stumpage prices where the increment or harvested wood was divided by timber owner (State Forest Management Centre or other ownership), assortment and stumpage prices by timber species. Data were available for both State Forest Management Centre and other ownership (including also state forests) forests. Stumpage prices are prices that are paid for standing tree for the right to harvest. Stumpage prices are direct market prices and therefore show exchange value.

Intermediate price data were available from State Forest Management Centre. In order to calculate stumpage prices felling costs had to be subtracted from intermediate prices. Felling costs consist average stem volume of harvest (calculated using height and diameter by age and tree species) and average transport distance. Felling costs were available from National Accounts.

The spatial distribution of monetary values of wood provision based on stumpage prices of increment were calculated based on the map and spatial distribution of increment produced during the valuation of the service in biophysical units. The results are presented in Table 8. The total for stumpage prices of removals is provided in the table, but spatial distribution based on ecosystem extent was not found as it is not included in the final supply and use tables.

Table 8. Stumpage prices based on net increment and removals, million EUR, 2022

	Settlements and other artificial areas	Forest and woodland	Total
Stumpage price of net increment	0.72	513.28	514
Stumpage price of removals	n.a	n.a	762

Discussion of the alternatives for the valuation methods for wood provisioning as an ecosystem service.

The Eurostat Guidance Note on Accounting for the Wood provision Ecosystem Service [12] (version February 2023) suggests to define wood provision as "*the ecosystem contributions to the growth of trees and other woody biomass*". The proposed Forest accounts legal module defines net increment as follows: "*Net annual increment of timber is defined as the average annual volume growth of live trees, calculated from the stock of live trees (growing stock) available at the start of the year less the average annual mortality*".

Analyses of the conflict and competition between forest ecosystem wood provisioning service and other services

Wood provisioning service current definition and recommendation treat the forest wood provisioning service as if in isolation, without considering other services. The experts of Statistics Estonia and Tallinn University of Technology have discussed this topic in the UN London Group article[13]. The authors claim that in the case of a forest, an important fact is that the forest ecosystem cannot provide all services simultaneously in equal volumes. Thus, wood, the main provisioning service of the forest ecosystem, competes with regulatory and cultural services. For example, a forest that has undergone clear-cutting no longer has the biological characteristics of a forest ecosystem and cannot provide the regulatory and cultural services typical of a forest ecosystem. The fact that the wood supply service does not occur in isolation from other forest ecosystem services, and often reduces the ability to provide other services, makes accounting for forest ecosystem services more complex. According to the proposal of the Guidance Note, the annual growth of wood is recommended as a mandatory indicator in European context for accounting for wood, the main supply service of the forest ecosystem. The main drawback of the proposed headline indicator is that the growth of wood (in other words, the increase in biomass) is not directly related to the wood cut from the forest and entering the economy. An alternative and more real economy-based approach would be to account for the removals (second proposed indicator for ecosystem accounting in relevant guidance note). According to this definition

[12] Eurostat – Unit E2. Doc. Doc. ENV/EA/TF/2023_1/2. Wood provision ecosystem service – guidance note. Version prepared for the Task force on ecosystem accounting after a written consultation by the Environmental accounts working groups (WG EA and MESA) (February 2023)

[13] Kaia Oras, Kätlin Aun, Grete Luukas, Statistics Estonia; Üllas Ehrlich, Tallinn University of Technology. Comparison of crop provision and wood provision ecosystem services. UN London Group of Environmental Accounting, 2023.

accounting of wood supply services would be based on the wood that actually enters the economy (i.e. felling volumes). Functioning accounting exists for removals and is more easily available than data on annual growth.

Advantages and disadvantages of using the increment as an indicator for wood provision ecosystem service flow

There is another downside to assessing the wood provisioning ecosystem service on an incremental basis. Formally speaking, increment is (almost) totally the contribution of the ecosystem, but the problem is that the forest ecosystem does not consist only of wood. Wood increment occurs in young and less valuable forests as a habitat even faster than in old forests, which, according to the calculation based on increment, means that young forests are more valuable, i.e. they offer more services. In reality, it is just the opposite, old forests offer practically all ecosystem services (both habitat and recreational services and other welfare services) more than young forests.

In addition, increment-based statistics favour the use of wood supply services and larger cutting volumes. It is a fact that an old (ripe for logging) forest is more valuable as a source of wood than a young forest. Of course, economic logic favours cutting down the old forest. However, statistics based on increment allow to show that the increment is greater than the use of wood, despite the fact that the area of the old forest is decreasing and the services of the ecosystem are also decreasing.

The reduction of the area of old forests is big problem regarding the use of natural resources in Estonia, which has arisen precisely because of the emphasis on increment as basis of forest statistics, which allows the deterioration of the age structure of forests, without reducing the annual increment. In order to stop the deterioration of the age structure of forests, the statistics of the wood provisioning service of the forest ecosystem should be revised.

In the case of the wood service of the forest ecosystem, the accounting of assets and services cannot be kept strictly separate, because the volume of forest cutting directly depends on the assessment of the volume and condition of the asset. It can be said that the cutting volumes (provisioning service!) are determined by estimations given to the asset.

Old forest as a non-renewable resource

Old-growth forests are a scarce and diminishing resource not only in Estonia, but also in other parts of the world. The special value of the ecosystem of the old forest is also emphasized by Joy E. Hecht "in his classic work “National Environmental Accounting”[14] and recommends using the El Serafy method for old forest accounting.

The El Serafy Method[15] is an approach used in environmental economics, particularly for valuing natural resources. It was developed by Salah El Serafy as a way to adjust national income accounting to better reflect the depletion of natural resources. The method is often used in the context of sustainable development and involves separating the income generated from the extraction of non-renewable resources into two components: the amount that can be considered 'true income' and the portion that should be regarded as capital depletion.

The main purpose of the El Serafy Method is to ensure that economic indicators like GDP reflect not just the immediate economic benefits of resource extraction, but also consider the long-term sustainability of resource use. The main economic content of the EL Serafy method is that the income from natural resource extraction is split into true income (which can be consumed) and a depletion component (which should be reinvested to maintain the value of the asset base). The precise calculation involves determining the user cost and dividing the income into a sustainable part and a part that should be maintained or invested back. Applying this method helps indicate whether or not an economy's growth is sustainable. If the capital depletion is not reinvested or offset by investment in other forms of capital, the economy is not on a sustainable path[16].

Although the EL Serafy method is intended for analyses of non-renewable resources, one may argue that it may be appropriate to use this approach to value the use of old grown forests. Countries that still have old-grown forests typically re classify it from old-grown to second growth once any logging has occurred there. Thus, in a sense the old

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[14] Joy E. Hecht. National Environmental Accounting. Bridging the Gap between Ecology and Economy. Resources for the Future, Washington, DC, USA, 2005.

[15] A.Myrick Freeman III. The Measurement of Environmental and Resource Values. Resources for the Future (Publisher), 2013.

[16] Salah El Serafy. Macroeconomics and the Environment: Essays on Green Accounting (Advances in Ecological Economics series), Edward Elgar, UK, 2013

grown is a non-renewable resource, because once it is used at all, it no longer exists. Such forest services as providing habitat for biodiversity may in fact be largely lost if any logging is carried out in the old-growth forest, and they are therefore non-renewable. If the accounts factor in these kinds of services, then it would be appropriate to use El Serafy method to value their depreciation[1].

Treating old forests as a non-renewable resource in accounting is an idea worthy of consideration in Estonian forest statistics and accounting as well, considering the practical non-renewability of old forests.

Theoretical analyses of forest ecosystem wood provisioning service valuation, Statistics Estonia

The analyses presented in this subchapter[17] is based earlier work of Statistics Estonia[18] as the analyses stated earlier when 2022 data were not available yet. In addition, the analyses has based the calculation of the wood provisioning service of the forest ecosystem referred in the guidance note for wood provision[19] (which also proposes removals as a voluntary indicator in addition to net increment). For monetary valuation, the service was valued with stumpage prices calculated over increment and removals (harvested wood). The first is combined better with the physical indicator but the latter shows the real flow that enters economy better. Data on increment and removals was obtained from Estonian Environment Agency.

To obtain the increment data on spatial detail, data from the Forest Registry (as of January 2021) was used as primary data source. The increment was found for each forest stand compartment based on a simplified methodology using age, height, normal stand density and site quality class.

The wood supply service in physical units is given in table 24[20] of the Statistics Estonia report. The data shows that Wood provision (increment in FAWS, forest available for wood supply) was 11,777,520 m3.

Wood increment and harvested timber is also included in national accounts calculations and is a SNA value. Managed and economically restricted forest lands are taken into account, strictly protected forest is excluded. The calculations are made for each tree species and timber assortment both for State Forest Management Centre and other owners. First, the total volume lost due to natural death of trees is deducted from wood increment. Therefore, the increment of every tree species is reduced by the share of this approximation from the volume of increment. In order to calculate monetary value of wood provision service, calculations were done separately for increment and harvested wood but using the same stumpage prices where the increment or harvested wood was divided by timber owner (State Forest Management Centre or other ownership), assortment and stumpage prices[21] by timber species. The value of the wood provision ecosystem service was calculated by multiplying the stumpage prices with the increment or removals (harvested wood). Differences between tree species and assortments were considered.

The annual value of the supply service of the Estonian forest ecosystem is given in table 27 of the Statistics Estonia's Report[22]. Stumpage price based on net increment in 2020 was 238,1 million euros and the stumpage price based on removals 215,3 million euros.

Forest ecosystem wood provisioning service by alternative approach in Estonia, ELME

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[17] The analyses of this subchapter has been in large contributed by project expet professor Üllas Ehrlich. The adjustments were made by other authors of the report.
[18] Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC. Development of environmental accounts
Activity 2. Developing and refining ecosystem accounts D1.8.Description of the methodology for advancing ecosystem accounts, methodology. Methodological report.
[19] Eurostat – Unit E2. Doc. Doc. ENV/EA/TF/2023_1/2. Wood provision ecosystem service – guidance note. Version prepared for the Task force on ecosystem accounting after a written consultation by the Environmental accounts working groups (WG EA and MESA) (February 2023)
[20] Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC, Table 24. „Wood increment and removals (harvested wood) in land available for wood supply (AWS, FAWS- forest available for wood supply) and land not available for wood supply (NAWS, FNAWS- forest not available for wood supply), 1000 m3 overbark, 2020"
[21] Stumpage prices are prices that are paid for standing tree for the right to harvest. Stumpage prices are direct market prices and therefore show exchange value
[22] Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC, Table 27. „Stumpage prices based on net increment and removals, mln EUR, 2020"

ELME report[23] does not distinguish between stock and service for wood but uses the term "wood raw material". According to their methodology, by tree species (pine, spruce, birch, aspen, sycamore and gray alder, other tree species together) rough logs, fine logs, pulpwood, firewood and cutting waste were separated into assortments. For the areas covered by the forest register (as of 10.08.2022), assortments (m3 /ha) were calculated for each allotment that had the data required in the algorithm used, which were transferred to the spatial form based on the allotments' unique IDs.

The cost of wood quantities divided into assortments was presented according to three price scenarios: 1) average, 2) maximum and 3) minimum financial value of the last five years (2018–2022). The price of wood stocks in forests divided into assortments is 15,1 billion euros according to the average value of the last five years, 20,8 billion euros according to the maximum value, and 12,0 billion euros according to the minimum value.

In general, it can be said about the ELME approach that it is very detailed when taking into account the types of wood and the assortment of felling material, but from an economic point of view it does not consider the principles of the net present value method described above.

Additional discussion on the methods in forest accounting

Additional analyses of the methods used in accounting of forest as an asset was compiled and discussed from the viewpoint of semantics.

Net present value method

Both economic theory and the SNA suggest that forests should be valued based on current market price[24]. However, a simplified approach is also allowed: if that is difficult to observe they may be valued based on the market prices of similar assets that are easier to observe. In the real world outside of both economic theory and the SNA, actual market transactions for forest are rather uncommon, what means that observing the current market price may be difficult. The sales that do occur typically are of several types. In some cases, land and the vegetation on it are sold together, with no distinction between the value of the land and the value of the trees. In other cases, the right to harvest the trees is sold to a logging company. The sale price in this case is termed the stumpage price. A third observed price is the value of the trees after they have been cut, the so-called felling price. The felling price is readily observed. It is related to stumpage price by the following formula:

Stumpage price = felling price – costs of cutting the trees, including return on investment (or fixed capital)[3].

In the absence of good market data on the price of forests assets, they should be valued as the sum of the discounted future earnings stream from the forest, as this approximates what a national investor might be willing to spend on the forest. This requires access to a range of data:

- quantity of wood that can be harvested each year;
- price that will be paid for the harvest each year;
- input costs to the logger, which includes costs of felling the logs;
- a suitable discount rate for calculating the present value of the income stream.

The quantity of the wood may be estimated based on the current age structure and species composition of the forest, combined with knowledge of the growing cycle of each species. Data on the current age structure and species composition of the forests are collected in forest inventories and are available. Estimating future prices or production costs is more difficult, especially as wood prices vary widely with unrelated and largely unpredictable market changes. The sale price less the input costs to the logger gives the stumpage price, or net price of the forest. This is

[23] Helm, A., Kull, A., Kiisel, M., Poltimäe, H., Rosenvald, R., Veromann, E., Reitalu, T., Kmoch, A., Virro, H., Mõisja, K., Nurm, H-I., Prangel, E., Vain, K, Sepp, K., Lõhmus, A., Linder, M., Otsus, M., Uuemaa, E. (2023). Eesti maismaaökosüsteemide hüvede (ökosüsteemiteenuste) majandusliku väärtuse üleriigiline hindamine ja kaardistamine. Tehniline lõpparuanne. Riigihange "Maismaaökosüsteemiteenuste üleriigiline rahaline hindamine, sh metoodika väljatöötamine" (viitenumber 235366, Keskkonnaagentuur). Tartu Ülikool. Eesti Maaülikool. ISBN 978-9985-4-1398-2 (pdf).
[24] Joy E. Hecht. National Environmental Accounting. Bridging the Gap between Ecology and Economy. Resources for the Future, Washington, DC, USA, 2005

the income earned by the logger each year. Choosing a discount rate as also fraught with uncertainty, and the results are very sensitive to small changes in the rate chosen.

Net Price Method

In response to difficulties of estimating net present value, many accounting projects choose to apply the net price method instead. Following this approach, the value of the forest is simply the net price (or stumpage price) per hectare times the area of forest. The net price method is equivalent to the net present value, if the discount rate is the same as the natural growth rate of timber. Although it is not typically so in practice, many projects use net price method because the data requirements are so much simpler. The major practical issue is obtaining the stumpage price. Where actual transactions data are available, this is straightforward. However, in practice, it is usually necessary to estimate of the cost of felling and transporting them[25].

Experience of other countries

Two environmental accounting projects have been carried out in the Philippines[26]. Forests are key element of the Philippine economy and environment. The UN funded project implemented the approach of the 1993 SEEA (called Philippine SEEA). The PSSEA uses the net price method to value forest resource stocks, multiplying stumpage value by the physical data on opening stock to obtain opening values for the asset accounts. The results of the project show, that the stocks of forest decreasing in value. The PSEEA discussion data and its analyses of physical and monetary changes in the forests highlight the depletion due to harvesting, without including any natural growth that might counter the depletion. The PSSEA asset accounts do not consider any growth to be the result of human management. In a full accounting system, this issue would determine which value should be transferred from the asset account to the current account as depreciation.

Crop pollination

According to the amendment of Regulation (EU) 691/2011, the ecosystem service pollination is defined as ecosystem contribution by wild pollinators to the production of the crops referred to in the first indent. The contributions shall be reported in tonnes of pollinator-dependent crops that can be attributed to wild pollinators, by type of crop for the main types of pollinator-dependent crops comprising fruit trees, berries, tomatoes, oilseeds and "'other'".

The methodology for assessing pollination in physical units was built on previous experience and guidance in the respective guidance notes by Eurostat.

For monetary valuation of the service the method and model used in physical accounting was complemented with basic prices by crop type to find the monetary value of pollinator-dependent production of crops.

The supply and use tables and more detailed distribution by ecosystem types is given in Annex "D1.8 Dataset on ecosystem service supply-use.xlsx" (MS EXCEL file).

Crop pollination – physical account

Biophysical and monetary service flow was modelled using spatial data of crops and pollinator habitats. Input data included yearly yield data for 2024 from agricultural statistics (PM0281: Agricultural land and crops by county[27]), spatial data of agricultural support and land parcels (Estonian Agricultural Registers and Information Board (ARIB)[28], ecosystem extent map), basic unit prices of agricultural crop products.

[25] Joy E. Hecht. National Environmental Accounting. Bridging the Gap between Ecology and Economy. Resources for the Future, Washington, DC, USA, 2005
[26] Joy E. Hecht. National Environmental Accounting. Bridging the Gap between Ecology and Economy. Resources for the Future, Washington, DC, USA, 2005
[27] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__taimekasvatussaaduste-tootmine/PM0281/table/tableViewLayout2
[28] https://avaandmed.eesti.ee/information-holders/pollumajanduse-registrite-ja-informatsiooni-amet

The methodology proposed by scientists of Wageningen University and Research [29] was followed for calculating and modelling of the biophysical value of the pollination service. However, it was needed to make some modifications in the methodology as original calculations in the Netherlands were done using raster data with fixed cell size, but currently Estonian spatial input was in vector format.

Crop field units with their respective grown crop, pollinator habitat units and distances between them were derived through spatial analyses. On all crop field units where a crop which requires pollination is grown and all suitable habitat units within 1750 meter radius (from the middle of crop field unit to the middle of habitat unit) of the crop field unit were chosen to the dataset on which calculations were done. Due to time constrains the spatial data was not transformed from vector to raster, therefore further calculations were done in table form and therefore the precision of the modelling also decreased.

Pollination requirement was linked to the crop field units based on the crop grown there and habitat suitability per ecosystem type was linked to habitat units.

Crops differ in pollination demand. Based on the pollination requirement of the crop, crop field units were assigned a value of pollination requirement on the scale of 0-100. The values for the pollination requirement were derived from Klein et al. (2007) and modified for Estonia with the expert knowledge of entomologist of University of Life sciences, professor Mänd in previous work on ecosystem accounting by Statistics Estonia[30].

Ecosystems are also different in suitability for habitat to pollinators. Data was collected about the suitability of the ecosystem units for the habitat for wild pollinators such as wild bees, bumblebees, butterflies, and hoverflies. Wild pollinators require sufficient resources for nesting (e.g. suitable soil substrate, tree cavities, etc.) and sufficient forage (i.e. pollen and nectar). Based on SEEA EEA report[31], and expert knowledge of entomologist of University of Life sciences, professor Mänd and ecologist of Tallinn University, associated professor Rivis, each ecosystem for the suitability for pollinators habitat on scale 0 – 100 where 100 means most suitable and 0 unsuitable, was assessed in previous work on ecosystem accounting by Statistics Estonia[32].

Using the obtained dataset the relative visitation rate (scale 0-100) in crop field unit c from surrounding habitat units h was calculated [33]

$$v_c = \sum_{h=1}^{H} S_h \frac{e^{-0.00053 d_{hc}}}{\sum e^{-0.00053 d}}$$

where

S_h represents the relative pollinator abundance (scaled 0 – 100, where 100 marks maximum suitability) in map unit h (based on the suitability for nesting and foraging for pollinators of the habitat in map unit h), habitat suitability.

d_{hc} is the distance between map unit h and the crop in map unit c.

d describes the distance between the crop field unit c and any possible ecosystem around it. $\Sigma e^{-0.00053d}$ describes the sum of all the distances between the crop field unit c and all possible ecosystems around it.

To use this equation for vector data (polygons) an estimation of the average d was needed, this was obtained based on the average area of crop field. The value of d in our test area was calculated on raster map with the help of Dr. Ir. Marjolein Lof from Wageningen University & Research. For the field with an area of 7.21 ha, which translates into a

[29] Remme, R., Lof, M., de Jongh, L., Hein L., Schenau, S., de Jong, R., Bogaart, P. (2018) The SEEA EEA biophysical ecosystem service supply-use account for the Netherlands. Wageningen University and Research

[30] Statistics Estonia, 2020. Development of the land account and valuation of ecosystem services regarding grassland ecosystem services (Eurostat Grant Agreement no NUMBER — 831254 — 2018-EE-ECOSYSTEMS). https://www.stat.ee/sites/default/files/2021-06/Methodological%20report_831254_2018_EE_ECOSYSTEMS_revised_version_31_03.pdf

[31] Remme, R. et al (2018) The SEEA EEA biophysical ecosystem service supply-use account for the Netherlands. Wageningen University and Research

[32] ibid

[33] Remme, R., Lof, M., de Jongh, L., Hein L., Schenau, S., de Jong, R., Bogaart, P. (2018) The SEEA EEA biophysical ecosystem service supply-use account for the Netherlands. Wageningen University and Research

square cell measured 268x268 m it was calculated how many fields, and at what distances, an ecosystem providing pollination can potentially be connected with. If all natural vegetation within 6 km radius of the crop field is taken into account, the sum of all visitation rates ($\Sigma e^{-0.00053d}$) is 257.5922. The obtained value of d was used in the calculations as a constant. If the crop fields in the local landscape are bigger or smaller than the average size of crop field based on which the d was calculated on, it will result in an under or over estimation of pollinator visitation rate and thereof also the ecosystem service value.

Pollination P_c is a function of the relative visitation rate,

$$P_c = f(v_c)$$

where $P_c = 5v_c$ for v_c between 0 and 20 and 100 for $v_c \geq 20$.

Next potential crop production reduction which is described by crop yield (kg) = yield per hectare by county (kg/ha) *crop field area (ha) in absence of pollination was calculated. Here in the calculations changing from yield (kg) to yield (€) by incorporating average crop basic price gives the monetary value of the ecosystem service instead of biophysical. The potential crop production reduction in monetary units is then described as crop yield (€) = yield per hectare by county (kg/ha) * average crop basic price (€/kg)*crop field area (ha).

The avoided production reduction represents the use of the pollination service by the crops. Avoided production reduction in the presence of pollinators APR_c is calculated

“Avoided production reduction” = “potential production reduction” * (“pollination”)/100

The contribution (supply) of the ecosystems to the avoided production reduction, APRh is calculated:

$$APR_h = \sum_{c=1}^{C} APR_c \frac{\sum_{h=1}^{H} S_h \frac{e^{-0.00053 d_{ch}}}{\sum e^{-0.00053 d}}}{\sum_{h=1}^{H} S_h}$$

where

APR_c is the avoided production loss in the crop in map unit c,
d_{ch} is the distance between the crop c and the pollinator habitat h.
S_h is relative pollinator abundance in map unit h. Contribution to avoided production loss in crop fields by the ecosystem in map unit h is based on all crop fields that require pollination in a 6 km square around map unit h. This is calculated for all map units that contain an ecosystem that is suitable for pollinators.

The result of pollination ecosystem service was carried out in R by following the modified calculations of the modelling of avoided production reduction in the presence of pollinators. The total value of the pollination service was 105 thousand tons. The ecosystem service value by ecosystem types and crop types is shown in Table 9.

The use of the service is assigned, like the crop provision service, to the intermediate consumption by industries (agriculture activity) (Table 10).

Table 9. Supply of crop pollination ecosystem service (1000 tons) by crop types and ecosystem types, 2022

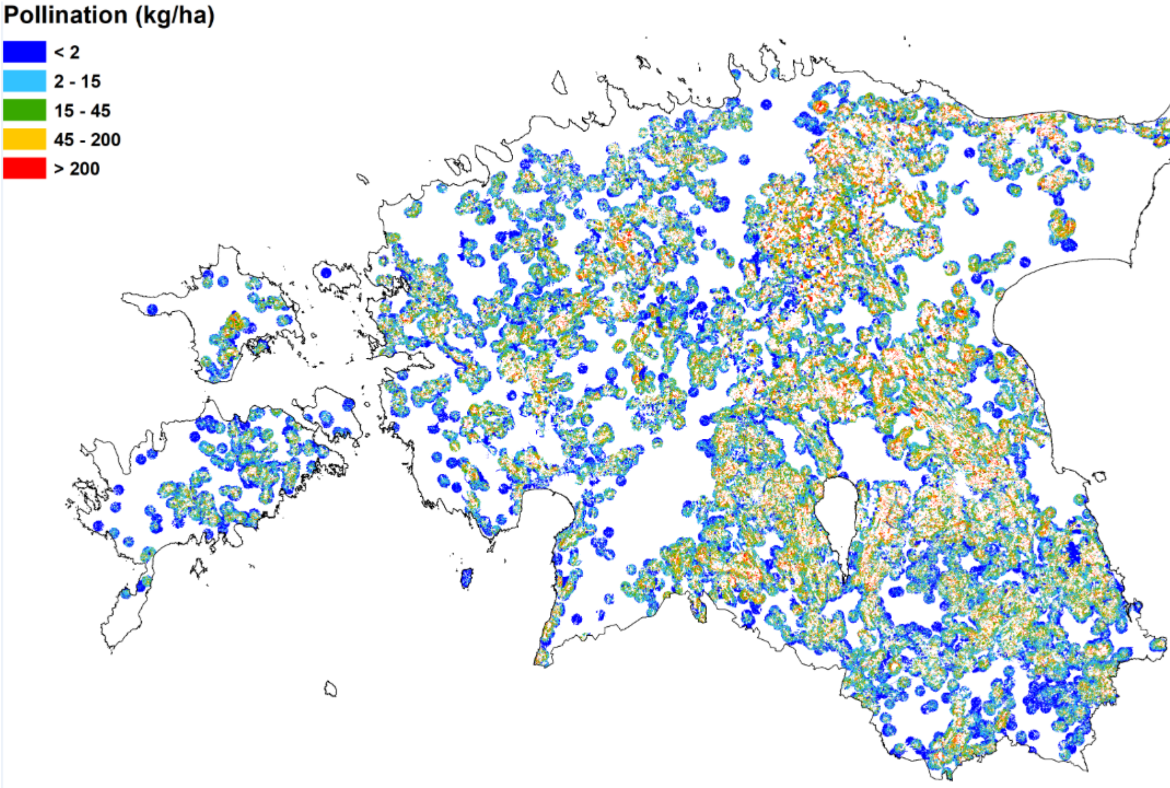
	MF.1.1 Crops (excluding fodder crops)	MF.1.1.1 Cereals	MF.1.1.4 Pulses	MF.1.1.6 Oil-bearing crops	MF.1.1.7 Vegetables	MF.1.1.8 Fruits
1 Settlements and other artificial areas	17.9	1.4	4.0	11.4	0.5	0.6
2 Cropland	2.5	0.2	0.5	1.4	0.1	0.3
3 Grassland (pastures, semi-natural and natural grassland	34.9	3.0	7.7	21.9	0.9	1.4
4 Forest and woodland	49.7	4.1	11.2	32.0	0.9	1.5
5 Heathland and shrub	0.3	0.0	0.1	0.2	0.0	0.0
6 Sparsely vegetated ecosystems	0.1	0.0	0.0	0.0	0.0	0.0
7 Inland wetlands	0.3	0.0	0.1	0.2	0.0	0.0
11 Coastal beaches, dunes and wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Total supply	105.7	8.7	23.5	67.2	2.4	3.9

Table 10. Use of crop pollination ecosystem service (1000 tons), 2022

	Intermediate consumption by industries	Government final consumption	Households final consumption	Gross capital formation	Exports	Total use
MF.1.1 Crops (excluding fodder crops)	105.71					105.71
MF.1.1.1 Cereals	8.67					8.67
MF.1.1.4 Pulses	23.54					23.54
MF.1.1.6 Oil-bearing crops	67.23					67.23
MF.1.1.7 Vegetables	2.39					2.39
MF.1.1.8 Fruits	3.87					3.87

Spatial distribution of the ecosystem service (Figure 4) was obtained simultaneously with the calculations of the model where a value based on the contribution to the increased crop yield in nearby fields was attributed to each ecosystem asset that was a suitable pollinator habitat.

Figure 4. The ecosystem service provisioning areas and values of ecosystem service of crop pollination. The areas coloured from blue to red represent service provisioning areas according to the unit value (kg/ha) supplied by ecosystem assets. Areas coloured white represent areas that do not supply the ecosystem service in the current scope of the study.



Pollination – monetary valuation

By incorporating average crop basic price data in the step of calculations where potential crop production reduction is calculated, the result from the model for the ecosystem service is obtained in monetary units instead of biophysical. The total monetary value of the pollination service was 62.4 million EUR. The ecosystem service value by ecosystem types and crop types is shown in Table 11.

Table 11. Supply of crop pollination in monetary values, million EUR, 2022

	MF.1.1 Crops (excluding fodder crops)	MF.1.1.1 Cereals	MF.1.1.4 Pulses	MF.1.1.6 Oil-bearing crops	MF.1.1.7 Vegetables	MF.1.1.8 Fruits
1 Settlements and other artificial areas	10.5	0.4	1.4	0.3	1.3	7.1
2 Cropland	1.8	0.1	0.6	0.0	0.2	0.9
3 Grassland (pastures, semi-natural and natural grassland	20.8	0.8	3.1	0.5	2.6	13.8
4 Forest and woodland	28.8	1.2	3.3	0.5	3.8	20.1
5 Heathland and shrub	0.2	0.0	0.0	0.0	0.0	0.1
6 Sparsely vegetated ecosystems	0.0	0.0	0.0	0.0	0.0	0.0
7 Inland wetlands	0.2	0.0	0.0	0.0	0.0	0.1
11 Coastal beaches, dunes and wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Total supply	62.4	2.4	8.5	1.4	7.9	42.1

Air filtration

According to amendment of Regulation (EU) 691/2011, the ecosystem service air filtration is defined as the ecosystem contribution to filtering air-borne pollutants through the deposition, uptake, fixing and storage of pollutants by ecosystem components (particularly trees). This mitigates the harmful effects of the pollutants. The contributions shall be reported in tonnes of particulate matter adsorbed.

The respective guidance notes by Eurostat[34] further details that PM10 includes particles up to 10 µm in aerodynamic diameter, whereas PM2.5 represents the fraction of particles up to 2.5 µm in aerodynamic diameter. While measuring the service for PM2.5 is more relevant from the beneficiary's perspective, the choice of selecting PM2.5 or PM10, as indicator for this ecosystem service also depends on the availability of national data on (i) air quality and (ii) the capacity of vegetation to adsorb PM.

Due to PM2.5 being more relevant than PM10, 2.5 was chosen as an indicator for the assessment of air filtration ecosystem service. The assessment of the service (deposition of PM2.5) in physical units was done in co-operation with the Department of Air and Climate of Estonian Environmental Research Centre (EKUK).

For monetary valuation of the service, a benefit transfer method was applied.

These tables and more detailed distribution by ecosystem types and users is given in Annex "D1.8 Dataset on ecosystem service supply-use.xlsx" (MS EXCEL file).

Air filtration – physical account

The PM concentration ($PM_{2.5}$) C_{PM} was used to calculate the amount of deposition. Following emissions assessments and modeling were carried out for the year 2022:

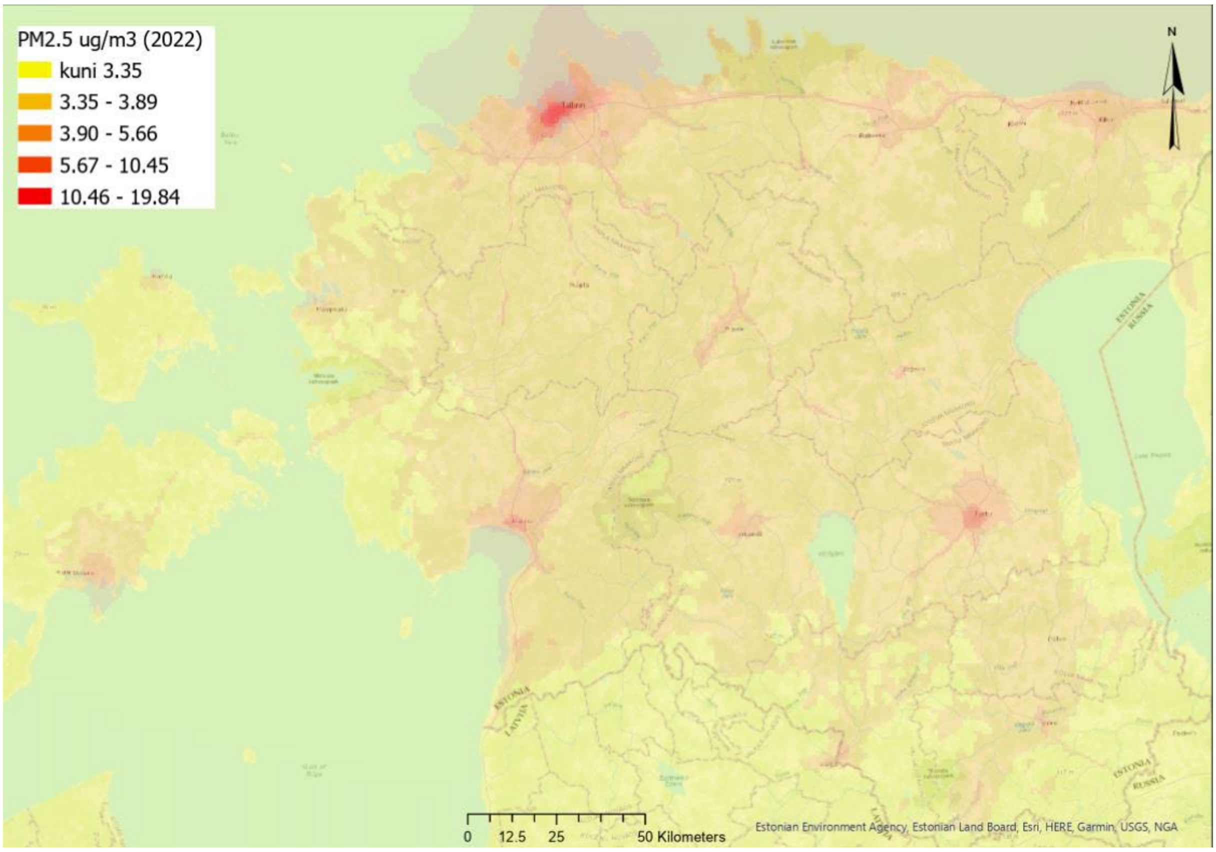
- Fine particles ($PM_{2.5}$) from all anthropogenic sources, like:
    - Traffic,
    - Residential wood combustion,
    - Energy and industrial sector,
    - Agriculture

National emissions data (2022) was used as input for the emissions, which were validated with air quality monitoring results.

The emission dataset was imported into the Airviro modeling system and emission sources were identified as grid sources. The modeling utilized meteorological observation data from the year 2022. 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 5) were compared to monitoring data at monitoring points. The model was considered reliable if sufficient agreement was obtained at all monitoring points.

[34] Eurostat – Unit E2. Guidance note for accounting for the air filtration ecosystem service in the EU – draft for a brief review by 04/12/2023 by the TF (before written consultation by the Environmental Accounts Working Groups) (November 2023)

Figure 5. Modelled $PM_{2.5}$ yearly concentration, µg/m^3



For the deposition velocity Copernicus Land Monitoring service was used, where the open access LAI data with 1000 metre spatial resolution (Figure 7) and for the 2022 vegetation period (May to end of August), was used. In order to compute the deposition for a certain time period, the instantaneous deposition must be multiplied for the number of seconds of the selected period. The following equation yields the Vd in a certain pixel for a certain period:

$Vd = Vd_{(LAI)} \times LAI$ (Equation 1)

With:
Vd = Deposition velocity for PM per period in cm/s, adjusted by actual LAI. In the case of $PM_{2.5}$, but not PM_{10}, Vd is amongst others influenced by wind speed (see Annex 1).
$Vd_{(LAI)}$ = Deposition velocity values for PM per unit of LAI and period, in cm/s, see Table 1
LAI = Leaf Area Index per period.

Table 12. $Vd_{2.5LAI}$ as a function of wind speed

Wind speed (m/s)	$Vd_{(LAI)}$ (cm/s)
0	0.000
1	0.030
2	0.087
3	0.143
4	0.160
5	0.176
6	0.182
7	0.504
8	0.819
9	0.810
10	1.836
11	1.772
12	1.688
13	1.625

A basic method of annual average Vd(PM2.5) was used according to equation 1.

Yearly average wind speed data from Copernicus was used and are presented in Figure 6.

Figure 6. Copernicus wind speed data, m/s

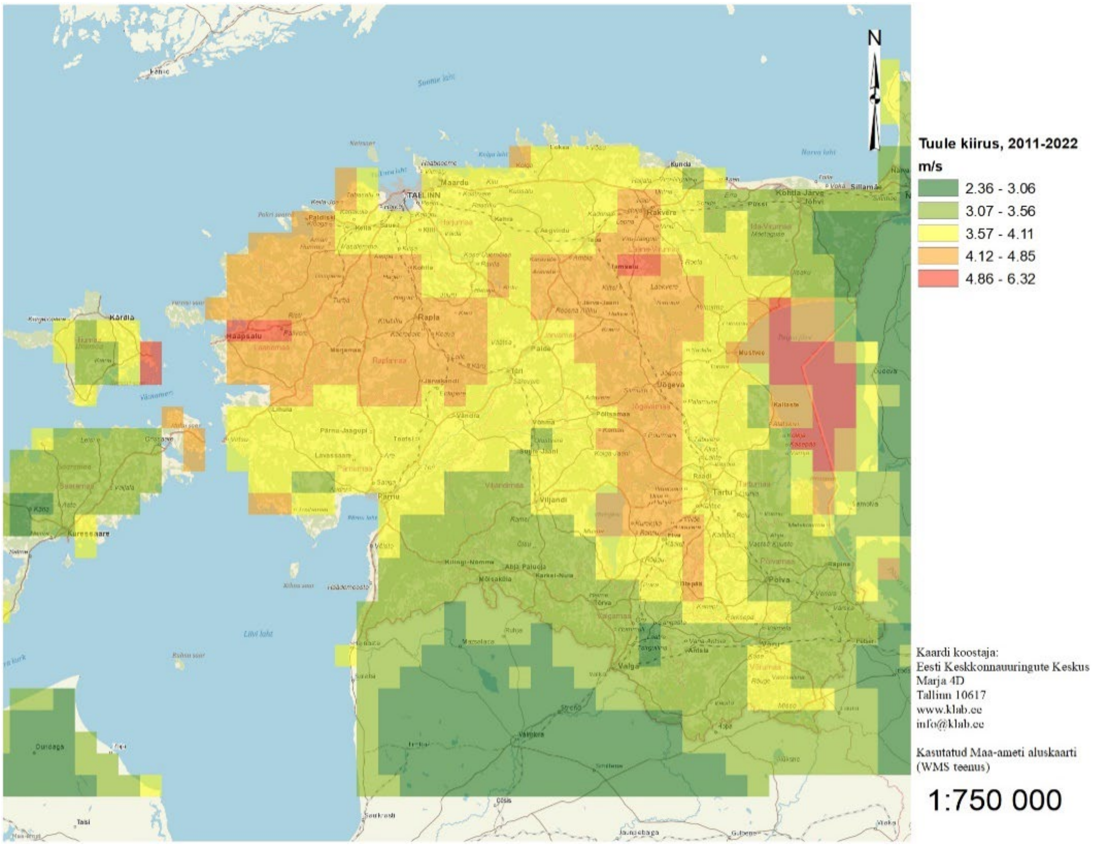
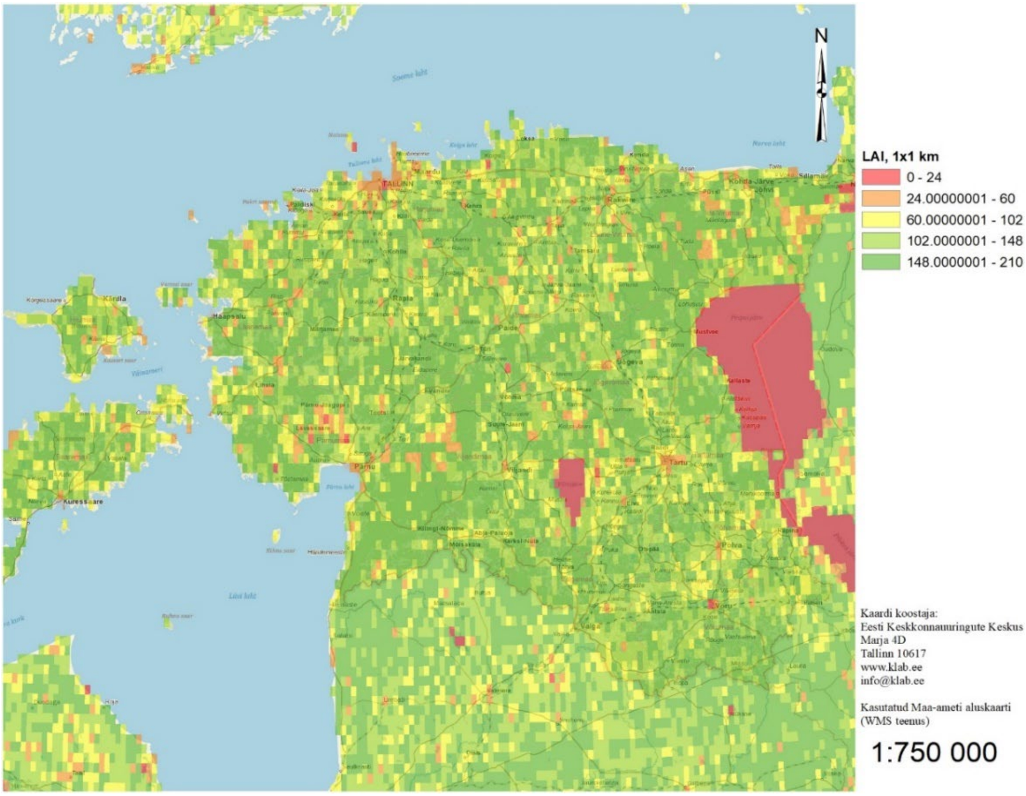


Figure 7. Used LAI data



Based on $PM_{2.5}$ concentration and Vd data the PM2.5 deposition was calculated, using following formula:

$PM_{2.5}$ deposition (tonnes/km^2/year) = Vd (cm/s) × C_{PM} (μg/m^3) × 3.1536 ×10^{-3} (Equation 2)

Total $PM_{2.5}$ deposition (tonnes/year) = ∑ PM deposition (tonnes/km^2/year) (Equation 3)

$PM_{2.5}$ deposition (tonnes/km^2/year) are presented in Figure 8 and in total 552 tonnes of $PM_{2.5}$ was adsorbed due to air filtration in 2022. In 2020, the result, using the same methodology, was 554 tonnes of PM2.5 are adsorbed.

The obtained map for deposited PM2.5 was combined with ecosystem extent map and division between ecosystem types was found (Table 13). The users of the service are households (

Table 14).

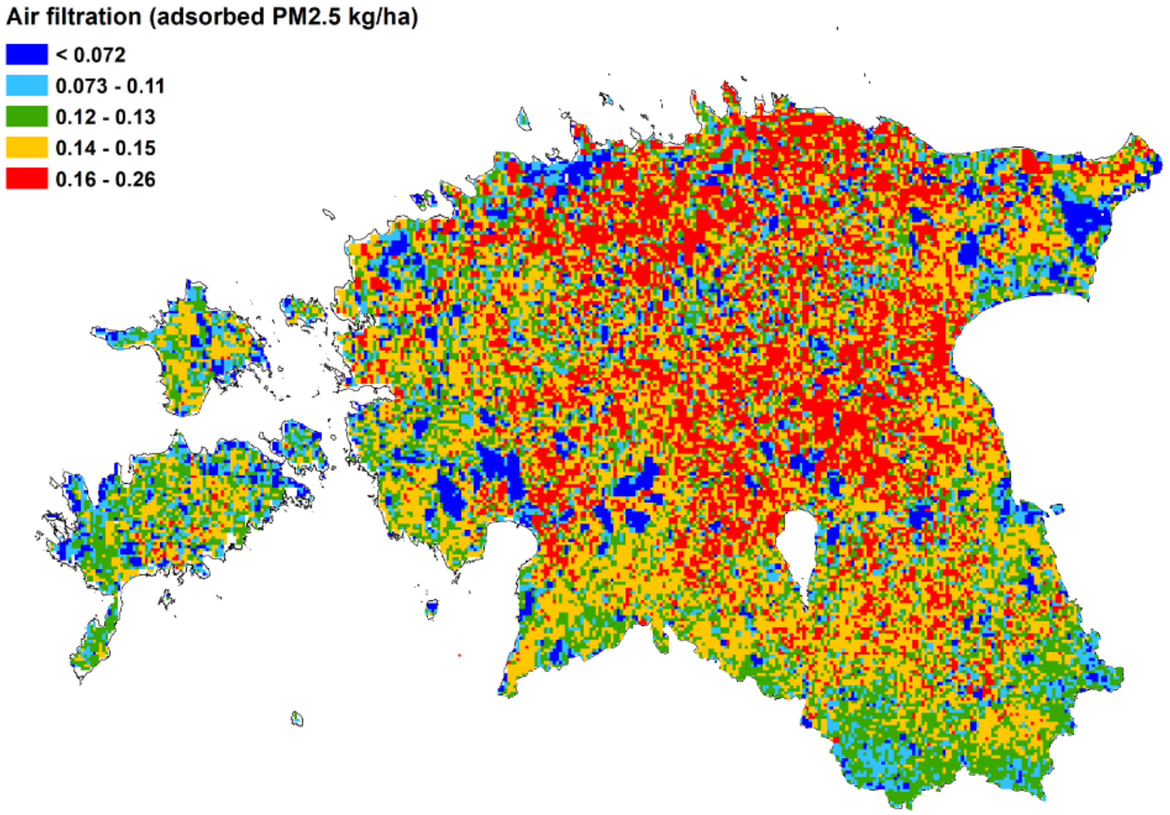
Table 13. Air filtration – supply table (tonnes of PM2.5 adsorbed), 2022

Ecosystem	Air filtration (Tonnes of PM2.5 adsorbed)
1 Settlements and other artificial areas	33.703
2 Cropland	108.068
3 Grassland (pastures, semi-natural and natural grassland	53.763
4 Forest and woodland	326.169
5 Heathland and shrub	1.619
6 Sparsely vegetated ecosystems	0.334
7 Inland wetlands	22.417
8 Rivers and canals	3.310
9 Lakes and reservoirs	2.603
10 Marine inlets and transitional waters	0.011
11 Coastal beaches, dunes and wetlands	0.062
12 Marine ecosystems (coastal waters, shelf and open ocean	0.002
Total supply	552.061

Table 14. Air filtration – use table (tonnes of PM2.5 adsorbed), 2022

	Intermediate consumption by industries	Government final consumption	Households final consumption	Gross capital formation	Exports	Total use
Tonnes of PM2.5 adsorbed			552.061			552.061

Figure 8. Air filtration ecosystem service (PM2.5 deposition in kg/ha). The areas coloured from blue to red represent service provisioning areas according to the physical unit value kg/ha). Areas coloured white represent areas that do not supply the ecosystem service.



Air filtration – monetary valuation

The monetary value of air filtration was evaluated using benefit transfer method based on a study by Baro et al. (2014)[35].

Baro et al. (2014) conducted research within the administrative boundaries of the municipality of Barcelona, Spain. There is 1.62 million inhabitants in an area of 101.21 km^2. The total green space within the municipality of Barcelona amounts to 28.93 km^2 representing 28.59 % of the municipal area and a ratio of 17.91 m^2 per inhabitant. In the last decade, the city has repeatedly exceeded the EU limit values for average annual concentrations of nitrogen dioxide (NO2) and PM10 pollutants (40 lg m^3 for both pollutants).

The i-Tree Eco model was used to quantify ecosystem services and disservices in Barcelona. The Public Health Agency of Barcelona provided PM10 concentration data from the 13 operational monitoring stations of the city during the year 2008. The i-Tree Eco model estimates dry deposition of air pollutants (i.e., pollution removal during

[35] Baro, F., Chaparro, L., Gomez-Baggethun, E., Langemeyer, J., Nowak, D.J., Terradas, J. (2014) Contribution of Ecosystem Services to Air Quality and Climate Change Mitigation Policies: The Case of Urban Forests in Barcelona, Spain. AMBIO 2014, 43:466–479

non-precipitation periods), which takes place in urban trees and shrub masses. Externality value applied to the case study is transferred from U.S report where PM10 = 6614 USD per ton (year 2007) [36].

Air filtration in case of PM10 removal by Barcelona trees and shrubs is estimated at 166.0 tons per year with an economic value of 1,097,964 USD per year (USD 2008 year).

Based on the findings of the selected study, the following assumptions were made to calculate the monetary value of PM2.5 deposition by Estonian ecosystems in 2022:

1. Adsorbed PM2.5 was 552 tons in 2022,
2. The monetary value of PM10 absorption by trees and bushes was 6614 USD/ton (year 2007) [37];
3. According to the Estonian ambient air monitoring map[38] PM10 measured in Estonian air contains an average of 40% PM2.5 over the last 10 years;
4. The exchange rate of the euro and the US dollar in 2022 was 1.173[39].

Total monetary value of Estonian ecosystem ability to deposit PM2.5 is 1.28 million EUR in 2022. The value of the PM 2.5 deposition by ecosystem is presented in Table 15.

Table 15.Physical and monetary value of deposited PM2.5 by ecosystem types, 2022

Ecosystem	Air filtration (tonnes of PM2.5 adsorbed)	Monetary value of PM2.5 deposition, thousand EUR
1 Settlements and other artificial areas	33.703	78.124
2 Cropland	108.068	250.502
3 Grassland (pastures, semi-natural and natural grassland	53.763	124.622
4 Forest and woodland	326.169	756.059
5 Heathland and shrub	1.619	3.753
6 Sparsely vegetated ecosystems	0.334	0.775
7 Inland wetlands	22.417	51.964
8 Rivers and canals	3.310	7.673
9 Lakes and reservoirs	2.603	6.033
10 Marine inlets and transitional waters	0.011	0.024
11 Coastal beaches, dunes and wetlands	0.062	0.145
12 Marine ecosystems (coastal waters, shelf and open ocean	0.002	0.004
Total supply	552.061	1284.172

Global climate regulation

According to the amendment of Regulation (EU) 691/2011, the ecosystem service local climate regulation is defined as the ecosystem contribution to reducing concentrations of greenhouse gases in the atmosphere through the removal (net sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. The

[36] Murray, F.J., L. Marsh, and P.A. Bradford. 1994. New York state energy plan Vol. II: issue reports. Albany, NY: New York State Energy Research and Development Authority.
[37] Murray, F.J., L. Marsh, and P.A. Bradford. 1994. New York state energy plan Vol. II: issue reports. Albany, NY: New York State Energy Research and Development Authority.
[38] https://xn--huseire-00a.ee/?zoomLevel=8&lat=58.88711&lng=25.569944
[39] https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm

contributions shall be reported in terms of tonnes of net sequestration of carbon and tonnes of organic carbon stored in terrestrial ecosystems, including above ground and below ground stock.

It is noted in the respective guidance note by Eurostat that LULUCF sector (land use and land use change) in national greenhouse gas (GHG) inventories provide much of the data required to account for net carbon sequestration and carbon storage. In this work data on sequestration and emissions from GHG was used. Existing international reporting data from Greenhouse gas inventories can be easily used as input data, however alignment between ecosystem types in LULUCF and ecosystem extent needs to be tackled separately considering also which data need to be included or are included in LULUCF (managed vs unmanaged land). The latter aspect is important when dealing with natural wetlands which can be potential carbon sinks and, in this case, additional data sources need to included. In current work natural wetlands were excluded but it is foreseen that detailed spatial data for carbon sequestration becomes available in the future and then estimations can be made

To calculate carbon storage separate spatial datasets for carbon stock in soil and carbon stock in woody above- and below-ground biomass produced in ELME2 project were used. 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" which is led by the Ministry of Climate (completion by 2027). In the same project workflow updated data on carbon capture would be produced.

Average EU ETS price in 2022 was combined with physical indicators (net sequestration and carbon storage) to find the economic value of the service.

These tables and more detailed distribution by ecosystem types and users is given in Annex "D1.8 Dataset on ecosystem service supply-use.xlsx" (MS EXCEL file).

Global climate regulation – physical account

The data from National Inventory Report of greenhouse gas emissions in Estonia 1990-2022[40] was used to find carbon-related greenhouse gas (CO2, CH4) removals and emissions.

Net CO2 and CH4 flows are given in kilotons and these were converted to tons of carbon by using conversion factors: 1 ton CO2 equals 0.27 ton C and 1 ton CH4 equals 0.75 ton C respectively (Table 16).

Table 16. Carbon-related greenhouse gas removals and emissions, 2020, kt (kt=thousand tons). The signs for removals are negative (–) and for emissions positive (+).

Land-use category	CO2, kt	CH4, kt	CO2-C, kt C (CO2 = 0.273C)	CH4-C, kt C (CH4 = 0.75C)	N2O, kt
A. Forest land	-1676.4963	2.6731	-452.6540	2.0048	0.9121
B. Cropland	844.4111	NO,NE,NA	227.9910		0.0243
C. Grassland	-171.9770	0.0001	-46.4338	0.0001	0.0000
D. Wetlands	1305.1405	0.0041	352.3879	0.0031	0.0077
E. Settlements	308.8507	NO,NE	83.3897		0.0411
F. Other land	29.2455	NO	7.8963		0.0048
G. Harvested wood products	-641.5779				
H. Other (please specify)	NO	NO			NO
Total LULUCF	-2.4034	2.6773	-0.6489	2.0080	1.0027

*NO (not occurring, IE (included elsewhere), NE (not estimated), NA (not applicable)

[40] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/national-inventory-submissions-2022

It can be seen that forest and grasslands are the only land-use categories where carbon is sequestered and not emitted. Harvested wood products (HWP) are excluded from the service value, since HWPs are reported in a separate category in the GHG inventories.

LULUCF includes only managed land. All forest is managed in Estonia. Managed land for wetlands category includes only peatlands drained and managed for peat extraction and excludes natural unmanaged wetlands. Wetlands, peatlands in particular, in their natural state are known to be carbon sinks, therefore they can be potential service providers. This aspect is also mentioned in the guidance note for global climate regulation. The guidance note gives further recommendations how to find carbon sequestration for unmanaged wetlands that are not included in LULUCF. An easy approach would be to estimate average per hectare annual carbon sequestration in unmanaged wetlands based on literature and to then to multiply that with the area of these wetlands. The guidance note proposes that as a default value, in case no national data are available, the net C sequestration in European undrained temperate peatlands can be assumed to be 0.56 (+ 0.19) tons C per hectare per year in all ecosystem types. It is assumed that peatlands in their natural state remove approximately 2 tons of CO2 (0.54 tons of C) per hectare in Estonia[41]. However, it is also noted by experts that due to drainage, which affects the majority of peatlands in Estonia directly or indirectly, wetlands in total have turned from being CO2 sinks to CO2 sources[42]. In this case, more detailed data and especially spatial data are necessary. Currently net sequestration in unmanaged wetlands is not included in the global climate service indicator 'net sequestration'.

Based on the suggestion by experts an assumption was made, that the annual net increment of stands has a strong correlation with carbon sequestration. Therefore, the contribution to the supply of the service by different forest ecosystems (Table 17) was obtained by the spatial allocation of carbon sequestration in forests based on net increment (see Figure 3. Wood provisioning (based on net increment) areas and values. The areas coloured from blue to red represent service provisioning areas according to the physical unit value m3/ha). Areas coloured white represent areas that do not supply the ecosystem service.). The dataset and calculation of increment is described in chapters of wood provision. The total value of sequestered CO_2 is based on the National Inventory Report of greenhouse gas inventory, no calculations were done to assess the carbon content in the biomass of forest increment. For grasslands the carbon sequestration was distributed per ecosystem area.

Carbon storage was estimated based on separate spatial datasets for carbon stock in soil and carbon stock in woody above- and below-ground biomass prepared in ELME2 project[43]. To calculate carbon storage for ecosystem types, the datasets for carbon stock in soil and carbon stock in woody above- and below-ground biomass were combined with the extent map and for every ecosystem asset an average value of the stock in tons C/ha was found. Distribution between ecosystem types was then found by aggregating by ecosystem type. The results can be seen in Table 17 Illustrative map on the spatial distribution of carbon stock is presented in Figure 9. Table 18 shows the use of the global climate regulation service, the user of the service is government.

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[41] Estonian Ministry of Environment, Draft "Eesti turbaalade kaitse ja säästliku kasutamise alused" (05.10.2010)
[42] Ilomets, M., 2005. Turba juurdekasv Eesti soodes. Tallinna ülikool, ökoloogia instituut.
[43] „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

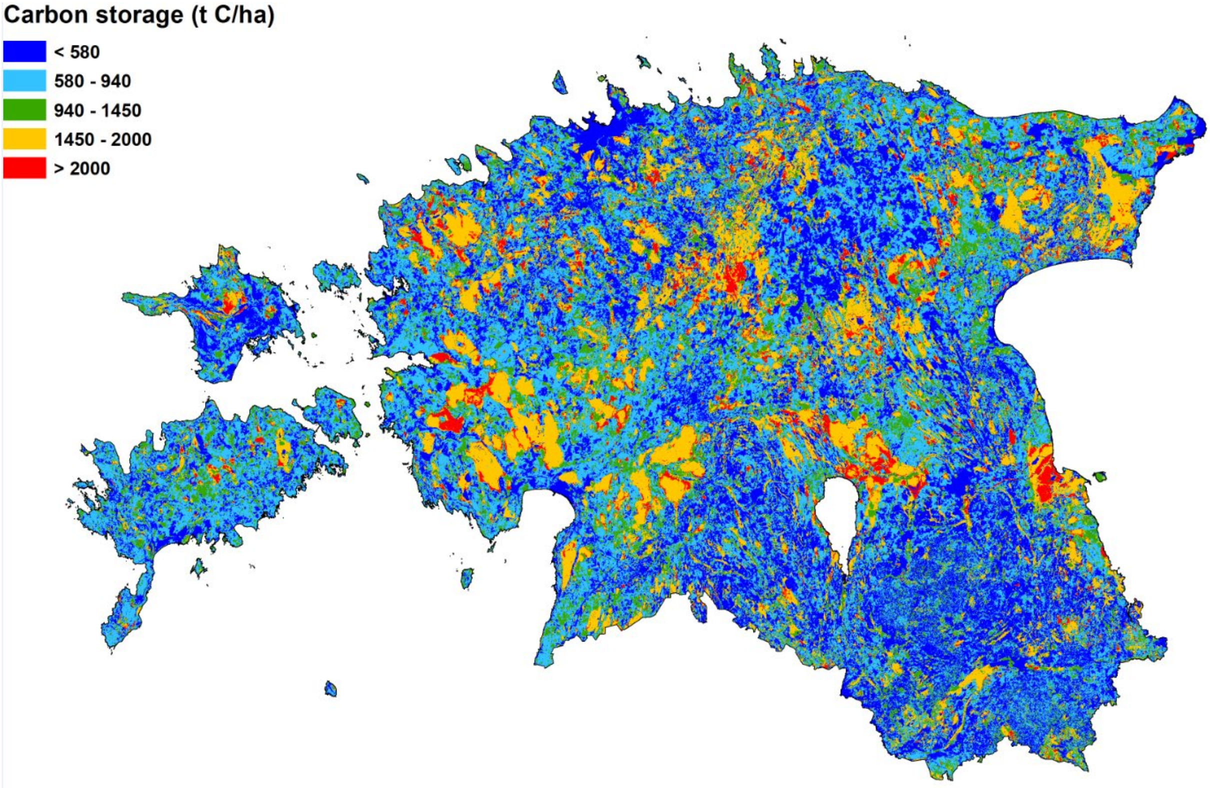
Table 17. Supply of global climate regulation, tonnes, 2022

	Net carbon sequestration (tonnes)	Stored organic carbon (tonnes)
1 Settlements and other artificial areas	630.6	152 514 320
2 Cropland		557 511 530
3 Grassland (pastures, semi-natural and natural grassland	46 433.8	385 212 935
4 Forest and woodland	452 023.4	2 418 070 842
5 Heathland and shrub		11 967 133
6 Sparsely vegetated ecosystems		2 415 463
7 Inland wetlands		485 431 298
8 Rivers and canals		44 452 594
9 Lakes and reservoirs		14 358 707
10 Marine inlets and transitional waters		160 409
11 Coastal beaches, dunes and wetlands		1 743 615
Total supply	499 087.8	4 073 838 845

Table 18. Global climate regulation – use table, 2022

	Intermediate consumption by industries	Government final consumption	Households final consumption	Gross capital formation	Exports	Total use
Net carbon sequestration (tonnes)		499 087.8				499 087.8
Stored organic carbon (tonnes)		4 073 838 845				4 073 838 845

Figure 9. The ecosystem service provisioning areas and values of carbon storage. The areas coloured from blue to red represent service provisioning areas according to the physical unit value t C/ha). Areas coloured white represent areas that do not supply the ecosystem service.



Global climate regulation – monetary valuation

Payment for ecosystem services (PES) schemes was considered the best technique to assess the monetary value of the service. European Union (EU) Emissions Trading System was chosen as an appropriate PES scheme and the yearly average European Union Allowance (EUA) price (€/t CO2) was chosen as a unit price. The calculated yearly average EUA price for year 2022 was 83.47 €/t CO2[44].

CO2 net sequestration was multiplied with the EUA price. Carbon stock in tons C was first converted to carbon stock in tons CO2 (ton CO2=3.67 ton C) and then multiplied with the EUA price. The results and division by ecosystem types are presented in Table 19.

The use of the service is attributed to government as was the case in physical account of global climate regulation ecosystem service.

[44] https://icapcarbonaction.com/en/ets-prices

Table 19.Supply of global climate regulation, million EUR, 2022

	Net carbon sequestration (tonnes)	Monetary value of net CO2 sequestration, million EUR	Stored organic carbon (tonnes)	Monetary value of stored organic carbon, million EUR
1 Settlements and other artificial areas	630.6	0.19	152 514 320	47 150
2 Cropland			557 511 530	172 354
3 Grassland (pastures, semi-natural and natural grassland	46 433.8	14.35	385 212 935	119 088
4 Forest and woodland	452 023.4	139.74	2 418 070 842	747 542
5 Heathland and shrub			11 967 133	3 700
6 Sparsely vegetated ecosystems			2 415 463	747
7 Inland wetlands			485 431 298	150 070
8 Rivers and canals			44 452 594	13 742
9 Lakes and reservoirs			14 358 707	4 439
10 Marine inlets and transitional waters			160 409	50
11 Coastal beaches, dunes and wetlands			1 743 615	539
Total supply	499 087.8	154.29	4 073 838 845	1 259 420

Local climate regulation

According to the amendment of Regulation (EU) 691/2011, the ecosystem service local climate regulation is defined as the ecosystem contribution to regulating ambient atmospheric conditions in urban areas through vegetation that improves the living conditions of people and supports economic production. It shall be expressed and reported as the reduction of temperature in cities, due to the effect of urban vegetation, in degrees Celsius on days exceeding 25 degrees Celsius.

The assessment of the service (reduced temperature in degrees Celsius as cooling effect of vegetation) in physical units was done in co-operation with Estonian Environment Agency and an expert from Tallinn University of Technology. The assessment is based on the methodology described in the respective guidance note by Eurostat (fifth draft, 5.10.2023)[45]. Since then the guidance note has gone through revisions and the methodology has matured, therefore there are methodological differences in the approach applied when compared to the latest available guidance note. Regardless, the results were attempted to fit in the frame of newer versions of guidance and several unresolved issues were detected, which are discussed in subchapter “Discussion and future work”. Current results of the ecosystem service local climate regulation estimation is a first attempt to compile this statistics. Being however a major methodological work, the results are still to be considered preliminary. In upcoming work in 2025 methodological development work is foreseen as regards for example the interpretation of the results.

Possible monetary valuation methods were researched during the project. Reporting average values of reduced temperature is foreseen, which leaves quantifying the total supplied and used service open for discussions if it should be connected with the reported physical indicator. Possible valuation methods would include avoided health costs or replacement costs based on the population of benefitted people and number of days exceeding 25 degrees Celsius which would quantify the supplied service. In 2022, the number of days with maximum temperature exceeding 25°C was 34.

[45] Eurostat – Unit E2. Doc. Doc. ENV/EA/TF/2023_3/3. Guidance note for accounting for the local climate regulation ecosystem service in the EU – fifth draft. Task force on ecosystem accounting. 5 October 2023.

Alternative valuation method is contingent valuation method. Willingness to pay study on urban ecosystem services, which included microclimate regulation was carried out in 2019. The results were then crosswalked and distributed to ecosystem types of EU ecosystem typology.

The model for assessing the service in physical units is planned to develop further along with testing the model built in INCATool. The monetary valuation, as well, should be developed further.

The supply and use tables and more detailed distribution by ecosystem types and users is given in Annex "D1.8 Dataset on ecosystem service supply-use.xlsx" (MS EXCEL file).

Local climate regulation – physical account

Methodology for the assessment of the cooling effect for local climate regulation ecosystem service by Local Administrative Units (LAU) was developed considering the „Guidance Note for Accounting for the Local Climate Regulation Ecosystem Service in the EU" (Fifth Draft), further referred as „Guidance".

Input data

Used inputs to the cooling model, as suggested by Guidance were:

1.***Land Surface Temperature (LST)-*** as derived from public Landsat 8/9 data, downloadable from the USGS website or preferably by Python (Py) package *Landsat Xplore*. Currently the LST values are calculated from Landsat Level 1 (L1) data, bands B4, B5, B10, as suggested in [2], as more accurate compared to approach [1].

2. ***Tree cover (TCD)*** *data r*etrieved from the Copernicus High Resolution Layer. While the suggestion of the Guidance is to use data in m^2 per 100m-by-100m pixels. Still as the raw data are more precise, the data of 10m by 10m were used for possible more fine-grained analysis further aggregation in later stage. Last available data is from 2018.

3. ***Evapotranspiration (Evap.)*** *from the vegetation,* available on the Google Earth Engine platform

4. Suggested *(by the Guidance)* daily **air temperature (daily absolute maximum)** data can be obtained from modelled data or from in-situ measurements from weather stations, but in this approach **not used.**

Method and implementation

The described below approaches, algorithms, data processing, presentation and export of map layers were implemented by Python (Py) scripts and appropriate *Py* packages and APIs (*application program interfaces*). Example source code scripts and example data are available for inhouse use at Estonian Environment Agency and Statistics Estonia, as this part is not enough documented to be directly used by third parties.

The analysis has been done over one - 2022 year – and 3 cities of Estonia, in the borders of the LAU (local administrative units) – **Tallinn, Tartu, Narva**.

Steps for calculation of the cooling effect:

1) the shape files of the LAUs from the Estonian geoportal (Estonian topographical base maps to be downloaded, (https://geoportaal.maaamet.ee/eng/spatial-data/topographic-maps/estonian-basic-map-1-10-000/etak-layer-names-and-descriptions-p710.html)

2) retrieving the Landsat 8/9 images,

a) get the lists of available images of Level 1, with maximum cloudiness of 15%, from summer period 01.05.2022 to 30.09.2022 (for 2022-year analysis),

b) download the *Level 1* (L1) datasets of found in previous step specific dates,

c) extract from downloaded L1*.*tar* archive files corresponding *GeoTIFF* files, needed for LST calculation (bands B5, B5, B10),

d) calculate the LST estimation for every Landsat 30x30 m pixel, reproject them to Estonian coordinates EPSG:3301, check the point being inside of LAU boundaries and plot the temperature map for the specific scene (date) and LAU, as a heatmap,

e) select by visual inspection artefact-free (e.g. missing of clouds) good datasets by date (and dataset IDs) for LAU under interest,

2) for selected in previous step datasets download nearest by date (of 8-day interval) Evapotranspiration (*Evap.*) maps from Google Earth – by corresponding JavaScript,

3) download from Copernicus TCD dataset the latest 10x10m maps (for Estonia, set of 4 GeoTIFF maps),

4) for each LAU under interest find by linear regression fitting function - the slope for every Landsat image,

a) LST as linear function of *TCD*, over all pixels, so LST approximated as $LST= LST_{tcd0} +a_{tcd} * TCD$,

b) LST as linear function of *Evap.*, over all pixels, so LST approximated as $LST= LST_{evap0} +a_{evap} * Evap$,

c) also, a combined *TCD + Evap.* effect is estimated by fitting of linear regression of two variables

$LST= LST_0 -+ a_{evap2} * Evap. + a_{tcd2} * TCD$, *where* a_{evap2} *and* a_{tcd2} are coefficients (slopes) for the combined *TCD* and *Evap.* effect.

These slope values (as coefficients) are averaged over summer, to have for each LAU one TCD-slope a_{tcd} and one Evap. slope a_{evap} coefficient.

5) projecting the TCD map to specific LAU map in Estonian coordinates, e.g. in 30x30m grid and multiply every TCD value pixel (0…100, in %) to the TCD-slope coefficient, exporting the TCD cooling map as GeoTIFF, for given LAU- to get the cooling map of TCD

The same procedure is applied for *Evap.* map - to get the cooling map of *Evap.*

The same procedure is applied to get combined *TCD+Evap* map. By using of the combined coefficients (slopes) – a_{evap2} *and* a_{tcd2} found in c).

In the final step the *TCD+Evap* cooling pixels are masked by area-cover map the 12 classes *(Settlements and other artificial areas. Cropland, Grassland, Forest and woodland etc.)* and the cooling effect is calculated for each class of 12.

Results

1. Relationship of the LST from the tree coverage (TCD) and evapotranspiration (Evap.).

1.1 Separate fitting of *TCD* and *Evap.* by linear regression

For Tallinn the Landsat 8 /9 datasets of 2022-06-06, 2022-07-22 and 2022-08-16 were filtered out, for Tartu 2022-06-06, 2022-06-23, 2022-08-18 and for Narva 2022-06-24, 2022-08-11, 2022-08-18.

The TCD slope of LST was found by linear regression model by averaging the values of each Landsat dataset.

For Tallinn the coefficients estimated were -0,05 °C / TCD% and -0,50 °C/Evap (mm/day).

For Tartu the coefficients estimated were -0,04 °C / TCD% and -0,35 °C/Evap (mm/day).

For Narva the coefficients estimated were -0,032 °C / TCD% and -0,32 °C/Evap (mm/day).

1.2 Combined fitting of TCD and Evap. by linear regression

Coefficients (slopes) for linear regression fitting of LST to inputs of *TCD* and *Evap.* simultaneously were calculated, over the same datasets as described in separate fitting case (3.1.1), The results were the following.

For Tallinn the coefficients estimated were -0,045 °C / TCD% and -0,35 °C/Evap (mm/day).

For Tartu the coefficients estimated were -0,032 °C / TCD% and -0,31 °C/Evap (mm/day).

For Narva the coefficients estimated were -0,022 °C / TCD% and -0,24 °C/Evap (mm/day).

2. Pixel-level cooling effect calculation from TCD and Evap. data.

The corresponding average TCD and Evap. slope coefficients are multiplied accordingly to TCD and Evap. pixel values (being originally in % units and after multiplication by slope coefficients will be in °C units, showing the cooling effect in the pixels). Examples of the TCD and Evap. maps for 3 cities are shown in the ANNEX 7.

Result of the overall procedure is the GeoTIFF maps of 3 LAU-s (Tallinn, Tartu, Narva) for the given year (2022) of cooling effect, as input to the final aggregation of the cooling pixels for final reporting.

3. The aggregated cooling values according to the ecosystem types

The cooling pixel values for both *TCD* and *Evap.* are aggregated according to t*he ecosystem types.* First, the map of the extent map is used (10x10m GeoTIFF), with 29 classes and then grouped to 12 types, similarly as proposed in the "Alternative cooling effect estimation Methodology", see ANNEX 7 according to the Table of the Appendix 3. The presented values are weighted according to their relative area of the LAU.

Table 20. Tallinn 2022 - estimated average daily cooling (°C) by Tree Coverage (TCD) and Evapotranspiration for period May-September.

	Settlements and other artificial areas	Cropland	Grassland	Forest and woodland	Heathland and shrub	Sparsely vegetated ecosystems	Inland wetlands	Rivers and canals	Lakes and reservoirs	Marine inlets and transitional waters	Coastal beaches; dunes and wetlands	Marine ecosystems
	1	2	3	4	5	6	7	8	9	10	11	12
TCD-cooling	-0.30	-0.01	-0.18	-0.15	0.00	0.00	-0.00	-0.00	-0.03	0.00	-0.00	-1.38*
Evap-cooling	-0.23	-0.02	-0.14	-0.15	-0.00	0.00	-0.00	-0.00	-0.03	0.00	-0.00	-0.88*
TCD+Evap cooling	-0.45	-0.025	-0.27	-0.25	-0.00	0.00	-0.01	-0.00	-0.06	0.00	-0.00	-2.01*

*- The differentiation of the cooling effect of water ecosystems, especially marine, needs to be clarified, for example, whether to equate it to zero, even though the pixels may contain forest

Table 21. Tartu 2022 - estimated average daily cooling (°C) by Tree Coverage (TCD) and Evapotranspiration for period May-September.

	Settlements and other artificial areas	Cropland	Grassland	Forest and woodland	Heathland and shrub	Sparsely vegetated ecosystems	Inland wetlands	Rivers and canals	Lakes and reservoirs	Marine inlets and transitional waters	Coastal beaches; dunes and wetlands	Marine ecosystems
	1	2	3	4	5	6	7	8	9	10	11	12
TCD-cooling	-0.23	-0.87	-0.22	-0.56	-0.01	0.00	-0.04	-0.01	-0.02	0.00	0.00	0.00
Evap-cooling	-0.19	-0.50	-0.15	-0.44	-0.01	0.00	-0.02	-0.01	-0.02	0.00	0.00	0.00
TCD+Evap cooling	-0.38	-1.20	-0.33	-0.90	-0.01	0.00	-0.05	-0.02	-0.03	0.00	0.00	0.00

Table 22. Narva 2022 – estimated average daily cooling (°C) by Tree Coverage (TCD) and Evapotranspiration for period May-September.

	Settlements and other artificial areas	Cropland	Grassland	Forest and woodland	Heathland and shrub	Sparsely vegetated ecosystems	Inland wetlands	Rivers and canals	Lakes and reservoirs	Marine inlets and transitional waters	Coastal beaches; dunes and wetlands	Marine ecosystems
	1	2	3	4	5	6	7	8	9	10	11	12
TCD-cooling	-0.49	-0.25	-0.22	-0.53	-0.01	0.00	-0.09	0.00	-0.01	0.00	0.00	0.00
Evap-cooling	-0.37	-0.19	-0.16	-0.46	-0.01	0.00	-0.12	0.00	-0.01	0.00	0.00	0.00
TCD+Evap cooling	-0.71	-0.33	-0.29	-0.75	-0.02	0.00	-0.16	0.00	-0.02	0.00	0.00	0.00

Supply and use tables

For calculating the value of local climate regulation in the supply table the results of estimated average daily cooling obtained from combined fitting of TCD and Evap. by linear regression were averaged for all the cities in Estonia. Results are presented in Table 23. The results are reported as averages for a day during summer period (1. May to 30. September).

Table 23. Local climate regulation – supply table (average daily reduced temperature °C), 2022

Ecosystem	Local climate regulation (average daily reduced temperature °C)
1 Settlements and other artificial areas	-0.51
2 Cropland	-0.52
3 Grassland (pastures, semi-natural and natural grassland	-0.30
4 Forest and woodland	-0.63
5 Heathland and shrub	-0.01
6 Sparsely vegetated ecosystems	0.00
7 Inland wetlands	-0.07
8 Rivers and canals	-0.01
9 Lakes and reservoirs	-0.04
10 Marine inlets and transitional waters	0.00
11 Coastal beaches, dunes and wetlands	0.00
12 Marine ecosystems (coastal waters, shelf and open ocean	-0.67*

*- The differentiation of the cooling effect of water ecosystems, especially marine, needs to be clarified, for example, whether to equate it to zero, even though the pixels may contain forest

It is recommended in the guidance note to report complementary variables to disentangle the supply and use of the service, especially when the service was calculated as average for the whole summer period as opposed to daily modelling on days exceeding 25 degrees Celsius.

According to hourly maximum temperature, based on weather station data[46], in 2022, in Estonia, the average number of days with maximum temperature exceeding 25°C was 34, number of days with maximum temperature exceeding 30°C was 11 and number of days with maximum temperature exceeding 35°C was 0.

The users of the service are households (Table 24).

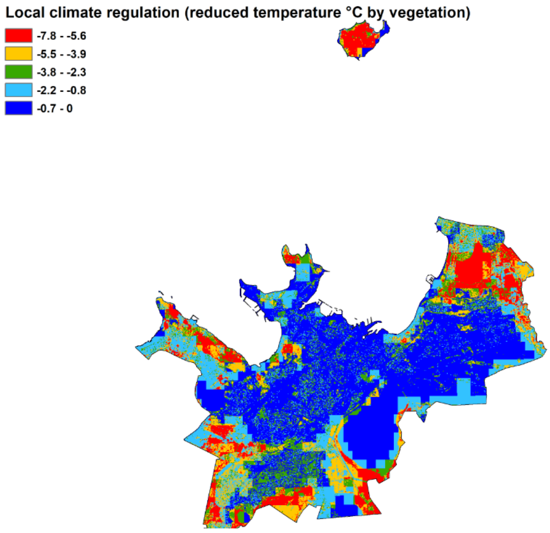
[46] Estonian Environment Agency, Historical weather data https://www.ilmateenistus.ee/kliima/ajaloolised-ilmaandmed/

Table 24. Local climate regulation – use table (average daily reduced temperature °C), 2022

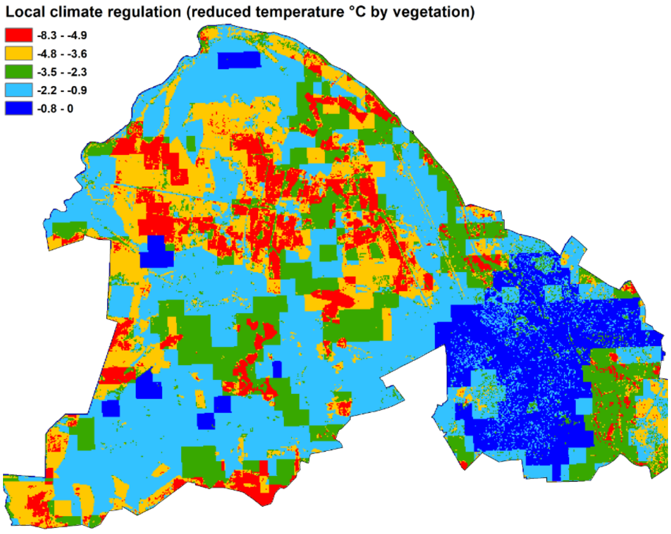
	Intermediate consumption by industries	Government final consumption	Households final consumption	Gross capital formation	Exports	Total use
Local climate regulation (average daily reduced temperature °C)			-0.23			-0.23

Figure 10. Local climate regulation (reduced temperature °C by vegetation) in Estonian cities (Tallinn, Tartu, narva9 by local administrative unit (LAU).

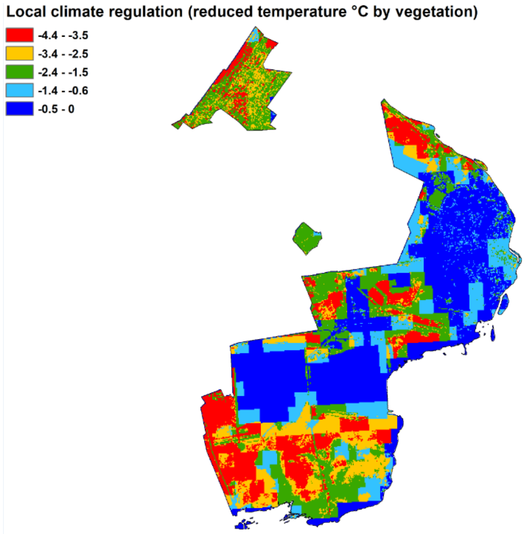
Tallinn – Local climate regulation (reduced temperature °C by vegetation)



Tartu - Local climate regulation (reduced temperature °C by vegetation)



Narva - Local climate regulation (reduced temperature °C by vegetation)



Discussion and future work

Some cities of Estonia e.g. (Tartu, Pärnu) include in the borders of LAU large areas of natural ecosystems and neighboring villages, this has influence on the analysis of the results. Using FUA-functional urban area (smaller area than LAU) has been better option for Tartu and Pärnu. FUA has given more concentrated results showing the urban temperatures.

Various LST derivation approaches from Landsat 8/9 Level 1 (L1) or Level 2 (L2) data could be more investigated to use the most appropriate approach for Estonian cities, not to be limited by [1,2] or direct using of L2 LST-data.

As future work, also suggested in the *Guidance*, the data fusion with other satellite sensor data (e.g. of MODIS) and other available data and modern statistical methods (like machine learning) could probably be reasonable for Estonian LAUs. This could be significant (and interesting) R&D effort, but with not yet predictable usefulness. Also, as the urban temperature heatmaps have repeating patterns, the models of the city temperatures can be created with further possibility to predict the temperature maps by actual data from very few in-situ measurement points.

As comment of today, other optional values (expected by the *Guidance)*, cannot be reported, as there is lack of in-situ measured air-temperature data and datasets, which is metrologically and meteorologically trustful for the Estonian cities. Also, it is not clear are the existing models precise and accurate enough for current urban cooling estimation context. To mention –about availability of in-situ data, typically there is only one weather station per city, located beyond the LAU borders. According to the World Meteorological Organization (WMO) guidelines [6] and for the representative reasons, weather stations are located in the open area, away from high buildings, trees, or other obstructions and artificial surfaces, so typically out of the cities.

Still, for Pärnu city the availability of real data could be very soon available from many measurement points. Also, fusion of other data, e.g. of road weather station measurements – can be investigated.

The mandatory fields to be reported according to the *Guidance* regarding cooling effect over 12 area classes are *Settlements and other artificial areas. Cropland, Grassland, Forest and woodland, Heathland and shrub, sparsely vegetated ecosystems, Inland wetlands, Rivers and canals, Lakes and reservoirs, Marine inlets and transitional waters, Coastal beaches, dunes and wetlands, Marine ecosystems*.

As additional comment - the proposed *Guidance note* approach considers cooling effect only of *Tree Coverage* (TCD) and *Evapotranspiration (*Evap.) from the vegetation, so no effect of *cooling by rivers, lakes, marine ecosystems* is considered. At the same time these area-classes:

a) seem to have significant influence in lowering the average temperature over LAU.

b) and furthermore, this influence of *„water bodies*" seems to be still expected in the reporting part, as mentioned in several of the12 area classes of the *Guidance*.

Also, one can notice – e.g. for Tartu city, the Evapotranspiration occurs even in places where Tree Cover Density is zero. So, the relationship of these two cooling phenomena to the urban temperature could need further investigation.

As "Air temperature dataset Maximum (daily maximum)" input data was not used as an input in the used method. Therefore, the steps suggested by *Guidance* for the linear correlation a) of the LST to TCD and b) LST to Evap. part are applied, but the step of fitting the TCD and Evap. to actual air temperature Tair is not implemented.

It should be mentioned that the initial comparison between the weather station data and the LST relationship has been done, but this study did not give any clear understanding of possible corrections and so needs further investigation. For further work some references are [3-5].

Additionally the size of the effect of evaporation and tree cover density in the model needs to be further specified and analyzed in order to interpret the results better.

The differentiation of the cooling effect of water ecosystems, especially marine, needs to be clarified, for example, whether to equate it to zero, even though the pixels may contain forest.

References

[1] G. Kaplan, U. Avdan, and Z. Yigit Avdan, "Urban Heat Island Analysis Using the Landsat 8 Satellite Data: A Case Study in Skopje, Macedonia," in Proceedings of the 2nd International Electronic Conference on Remote Sensing, 03 2018

[2] V. Sagris and M. Sepp, "Landsat-8 tirs data for assessing urban heat island effect and its impact on human health," IEEE Geoscience and Remote Sensing Letters, vol. 14, no. 12, pp. 2385–2389, 2017.

[3] M. Naserikia, M. A. Hart, N. Nazarian, B. Bechtel, M. Lipson, and K. A. Nice, "Land surface and air temperature dynamics: The role of urban form and seasonal-ity," Science of The Total Environment, vol. 905, p. 167306, 2023. [Online]. Available:

https://www.sciencedirect.com/science/article/pii/S0048969723059338

[4] A. Gemitzi, P. Dalampakis, and G. Falalakis, "Detecting geothermal anomalies using Landsat 8 thermal infrared remotely sensed data," International Journal of Applied Earth Observation and Geoinformation, vol. 96, pp. 1–13, 04 2021.

[5] F. Arabi Aliabad, M. Zare, H. Ghafarian Malamiri, and E. Ghaderpour, "Improving the accuracy of Landsat 8 land surface temperature in arid regions by Modis water vapor imagery," Atmosphere, vol. 14, no. 10, 2023. [Online]. Available: https://www.mdpi.com/2073-4433/14/10/1589

[6] World Meteorological Organization, Guide to Climatological Practices, WMO-No. 100. Secretariat of the World Meteorological Organization, 2018.

An overview of studies on the calculation of economic value of the local climate regulation ecosystem service

The proposed legal module Ecosystem accounts defines the local climate regulation service as evaporative cooling of ambient air provided by urban trees. (Hereafter: *microclimate regulation.*) This service is of particular relevance to urban areas where most people are concentrated as well as due to the urban heat island effect where urban areas heat up more than the rural areas. According to the European Commission Eurostat guidance note (2023) the microclimate regulation is expressed and reported as the reduction of temperature in cities, due to the effect of urban vegetation on days exceeding 25 degrees Celsius (measured during a 24h period). [47]

The main aim of this paper is to give an overview of the studies where the economic value of the urban microclimate regulation has been calculated, and analyses which of these studies can be used for benefit transfer. Three limiting factors of the search was set following:

1. The study calculates the economic value of microclimate regulation in urban areas;
2. The publication period of the article is from 2010 to the present day;
3. The study was carried out in countries with similar or close socio-economic and climatic conditions to Estonia.

The following databases was used: Ecosystem Services Valuation Database (ESVD)[48], research database EBSCO *via* Tallinn University of Technology library[49], The ReseachGate[50]. Also simple Google search[51] was used. The following key words was used to search appropriate scientific articles and reports: "monetary value", "economic value", "value", "microclimate regulation" "local climate regulation" "cooling", "heat reduction", "urban park", "urban forest", "urban tree", "heatwaves".

Below is presented study reports that may be considered to use for benefit transfer. No of these results are directly transferable as they have been carried out in countries with very different socio-economic and climatic conditions compare with Estonia.

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[47] Eurostat – Unit E2. Doc. Doc. ENV/EA/TF/2023_1/2. Guidance note for accounting for the local climate regulation ecosystem service in the EU – third draft. Task force on ecosystem accounting. 21 – 22 February 2023.
[48] https://www.esvd.net/
[49] https://taltech.ee/koik-andmebaasid
[50] https://www.researchgate.net/
[51] https://www.google.com/

1. McDonald and others (2020)[52] have assembled GIS-based information on tree cover and developed land-cover information for 97 US cities, housing 59 million people, and have used regression analyze to discover how much current urban tree cover reduces summer air temperatures and associated heat-related mortality, morbidity, and electricity consumption. To estimate the value of avoided morbidity a cost-of-illness approach is applied, quantifying the costs of emergency department and outpatient visits, hospitalizations, and the lost work productivity associated with these events. For estimating the value of avoided electricity consumption, data on average household residential electricity consumption and average cost per KWh of electric have used.

They found that 78% of urban dwellers are in neighbourhoods with less than 20% tree cover. Some 15.0 million people (25% of total) experience a reduction of 0.5–1.0°C from tree cover, with another 7.9 million (13% of total) experiencing a reduction of greater than 1.0°C. Relationships between temperature and health outcomes imply that urban tree cover helps avoid 245–346 deaths annually. For the 97 cities studied, the total annual economic value of avoided mortality, morbidity, and electricity consumption is an estimated $1.3–2.9 billion, or $21–49 annually per capita. Analysis estimated the value of avoiding one unit of heat-related impact, expressed in 2015 US dollars (USD, $).

The results of this study can be used for benefit transfer to calculate economic value of microclimate regulation in Estonia. During the transfer process the economic difference of the study country and Estonia must be levelled.

In the following articles, the economic value of the microclimate regulation of a specific ecosystem has been calculated using the conditional valuation method (CVM), i.e. the welfare value of the ecosystem service has been found.

2. Chen and Nakam (2015)[53] studied residents' preference and willingness to conserve homestead woodlands in coastal villages in Okinawa Prefecture, Japan. Homestead woodlands have played a key role in protecting settlements from strong wind and storm. To evaluate residents' willingness to conserve homestead woodlands the contingent valuation method (CVM) was used. The survey was conducted in December 2011 - January 2012. The sample size was 535, of which 480 answers were analyzed.

The majority of respondents (91%) favoured the conservation of homestead woodlands. Estimated mean and median lump sum willingness to pay (WTP) were JPY 1451 (USD 18[54]) per household and JPY 1000 (USD 12) per household, respectively.

The results of this study are useable for benefit transfer to calculate economic value of microclimate regulation of urban green areas. At the same time must consider that the willingness to pay for conservation of homestead woodlands was studied that is broader concept than microclimate regulation.

3. Zhang, *et al* (2021)[55] investigated residents' WTP for permeable pavement construction to mitigate urban heat impacts (UHI). The CVM was used and the WTP question was presented as follows: "If the Guangdong provincial government plans to replace more than 80% of the urban built-up area with permeable pavement by 2030, considering your financial condition and personal experience, would you agree to pay extra on your monthly water bill for the next 10 years to promote the construction of permeable pavement for UHI mitigation?" In questionnaire three bidding options were proposed: 5CNY, 20CNY, and 50CNY. The water bill was chosen as a payment vehicle in this study because it is compulsory and thus reduces the possibility of free riding.

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[52] McDonald, R.I., Kroeger, T., Zhang P., Hamel, P (2020) The Value of US Urban Tree Cover for Reducing Heat-Related Health Impacts and Electricity Consumption. Ecosystems volume 23, pages137–150
[53] Chen, B., Nakama, Y. (2015) Residents' preference and willingness to conserve homestead woodlands: Coastal villages in Okinawa Prefecture, Japan. Urban Forestry & Urban Greening. Volume 14 (4), pg 919-931. https://www.sciencedirect.com/science/article/pii/S1618866715001181
[54] USD 1 = 81.45 JPY (2011)
[55] Zhang, L., Yang, X., Fan, Y., Zhang, J. (2021) Utilizing the theory of planned behavior to predict willingness to pay for urban heat island effect mitigation. Building and Environment. Volume 204, 108136. https://www.sciencedirect.com/science/article/pii/S0360132321005370#bib66

799 urban residents of Guangdong Province responded to an online questionnaire. WTP intention was explored by establishing structural equation modelling based on the extended theory of planned behavior.

The findings show that the mean WTP was CNY 17.98 (USD 2.58[56]) per resident per month for permeable pavement construction for its UHI mitigation benefit. According to the official statistics, there were 115.21 million residents in Guangdong in 2019, so the present value of the total annual public WTP amounts to CNY 24.86 billion (USD 3.82 billion) per year.

Since the study does not specify how large area will be covered with permeable pavement, and how many degrees the UHI will decrease, the result obtained from benefit transfer is suitable to illustrate the situation in general.

Ecosystems that provide a microclimate regulation service are the subject of the following two studies.

4. Zhang, *et al* (2017)[57] conducted the study to estimate the economic values of and the dominant contributors to five key ecosystem services of wetlands in Beijing (total area 51 434 ha), by using the wetland inventory data in 2014 and economic valuation methods.

From June to August in Beijing, evaporation from water surfaces reaches is 363.8 mm; hence, the amount of evaporated water reaches approximately 134 million tons based on water surface ratio and wetland areas. The heat of water evaporation is 2260 kJ/kg in circumstances such as 1 standard atmospheric pressure and 100 °C; therefore, wetlands in Beijing can absorb approximately 3.03 PJ of heat through water evaporation during hot summer days, with an average value of 58.96 GJ/ha. River wetland can absorb 1.34 PJ of heat, reservoir wetland absorbs 1.15 PJ of heat as ponds, marshes and park wetlands are minor contributors to summertime heat absorption. However, reservoir wetland exhibits the highest absorption heat capacity with a value of 73.48 GJ/ha. On 2014, the price of electricity in Beijing was 0.5 RMB/kwh.

On 2014, total monetary value of the cooling effect of Beijing wetlands was calculated RMB 421 million[58] (USD 69 million) or RMB 8185 (USD 1333) per hectare.

5. Qianjiangyuan National Park in Kaihua County area is mainly (81.7%) covered by forest, remaining area is wetland and water. Zhao, *et al* (2019)[59] mapped ecosystem services of the park and calculated their economic value by using market value method and shadow engineering method. Studies were carried out in years 2005, 2010, 2015, and 2018.

According to the study methodology only wetland contributes to climate regulation. The value of regulating humidity have calculated by multiplying the average surface evaporation, steam power consumption converted from per unit volume of water and electricity price. The value of regulating temperature have calculated by multiplying the average surface evaporation, heat of vaporization of water and electricity price. Climate regulation service benefits people from May until September and therefor the value has calculated only for this period.

The total value of regulating humidity and temperature was RMB 0.51 billion (USD 63 million[60]), RMB 0.41 billion (USD 62 million[61]), RMB 0.27 billion (USD 42 million[62]), RMB 0.18 billion (USD 26 million[63]) in 2005, 2010, 2015 and 2018 respectively or USD 14.000, USD 13.800, USD 9.333 and USD 5.800 per one hectare of wetland in 2005, 2010, 2015 and 2018 respectively.

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[56] USD 1 = CNY 6.96 (2019)

[57] Zhang, B., Shi, Y., Liu, J., Xu, J., Xie, G. (2017) Economic values and dominant providers of key ecosystem services of wetlands in Beijing, China. Ecological Indicators. Volume 77, pg 48-58. https://www.sciencedirect.com/science/article/pii/S1470160X17300535

[58] USD 1 = RMB 6.14 (2014)

[59] Zhao, X., He, Y., Yu, C., Xu, D., & Zou, W. (2019). Assessment of Ecosystem Services Value in a National Park Pilot. Sustainability, 11(23), 6609. https://www.researchgate.net/publication/337451727_Assessment_of_Ecosystem_Services_Value_in_a_National_Park_Pilot#fullTextFileContent

[60] USD 1 = RMB 8.07 (2005)

[61] USD 1 = RMB 6.59 (2010)

[62] USD 1 = RMB 6.50 (2015)

[63] USD 1 = RMB 6.88 (2018)

According to the comment of reviewer of the Ecosystem Services Valuation Database, the results seem to be too high.

In conclusion, the methods considered for benefit analysis for local climate regulation gave different results. However, as the methods are also different, the results are not easily comparable. Also, the methods mainly rely on contingent valuation (willingness to pay) and not using the quantity of the physical indicator that is currently defined as the reduction of temperature due to the effect of vegetation in cities. Therefore, no basis was found for the application of benefit transfer method for this service.

Local climate regulation based on CVM study – monetary valuation

Regulating the microclimate (or lowering the temperature) in an urban environment is a service that is becoming more and more actual due to the warming of the climate, the increase in the number of consumers can also be predicted geographically, including in the northernmost countries of Europe. Unlike several other ecosystem regulatory services, such as carbon sequestration, microclimate has an immediate, directly felt effect on the welfare of individuals. Therefore, microclimate regulation service of the ecosystem has, in addition to the regulatory one, a strong welfare service component, and its value can be studied not only by the biophysical methods, but also by methods characteristic of the welfare services of the ecosystem.

The ecosystem microclimate regulation service has been studied as a welfare service mostly in Asia. For example, the contingent valuation (hereafter CVM) method has been used to study the ecosystem service value of urban forests in South Korea (Jo Jang-Hwan et. al., 2020)[64] and to study the ecosystem service value of forests in Japan (Bixia Chen, Yuei Nakama, 2015)[65]. Neither of the studies cited above specifically focuses on the microclimate regulation service of the ecosystem but examines this service together with other services. The same approach is used in the study of well-being services of urban ecosystems in Estonia (Ehrlich, 2022)[66] where microclimate-regulating services of urban ecosystems are studied in one CVM study together with other services of urban ecosystems.

A contingent valuation study on ecosystem services of urban green spaces in Estonia was conducted in 2019. The survey is based on 720 respondents and the sample structure was representative of the Estonian adult population. Whereas one of the aims of the CVM study was to find the financial equivalent of nonmarket services in the urban ecosystem, the structure of the questionnaire was more complicated than typical CVM survey. In addition to the typical parts of the CVM questionnaire, such as the simulated market scenario, the willingness to pay question (discrete choice format) and the sociometric part of the respondents, the questionnaire also included additional questions on the use and sufficiency of urban green areas. To link WTP to individual services of urban ecosystems, respondents were asked to rank urban ecosystems and ecosystem services according to their subjective preferences.

The estimation of the aggregated demand curve for the preservation and maintenance of urban green spaces of Estonian`s adult population is based on the actual distribution of WTP amounts obtained from the survey. The results are generalized to the proportion of the population with positive WTP, which is 90,5 per cent i.e. about 969000 persons 18 years of age or older in Estonia as of January 1st, 2019. In calculations, one respondent corresponds to 1486 inhabitants. The annual demand for urban green spaces by the Estonian adult population expressed through WTP is approx. 17,29 million euros.

In addition to identify willingness to pay for urban ecosystem services, an additional goal of the study was to divide willingness to pay between different services according to individuals' subjective preferences for services. The corresponding data are presented in Table 25.

[64] Jo Jang-Hwana, Park So-Heeb, Koo JaChoonc, Roh Taewood, Emily Marie Lime and Youn Yeo-Changb, 2020. Preferences for ecosystem services provided by urban forests in South Korea. Forest Science and Technology E-ISSN 2158-0715, 2020, VOL. 16, NO. 2, 86–103. https://doi.org/10.1080/21580103.2020.1762761

[65] Bixia Chen, Yuei Nakama, 2015. Residents' preference and willingness to conserve homestead woodlands: Coastal villages in Okinawa Prefecture, Japan. Urban Forestry & Urban Greening, Vol 14 (4), pg 919-931. https://www.sciencedirect.com/science/article/pii/S1618866715001181

[66] Ehrlich, Ü., 2022. Willingness to pay for urban ecosystem services as input for statistics: a case of Estonia. Estonian Discussions on Economic Policy, 30 (1-2), 85–103. DOI: 10.15157/tpep.vi1-2.22088.

Table 25. The willingness to pay of the Estonian population for urban ecosystem services.

Urban area ecosystem service	Importance	% (of inverse value)	WTP (thousand EUR)
City air purification	1.	14.9	2579.0
Photosynthesis (oxygen production)	2.	11.1	1924.8
Providing recreation and leisure opportunities	3.	10.9	1884.9
Traffic noise reduction	4.	10.3	1773.5
Habitat supply for biological species (e.g. birds)	5.	10.2	1766.1
Ensuring the diversity of urban space	6.	9.7	1673.1
Urban microclimate regulation and carbon sequestration	7.	9.7	1674.5
Offering aesthetic pleasure (flower buds, alleys)	8.	8.1	1401.7
Providing shade for people (e.g. from wind and sun)	9.	7.9	1360.7
Providing opportunities for environmental education	10.	7.2	1249.4
TOTAL		100	17287.8

The shortcoming of the study in relation to the identification of the microclimate regulation service of the urban ecosystem is the formulation of the service "Urban microclimate regulation and carbon sequestration" used in the questionnaire, which handles microclimate regulation and carbon sequestration together in one service. It can be assumed that the microclimate regulation service separately (without carbon sequestration) would have received a lower place in the ranking and thus a lower willingness to pay. However, according to the formulation in the questionnaire, individuals placed this service in seventh place (among 10 services), according to which approximately 1.7 million euros per year were attributed to this service from the total willingness to pay.

In addition to individuals' preferences for ecosystem services, the subjective importance of different urban ecosystems for people was also investigated, on the basis of which WTP was distributed among different ecosystems. The corresponding results are presented in Table 26.

Table 26. Distribution of WTP for the service “Urban microclimate regulation and carbon sequestration” between urban ecosystems.

Urban Ecosystem	WTP, thousand EUR
Big Parks	390.18
Small parks in the city centre	289.22
Tall landscaping (by the roads)	266.13
Forests within the city borders	210.82
Privately owned gardens	175.83
Lawn strips and flower pots by the sidewalks	175.35
Lawn strips by the road and between lanes	166.98
TOTAL, thousand EUR	1674.52
% of total value	9.69

People considered "Big parks" to be the most important ecosystem, whose "Urban microclimate regulation and carbon sequestration" service can be attributed 390 thousand euros per year from the total willingness to pay. "Small parks in the city center" (298 thousand euros) and "Tall landscaping" (266 thousand euros) follow. As expected, "Lawn strips and flower pots by the sidewalks" and "Lawn strips by the road and between lanes" are among the last ecosystem elements, as urban ecosystems with smaller biomass, which participate more modestly in climate regulation compared to parks.

The different urban green features were crosswalked to ecosystem types of EU ecosystem typology:

- 1.4 Urban greenspace: big parks, small parks in the city centre, tall landscaping (by the roads), forests within the city borders,
- 1.5 Other artificial areas: privately owned gardens, lawn strips and flower pots by the sidewalks, lawn strips by the road between lanes

Based on the obtained results monetary supply and use tables were compiled. The result is presented in Table 27. The service is only supplied in the ecosystem class Settlements and other artificial areas.

The users of the service are households.

Table 27. Monetary value of the supply of local climate regulation, million EUR, 2022

	Monetary value of local climate regulation services, million EUR
1 Settlements and other artificial areas	1.67
1.4 Urban greenspace	1.16
1.5 Other artificial areas	0.52

Nature-based tourism-related services

According to the amendment of Regulation (EU) 691/2011, the ecosystem service nature-based tourism-related services are defined as the ecosystem contribution, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. Those contributions shall be reported in number of overnight stays in hotels, hostels, camping grounds, etc. that can be attributed to visits to ecosystems.

The methodology for assessing nature-related tourism in physical units was built on previous experience and guidance in the respective guidance notes by Eurostat. The number of overnight stays was first distributed by degree of urbanisation and further the contribution by ecosystem types was calculated using Recreation Map Potential by JRC in INCA Tool version 2.1[67].

For monetary valuation, the service was valued with expenditures made during the trip.

The supply and use tables and more detailed distribution by ecosystem types is given in Annex "D1.8 Dataset on ecosystem service supply-use.xlsx" (MS EXCEL file).

Nature-based tourism-related services – physical account

The number of overnight stays of tourists in hotels, hostels, camping grounds, etc., that can be attributed to visits to ecosystems is considered the mandatory indicator for the nature-based tourism-related ecosystem service.

Guidance note by Eurostat[68] requires using a three step-approach for the measurement of the indicator:

1) Collecting tourism statistics on overnight stays
2) Isolating the ecosystem contribution in general
3) Apportioning overnight stays between ecosystem types.

We used statistics on nights spent in hotels, holiday and other short-stay accommodation; camping grounds, recreational vehicle parks and trailer parks published at NUTS level 2 published by Eurostat (Online data code: TOUR_OCC_NIN2D, (https://ec.europa.eu/eurostat/databrowser/view/tour_occ_nin2d/default/table?lang=en), which is also available in Statistics Estonia Database (TU111: Accommodation by type of settlement, https://andmed.stat.ee/et/stat/majandus__turism-ja-majutus__majutus/TU111). The input data on overnight stays is given in Table 28.

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[67] https://ecosystem-accounts.jrc.ec.europa.eu/inca-tool
[68] Eurostat – Unit E2. Guidance Note for Accounting for the Recreation-Related Ecosystem Service – Final Draft for Testing. (Version October 2023)

Table 28. Nights spent at tourist accommodation establishments by degree of urbanisation, 2022

	Domestic	Foreign	Total
Cities	941 895	2 151 292	3 093 187
Towns and suburbs	775 113	492 784	1 267 897
Rural areas	1 314 806	274 983	1 589 789
Total	3 031 814	2 919 059	5 950 873

At NUTS level 2 Estonia is considered as one region, including the bigger cities. There are more detailed tourism statistics available in Statistics Estonia, such as overnight stays by municipality level (TU112: Accommodated tourists and nights spent by county and country of residence, https://andmed.stat.ee/en/stat/majandus__turism-ja-majutus__majutus/TU112), which could be used to improve the accuracy of isolating the ecosystem contribution and the apportionment to ecosystem types in the next steps.

It is recommended that calculating the ratio of ecosystem contribution is done by applying Recreation Potential Map (RP, developed by JRC), which is based on the presence of reachable opportunities for nature-based activities (quantified using inland and water related elements). The ratio of ecosystem contribution could be then scaled based on additional data like input data on higher spatial accuracy, the degree of urbanization or trip purpose. However, as the Recreation Potential Map is not yet available for the member states to be used additional data sources could not be applied in this step and it was decided it is better to use degree of urbanization and corresponding ecosystem contribution ratios by expert judgement to reflect better the share of overnight stays that could be attributed to visits to ecosystems. Rough estimations based on available national statistics on overnight stays and trip purpose (percentage of trips for professional versus personal reasons in cities, rural areas and in between) were 20% for cities, 60% for towns and suburbs and 90% for rural areas (Table 29).

Table 29. Nights spent at tourist accommodation establishments attributed to visits to ecosystems, 2022

	Ecosystem Contributio Ratio	Domestic country	Foreign country	Total
Cities	20	188 379	430 258	618 637
Towns and suburbs	60	465 068	295 670	760 738
Rural areas	90	1 183 325	247 485	1 430 810
Total		1 836 772	973 414	2 810 186

The total number of overnight stays attributed to visits to ecosystems were further attributed to specific ecosystem types at level 1 on EU Ecosystem typology using the Recreation Potential Map developed by JRC. In Recreation Potential Map the spatial allocation is based on a weighted distribution inside NUTS2 regions, whereby the percentage of overnights stays attributed to an ecosystem is equal to the attractiveness metric of the ecosystem divided by the sum of all attractiveness metrics within the NUTS2 region.

The calculations were done in INCA Tool version 2.1[69] and the model was modified to use ecosystem extent map for year 2022 created by Statistics Estonia and aforementioned degrees of urbanisation. Recreation potential map is based on CORINE Land Cover map. When using Estonian ecosystem extent map misalignments between ecosystem types occurred. For example, ecosystem types ‘Settlements and other artificial areas and ‘Cropland’, which were attributed 0-value in default approach, now obtained values. It was decided not to modify the model further and therefore values for all ecosystem types were included. The result is presented in Table 30

[69] https://ecosystem-accounts.jrc.ec.europa.eu/inca-tool

Table 30. Supply of Nature-based tourism-related services by ecosystem types, 2022.

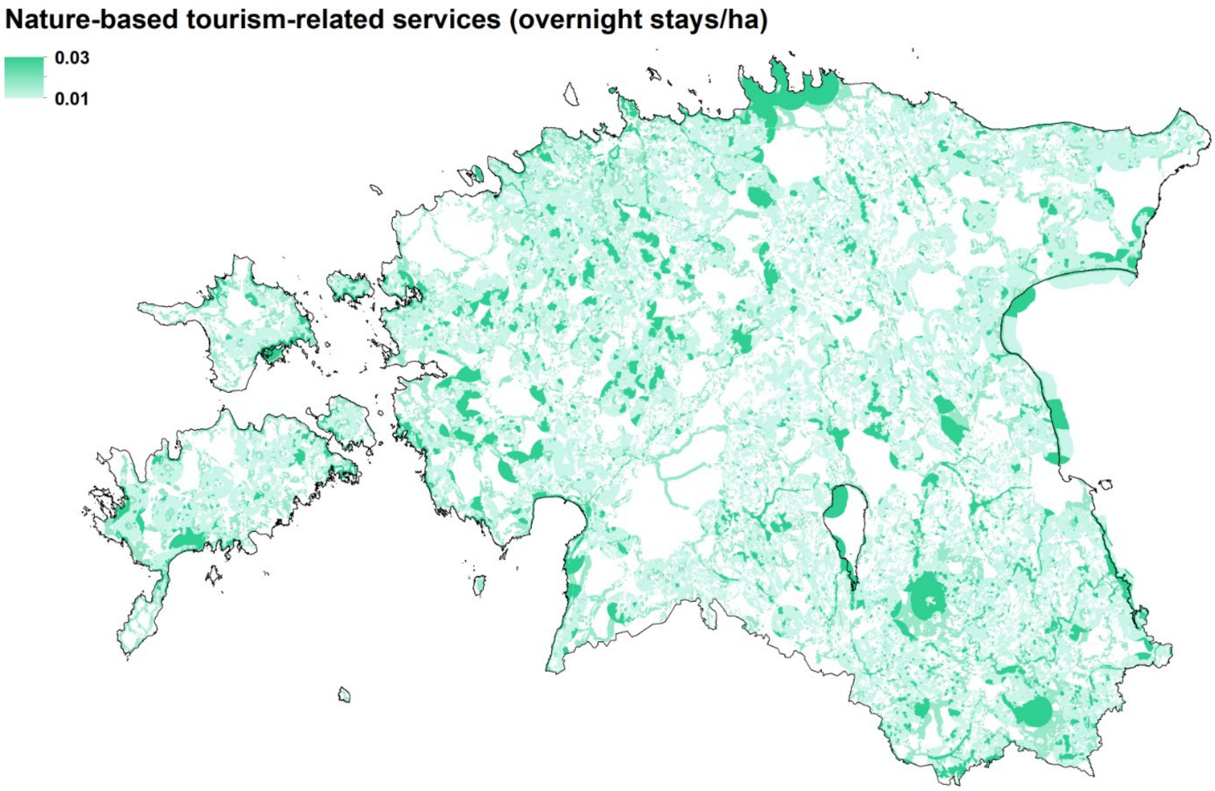
	Number of overnight stays that can be attributed to visits to ecosystems
1 Settlements and other artificial areas	178 924
2 Cropland	216 111
3 Grassland (pastures, semi-natural and natural grassland	355 484
4 Forest and woodland	1 677 465
5 Heathland and shrub	12 677
6 Sparsely vegetated ecosystems	2 985
7 Inland wetlands	202 493
8 Rivers and canals	21 357
9 Lakes and reservoirs	134 128
10 Marine inlets and transitional waters	961
11 Coastal beaches, dunes and wetlands	1 694
12 Marine ecosystems (coastal waters, shelf and open ocean	5 906
Total supply	2 810 185

The use of the service is divided between household and export. Domestic tourism by residents is to be reported as 'Households' final consumption'. Overnight stays performed by visitors who are not resident of the reporting country (also called inbound tourism) are to be reported as 'Exports'. The result is presented in Table 31 and as an illustrative map in Figure 11.

Table 31. Use of nature-based tourism-related services, 202.

	Households	Export	Total use
Number of overnight stays that can be attributed to visits to ecosystems	1 836 772	973 413	2 810 185

Figure 11. The ecosystem service provisioning areas and values of nature-based tourism-related services.



Nature-based tourism-related services – monetary valuation

For monetary valuation, the service was valued with expenditures made during the trip. Alternative valuation was done by time-use approach.

There is data available from tourism statistics on the average expenditure on an overnight domestic trip for holidays, leisure and recreation purpose (TU56: Expenditure on an overnight domestic trip of Estonian residents by main purpose of trip, https://andmed.stat.ee/en/stat/majandus__turism-ja-majutus__eesti-elanike-reisimine/TU56). In 2022 it was 204.98 EUR. The expenditure includes expenses for travel, accommodation, catering, entertainment, shopping and other money spent.

Table 32. Monetary value of the supply of nights spent at tourist accommodation establishments by ecosystem types using expenses made during the trip, million EUR, 2022

	Monetary value of nature-related tourism related services, million EUR
1 Settlements and other artificial areas	36.68
2 Cropland	44.30
3 Grassland (pastures, semi-natural and natural grassland	72.87
4 Forest and woodland	343.85
5 Heathland and shrub	2.60
6 Sparsely vegetated ecosystems	0.61
7 Inland wetlands	41.51
8 Rivers and canals	4.38
9 Lakes and reservoirs	27.49
10 Marine inlets and transitional waters	0.20
11 Coastal beaches, dunes and wetlands	0.35
12 Marine ecosystems (coastal waters, shelf and open ocean	1.21
Total supply	576.03

The use in monetary terms is divided similarly as was done for use in physical units.

Table 33. Use of nature-based tourism-related services, million EUR, 2022

	Households	Export	Total use
Monetary value of nature-related tourism related services , million EUR	376.50	199.53	576.03

Alternative valuation was done by applyingy the valuation by time use and use the monetary equivalent of contact time with ecosystems 56 EUR/overnight trip which was based on that 1 hour=7 EUR and that the average contact time of one person with nature (ecosystems) during one overnight trip is 8 hours. The results are seen in Table 34.

Table 34. Monetary value of the supply of nights spent at tourist accommodation establishments by ecosystem types using time use valuation, million EUR, 2022

	Monetary value of nature-related tourism related services, million EUR
1 Settlements and other artificial areas	10.02
2 Cropland	12.10
3 Grassland (pastures, semi-natural and natural grassland	19.91
4 Forest and woodland	93.94
5 Heathland and shrub	0.71
6 Sparsely vegetated ecosystems	0.17
7 Inland wetlands	11.34
8 Rivers and canals	1.20
9 Lakes and reservoirs	7.51
10 Marine inlets and transitional waters	0.05
11 Coastal beaches, dunes and wetlands	0.09
12 Marine ecosystems (coastal waters, shelf and open ocean	0.33
Total supply	157.37

Flooding mitigation

Flooding mitigation is not included in the amendment of Regulation (EU) 691/2011 as an item to be reported. The service was suggested to be included in the module fo ecosystem accounts during the discussions for proposal of the amendment of the regulation by the experts in Estonian Ministry of Climate. During the discussions and scoping of additional items that ecosystem accounts in Estonia should cover, the interest was reinforced (ANNEX 1). As a result assessing flooding mitigation was added as a task to be completed in this round of compiling ecosystem accounts for year 2022.

The assessment of the service was done in co-operation with Estonian Environment Agency. Based on discussions with experts and adjusted from guidance note by Eurostat[70], the task was defined as:

Evaluate the ecosystem service "flood regulation" for the year 2022 and develop the assessment methodology. The indicator for the actual provision of the service to society is the area (ha) of ecosystems regulating water flows, which protect downstream ecosystems (specifically highlighting those of economic importance, i.e., agricultural land and artificial areas) from flooding. The actual provision of the service is determined based on potential supply and demand. The basis for accounting for the service is the assessment and mapping of water flow regulation capacity, which characterizes the potential supply of the service. The demand indicator is the potentially flood-prone ecosystems (specifically highlighting those of economic importance, i.e., agricultural land and artificial areas).

Flooding mitigation and flood control is used interchangeably in the current chapter.

For monetary valuation of the service, replacement cost method was applied.

Flood control – physical account

Estimates for flood control potential and demand for flood control are based on data aggregated, integrated, and modelled in the Estonian MAES project, Countrywide Socioeconomic Assessment of Ecosystem Services[71] (ELME2). The base year for the ecosystem extent and service maps is 2022. Additionally, maps of the extent of open water[72] from the years 2018-2023 were used to create a map of areas where floods have occurred during the 6-year timeframe.

The objective of this analysis was to identify the spatial relationship between ecosystem service potential and demand. The potential for ecosystem services is represented by the water flow regulation map (m³/ha) from the ELME2 project, which highlights the capacity of ecosystems to mitigate floods and reduce flash floods caused by heavy rainfall. The ability to regulate water flows primarily depends on soil properties, including infiltration capacity, soil texture, and organic carbon content.

Among the flooded areas, croplands and heathlands/shrubs are the most efficient at retaining water, with an average retention capacity of 1847 m³/ha and 1858 m³/ha, respectively. Ecosystems capable of the least amount of water retention are sparsely vegetated ecosystems and coastal beaches, dunes and wetlands, with an average retention capacity of 1106 m³/ha and 1174 m³/ha, respectively (Table 35).

70 Eurostat – Unit E2. Guidance Note for Accounting for Flood Control Ecosystem Service in the EU – First Draft. Doc.ENV/EA/TF/2023_4/6. Task force on ecosystem accounting 28 - 29 November 2023.
71 https://loodusveeb.ee/en/countrywide-MAES-EE-socioeconomic-terrestrial
72 https://www.ilmateenistus.ee/siseveed/extent-of-open-water/?lang=en

Table 35. Flood control potential indicators.

	Area of flood control (ha)	Water flow regulation (m3)	Average water flow regulation (m3/ha)
1 Settlements and other artificial areas	1 732	2 307 617	1 332
2 Cropland	45 302	83 687 535	1 847
3 Grassland (pastures, semi-natural and natural grassland	26 734	42 185 714	1 578
4 Forest and woodland	495	871 290	1 758
5 Heathland and shrub	37	69 040	1 858
6 Sparsely vegetated ecosystems	574	634 720	1 106
7 Inland wetlands	13 206	22 663 317	1 716
11 Coastal beaches, dunes and wetlands	2 133	2 504 179	1 174
Total	63 479	154 923 412	-

The demand for flood control is defined by the extent of economic assets located in floodplains (ha). A map layer was created by overlaying the ecosystem extent map with areas that experienced at least one flood event between 2018 and 2023. Differentiation of economically significant ecosystems, such as urban areas, and cropland from forests, meadows and wetlands, was made based on ecosystem extent map.

During the years of 2018–2023, 110 094 ha of land (2,5% of Estonian land area, including inland water bodies except lakes Võrtsjärv and Peipsi) was affected by a flood event at least once. The demand for flood control within these areas, namely floods on economic assets occurred on 42,7% of the flooded areas – 1732 ha on settlements and other artificial areas and 45 302 ha on cropland (Table 36). By combining the product with the water flow regulation map (m^3/ha) from the ELME2 project, the potential for flood control was obtained (Figure 12). The water flow regulation potential within the flooded areas is estimated at 154 923 412 m3.

Table 36. Supply of flood control ecosystem service, 2022.

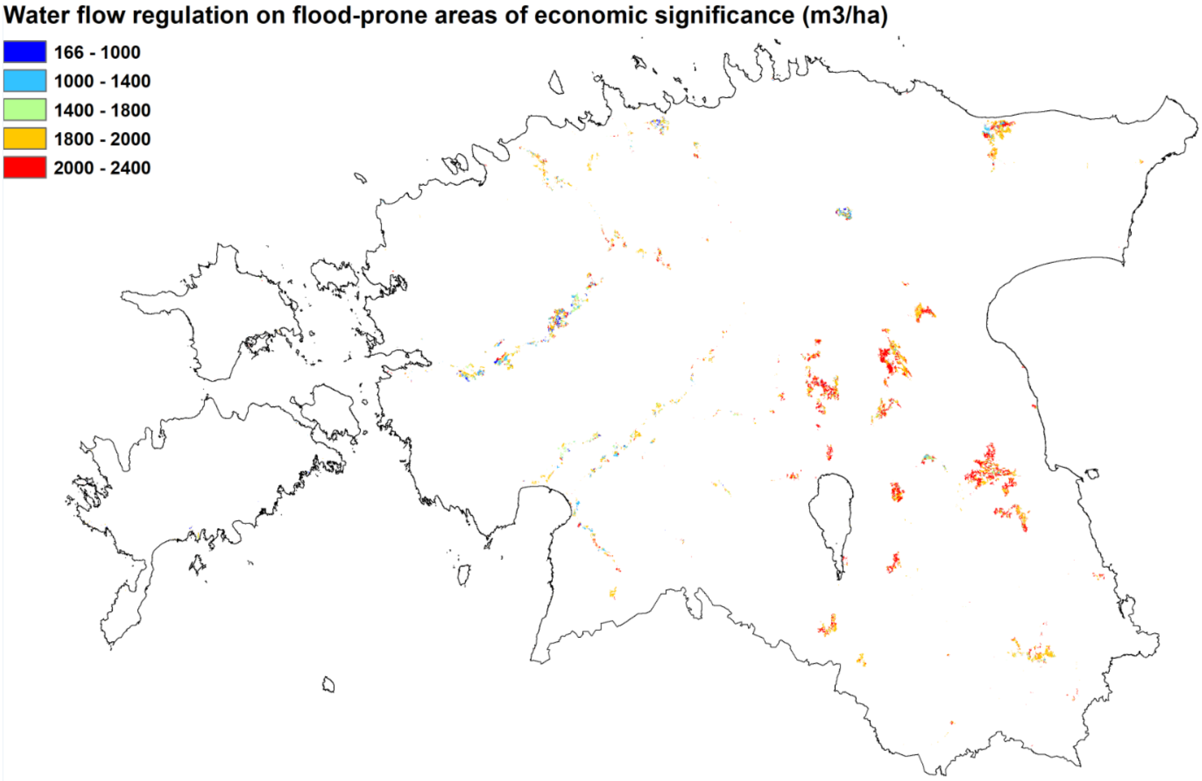
	Demand for flood control: flood-prone area (ha)	Flood control potential – water flow regulation (m3)
1 Settlements and other artificial areas	1 732	2 307 617
2 Cropland	45 302	83 687 535
Total supply	47 034	85 995 152

The use of the service is attributed to the most likely users of the land, where ecosystem service is supplied. For cropland, the users are industries, for settlements and other artificial areas, it is households (Table 37)

Table 37. Use of flood control ecosystem service, 2022

	Intermediate consumption by industries	Households	Total use
Demand for flood control: flood-prone area (ha)	45 302	1 732	47 034
Flood control potential – water flow regulation (m3)	83 687 535	2 307 617	85 995 152

Figure 12. Flood control ecosystem service represented as water flow regulation (m3/ha) on flood-prone areas of economic significance (Settlements and other artificial areas, croplands).



Since the maps of past floods were used to define the analysed area (demand for flood control), regions where the water flow regulation ecosystem service has effectively functioned (i.e., the ecosystem has rapidly buffered the flows and hence there are no reported flood events) over the 6-year period are not included in this analysis. As a result, the actual demand value of the ecosystem service is likely higher than the figures reported here. For further research, using ancillary products, e.g., earth observation data on soil moisture, is recommended. Also, the flood data could be more deeply explored to possibly gain more exact information on flooded forest areas under tree canopies, etc.

To represent the theoretical population-based demand for ecosystem services, a demand map layer for ecosystem services derived from population and accessibility data (created in ELME2[1]) was used. The population-based demand map assigns values from 1 to 10, with 1 representing areas of lowest demand and 10 representing areas of highest demand. By overlaying this layer with the ELME2 ecosystem extent map and the flood layer, the most critical flooded areas and the types of ecosystems they encompass are identified.

In addition, for analysing population- and accessibility-based demand for ecosystem services, the spatial demand values (ranging from 1 to 10) could be categorized into three classes: areas with the lowest demand (1–3), areas with medium demand (4–7), and areas with the highest demand (8–10). Most of the flooded area (39,1%) falls within the highest demand category (43 098 ha). The most croplands, settlements and other artificial areas are concentrated in the highest demand category, as these areas are typically located near population centres. In contrast, grasslands and inland wetlands that have experienced flood events are predominantly situated in areas with the lowest population demand, farther from population hotspots(Table 38).

Table 38 Population-based demand for ecosystem services, ha

	Settlements and other artificial areas	Cropland	Grassland	Forest and woodland	Heathland and shrub	Sparsely vegetated ecosystems	Inland wetlands	Rivers and canals	Lakes and reservoirs	Marine inlets and transitional waters	Coastal beaches, dunes and wetlands
Areas with the biggest demand (ha)	1123	25 522	7383	198	16	391	1818	*	*	*	235
Areas with medium demand (ha)	387	17 909	5423	115	0	84	2834	*	*	*	314
Areas with the least demand (ha)	222	1871	13 927	182	21	99	8555	*	*	*	1 583

**Ecosystems cannot be considered as flood control providers in the proposed approach*

Flooding mitigation – monetary valuation

The monetary value of flood regulation was found by replacement cost where the valuation of water storage capacity was based on the cost of artificially storing water. It was found that artificial storage of water is 0.53 €/m3/year. The water flow regulation potential within all the flooded areas is estimated at 154 923 412 m3, resulting in an ecosystem service value of approximately 83.3 million euros per year. The water flow regulation for settlements and other artificial areas and croplands was estimated at 85 995 152 m3, resulting in an ecosystem service value of approximately 45.6 million euros per year.

Table 39. Monetary value of flooding mitigation, million EUR, 2022.

	Area of flood control (ha)	Water flow regulation (m3)	Monetary value of flooding mitigation, million EUR
1 Settlements and other artificial areas	1 732	2 307 617	1.22
2 Cropland	45 302	83 687 535	44.35
3 Grassland (pastures, semi-natural and natural grassland	26 734	42 185 714	22.36
4 Forest and woodland	495	871 290	0.46
5 Heathland and shrub	37	69 040	0.04
6 Sparsely vegetated ecosystems	574	634 720	0.34
7 Inland wetlands	13 206	22 663 317	12.01
11 Coastal beaches, dunes and wetlands	2 133	2 504 179	1.33
Total	63 479	154 923 412	82.11

Supply and use tables

The supply and use tables record the actual flows of ecosystem services supplied by ecosystem assets and used by economic units during an accounting period and the same structure can be used for both physical and monetary terms (SEEA TR 2.27). In the project physical and monetary supply and use tables of ecosystem services for 2020 for Estonia were compiled.

Supply and use tables give complete and structured way to present and analyse calculated values of ecosystem services. The structure of the supply and use tables are similar to tables used in National Accounts and therefore values could easily be compared.

Supply table contains information about ecosystem types and ecosystem services. Different ecosystem types are considered as suppliers and ecosystem services are products that are supplied by ecosystem types. In the supply table it can be seen which ecosystem services are provided in which ecosystem asset.

Use table gives information about users of the services by ecosystem services. Users are distributed by institutional sectors and corporations are further broken down by NACE activity. In this grant project use is distributed between corporations, general government and households. Ecosystem services in supply and use tables are the same and total value of supply is equal to use as ecosystem service is provided only if it is used.

Table 40 and Table 41 show the supply and use of ecosystem services in physical account. Indicators describing the service have been added to the table to clarify which aspect of the service was accounted for. The services included in the table have different units, therefore summarizing over ecosystem types is not possible. Units recommended in the proposal for the amendment of regulation EU 691/2011 or respective guidance notes prepared by Eurostat were used.

Table 42 and Table 43 show the supply and use of ecosystem services in monetary account. The services have the same unit and are potentially additive. Therefore it was possible to calculate the total supply by ecosystem types and also bring out values for subcategories of services: provisioning (includes crop provision, crop pollination, wood provision), regulating (air filtration, global climate regulation: net carbon sequestration, global climate regulation: carbon storage, local climate regulation), cultural (nature-based tourism-related services: overnight stays). However, the gross values and also single monetary values should be treated cautiously considering the underlying assumptions of the definitions and methodologies.

Supply and use of the ecosystem services on a more detailed level 2 ecosystem types (using Classification of ecosystems for ecosystem accounting in Estonia) is presented in Annex "D1_6_ Dataset of the supply and use tables of ecosystem services_101022852_2020-EE-ENVACC" as MS EXCEL file.

Table 40. Supply of ecosystem services by ecosystem types (EU ecosystem typology, level 1) - physical account (2022)

		Ecosystem type												
Ecosystem service	**Indicator and unit**	**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**	**Total supply**
Crop provision	crop production in thousand tonnes		3 646	731										**4 377**
Crop pollination	production of pollinator-dependent crops in thousand tonnes	17.87	2.47	34.93	49.70	0.33	0.06	0.35				0.01		**105.71**
Wood provision	net increment in thousand m3	11			8 089									**8 100**
Air filtration	tonnes of PM2.5 adsorbed	34	108	54	326	2	0	22	3	3	0	0	0	**552**
Global climate regulation: net carbon sequestration	tonnes of net sequestration of carbon	631		46 434	452 023									**499 089**
Global climate regulation: carbon storage	tonnes of stored organic carbon	152 514 320	557 511 530	385 212 935	2 418 070 842	11 967 133	2 415 463	485 431 298	44 452 594	14 358 707	160 409	1 743 615		**4 073 838 845**
Local climate regulation	reduced temperature in degrees Celsius	-0.51	-0.52	-0.30	-0.63	-0.01	0.00	-0.07	-0.01	-0.04	0.00	0.00	-0.67	**-0.23**
Nature-based tourism-related services: overnight stays	number of overnight stays	178 924	216 111	355 484	1 677 465	12 677	2 985	202 493	21 357	134 128	961	1 694	5 906	**2 810 185**

Table 41. Use of ecosystem services by economic sectors - physical account (2022)

		Economic sector					
Ecosystem service	**Indicator and unit**	**Intermediate consumption by industries**	**Government final consumption**	**Households final consumption**	**Gross capital formation**	**Exports**	**Total use**
Crop provision	crop production in thousand tonnes	4 377					**4 377.00**
Crop pollination	production of pollinator-dependent crops in thousand tonnes	105.71					**105.71**
Wood provision	net increment in thousand m3	8 100					**8 100**
Air filtration	tonnes of PM2.5 adsorbed			552			**552**
Global climate regulation: net carbon sequestration	tonnes of net sequestration of carbon		499 088				**499 088**
Global climate regulation: carbon storage	tonnes of stored organic carbon		4 073 838 845				**4 073 838 845**
Local climate regulation	reduced temperature in degrees Celsius			-0.23			**-0.23**
Nature-based tourism-related services: overnight stays	number of overnight stays			1 836 772		973 413	**2 810 185**

Table 42. Supply of ecosystem services by ecosystem types (EU ecosystem typology, level 1) - monetary account (2022), million EUR

		Ecosystem type												
Ecosystem service	**Indicator and unit**	**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**	**Total supply**
Crop provision	Rent price method		71.90	27.74										**99.61**
Crop pollination	Market value of crop yield requiring pollination	10.30	1.80	20.95	28.89	0.19	0.03	0.21				0.01		**62.38**
Wood provision	Stumpage value of net increment		0.72		513.28									**514.00**
Air filtration	Benefit transfer	0.0781	0.2505	0.1246	0.7561	0.0038	0.0008	0.0520	0.0077	0.0060	0.0000	0.0001	0.0000	**1.2842**
Global climate regulation: net carbon sequestration	Revealed preference based on EU ETS price of net sequestrated carbon	0.19		14.35	139.74									**154.29**
Global climate regulation: carbon storage	Revealed preference based on EU ETS price of stored carbon	47 150	172 354	119 088	747 542	3 700	747	150 070	13 742	4 439	50	539		**1 259 420**
Local climate regulation	Willingness to pay study	1.67												**1.67**
Nature-based tourism-related services: overnight stays	Expenditures on overnight trip	36.68	44.30	72.87	343.85	2.60	0.61	41.51	4.38	27.49	0.20	0.35	1.21	**576.03**

Table 43. Use of ecosystem services by economic sectors - monetary account (2022), million EUR

	Economic sector					
Ecosystem service	**Intermediate consumption by industries**	**Government final consumption**	**Households final consumption**	**Gross capital formation**	**Exports**	**Total use**
Crop provision	99.61					**99.61**
Crop pollination	62.38					**62.38**
Wood provision	514.00					**514.00**
Air filtration			1.28			**1.28**
Global climate regulation: net carbon sequestration		154.29				**154.29**
Global climate regulation: carbon storage		1 259 420				**1 259 420**
Local climate regulation			1.67			**1.67**
Nature-based tourism-related services: overnight stays			376.50		199.53	**576.03**

Work on the semantics of ecosystem services

Comparison of methodologies and data among two national level approaches for the valuation of ecosystem services

Validation of the data and physical and monetary valuation methods were carried out as overall work on quality was foreseen. The method chosen was the evaluation by comparison of the results of ecosystem services assessed and methods developed by Statistics Estonia in one hand and the ELME2 project[73] ("Nationwide assessment and mapping of the economic value of the benefits (ecosystem services) of Estonian terrestrial ecosystems") in another hand. ELME2 project results were used as a reference point in order to find the aspects of improvements in Statistics Estonia's work and build necessary semantics in case of differences.

A summary table of the physical units and financial evaluation results of the analyzed ecosystem services was formed and presented in the ANNEX 6. The table provides also the synthesis and initial expert opinions of the way forward regarding single services as discussed on second methodological seminar. Findings of the comparisons of the approaches for evaluating and valuing ecosystem services were also analyzed and discussed during a methodological seminar. The analyses of differences in the valuation of ecosystem services between ELME and Statistics Estonia reveal the nature of these differences based on values and methods. The main finding was that the results depend on the assumptions made, theoretical framework applied and semantics used.

Comparing the methodological approaches applied by Statistics Estonia and ELME, it can be said that the Statistics Estonia has followed UN SEEA EA standards and guidance materials whereas ELME work has followed different approaches and was not restricted by statistical standards. Regarding the Statistics Estonia and ELME2 work, it can generally be said that while Statistics Estonia's work focuses on ecosystem services and valuation of their socioeconomic benefits, the ELME report places greater emphasis on ecosystem mapping and condition assessment along with services.

The comparisons made will be analysed and considered to enhance the knowledge and analyse the quality of the valuations carried out by Statistics Estonia. Comparisons may be adjusted in later phases in case of a feedback from experts or in case additional relevant information appears.

Discussion on the evaluation of ecosystem services, interpretation of the results from the perspective of environmental economics

An overview of the interpretation of the results for the evaluation of ecosystem services (agricultural production supply, pollination of agricultural production, wood supply, air filtration, global climate regulation, nature-based tourism services, local climate regulation, flood mitigation) was created in collaboration with the input from experts on environmental economics[74].

The evaluated ecosystem services are very different in terms of their content and their connection to the economic system. Agricultural production provision and wood provision are essentially provisioning services, in which the ecosystem service is expressed in production that can be expressed in physical units and has a market price. Air filtration, global climate regulation and flood mitigation are regulating services that do not enter the economy in the form of products that have a price on the market, so the financial equivalent of the value of these services must be found using indirect methods. The services related to nature-based tourism are expressed in the increase in the

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[73] Helm, A., Kull, A., Kiisel, M., Poltimäe, H., Rosenvald, R., Veromann, E., Reitalu, T., Kmoch, A., Virro, H., Mõisja, K., Nurm, H-I., Prangel, E., Vain, K, Sepp, K., Lõhmus, A., Linder, M., Otsus, M., Uuemaa, E. (2023). Eesti maismaaökosüsteemide hüvede (ökosüsteemiteenuste) majandusliku väärtuse üleriigiline hindamine ja kaardistamine. Tehniline lõpparuanne. Riigihange "Maismaaökosüsteemiteenuste üleriigiline rahaline hindamine, sh metoodika väljatöötamine" (viitenumber 235366, Keskkonnaagentuur). Tartu Ülikool. Eesti Maaülikool. ISBN 978-9985-4-1398-2 (pdf)

[74] Interpretation has been compiled with the major input from the project expert prof Üllas Ehrlich and should be considered as provisional.

welfare of individuals arising from the consumption of non-market services, the value of which is assessed on the basis of the expenses actually incurred by individuals.

Agricultural production provisioning service

When determining the physical units of the provisioning service of agricultural ecosystems, the Statistics Estonia's earlier grant work (Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC) is based methodologically on the definition of the proposal for the amendment of Regulation (EU) 691/2011. The ecosystem service crop provision is defined as the ecosystem contribution to plant growth as approximated by the amount of harvested crops for different uses. This includes food and fibre production, fodder and energy, and grazed biomass.

In environmental economics, the monetary evaluation of the provisioning service of agricultural ecosystems is uncomplicated, because the price of the entire agricultural production by the ecosystem can be attributed to the provisioning service and it can be argued that this is the monetary value of the service. In environmental accounting however, the provisioning service of agricultural ecosystems is where the contradictions between statistics and environmental economics are best revealed.

In Statistics Estonia's work, the use of four methods was analyzed and applied for the monetary evaluation of the provisioning service of agricultural ecosystems: rent price, resource rent, market price and hybrid[75]. All these methods are very different, and it is difficult (if not impossible) to decide which of them is objectively the most suitable, because the suitability depends on how the part of the economic system in the supply service is determined. It is not only a practical, but also a philosophical question.

There are very different positions on determining the share of the ecosystem in agricultural production. One possible point of view is that the contribution of the ecosystem is not reflected in the market price of agricultural production[76]. Another approach is that by attributing the market price of the entire production to the service of the ecosystem, the service is overvalued. Therefore, one of the methods used is resource rent, which in its economic content is the producer's profit. The disadvantage of the method is a very small value compared to the market price (only about 7% of the market price of the production). Although the method complies well with accounting rules and is based on actual turnover, its application cannot be considered justified because it underestimates the contribution of the ecosystem.

A compromise between different approaches seems to be the use of the rent price method, according to which the value of the ecosystem supply service is slightly more than one third of the market price of the production. The method is based on the concept that the tenant pays rent for the ecosystem's potential to provide agricultural output. Disadvantage is that this method is unsuitable for comparing different land use scenarios. If we change the intended purpose of agricultural land (for example, to residential land or forest land), we lose not only the value of the rent price, but the entire agricultural production for many years.

Therefore, there is currently no such methodology for assessing the value of the provisioning service of agricultural ecosystems, which would show the value of the ecosystem service as an inevitably necessary prerequisite for agricultural production and be suitable for evaluating alternative scenarios of land use.

Pollination service

A service closely related to agricultural ecosystems is pollination, the value of which has been financially assessed using the straightforward method, assessing how much production would be lost if the pollination service did not exist. In the case of such an approach, it is a separate question whether the income lost due to the absence of the service is suitable for use in economic accounting as the monetary value of the service. If it is decided that it is suitable, then this evaluation of the pollination service shows well the share of the service in the market price of agricultural production. In practice, one should avoid the situation where pollination service evaluation based on the market price of hypothetically lost production is used together with, for example, the resource rent or rent price

[75] Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC
Development of environmental accounts. Activity 2. Developing and refining ecosystem accounts
D1.8 Description of the methodology for advancing ecosystem accounts, methodology. Methodological report.
[76]The problem has been discussed in more detail: Oras, K., Ehrlich, Ü., Aun, K., Luukas, G., Two Languages or Two Narratives: Comparison of the Selected Market Price and Revealed Preferences Valuation Methods to the Stated Preferences Method; UN London Group on Environmental Accounting, 2020

method. This can lead to an outcome where the value of the pollination service exceeds the monetary value of the provisioning service, giving a distorted picture of the proportions of ecosystem services.

Wood provisioning service

In the case of the wood provisioning service of the forest ecosystem, it is easier to distinguish between the contribution of the ecosystem and the economic system than in the case of agricultural ecosystems. Compared to crops, the forest grows relatively independently and does not need annual economic system intervention. So, for example, a forest grows completely without human intervention.

The Eurostat Guidance Note on Accounting for the Wood provision Ecosystem Service [77] (version February 2023) suggests to define wood provision as "*the ecosystem contributions to the growth of trees and other woody biomass*".

Statistics Estonia valued the wood provision service using stumpage prices[78] calculated over increment and removals (harvested wood). The first is combined better with the physical indicator but the latter shows the real flow that enters economy better.

Although there is a risk of accounting double entries when using the stumpage price service value as a basis for statistics, in the case of the wood supply service, the distinction between the contribution to the economic system and the ecosystem is significantly easier compared to the supply service of agricultural ecosystems. It can be assumed that the stumpage price method reflects the contribution of the ecosystem to the value of the wood supply service.

However, the valuation of forest ecosystem services has another methodological complexity. The problem is that the wood supply service is either competitive or exclusive with other forest ecosystem services (depending on the final felling method). Therefore, the forest ecosystem cannot simultaneously provide a full range of wood supply service, regulating and welfare services for a longer period. If we evaluate the wood supply service on the basis of increment, the considering of the competitiveness of the services in the statistics is disturbed, because the annual increment of a young forest is even higher than that of an old forest. This gives the impression that logging on a concrete forest property does not affect growth, which means that it may not be reflected in the accounting of ecosystem services.

To evaluate the wood provisioning service of the forest ecosystem, the calculation of removals is better, because based on this, the impact of the wood provisioning service on other services with respect to which wood provisioning is competitive.

The complex treatment of forest ecosystem services in statistics needs further development. It is also recommended in the literature to treat the old forest as a non-renewable resource[79], which is justified considering the recovery time of the old forest ecosystem.

Air filtration service

Air filtration and local and also global climate regulation are regulating services, the accounting of which is in physical units requires cooperation with natural scientists. The monetary valuation of these services must consider, that do not have a direct output to the market. In the context of environmental economics services, these services are general-ecological services, which are assessed either by indirect or direct methods.

According to the definition of the proposal for the amendment of Regulation (EU) 691/2011, the ecosystem service air filtration is defined as the ecosystem contribution to filtering air-borne pollutants through the deposition, uptake, fixing and storage of pollutants by ecosystem components.

In Statistics Estonia's Report the PM concentration (PM2.5) CPM was used to calculate the amount of deposition. In total 554 tons of PM2.5 were adsorbed yearly due to "air filtration" in 2020.

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[77] Eurostat – Unit E2. Doc. Doc. ENV/EA/TF/2023_1/2. Wood provision ecosystem service – guidance note. Version prepared for the Task force on ecosystem accounting after a written consultation by the Environmental accounts working groups (WG EA and MESA) (February 2023)
[78] Stumpage prices are prices that are paid for standing tree for the right to harvest. Stumpage prices are direct market prices and therefore show exchange value.
[79] Joy E. Hecht. National Environmental Accounting. Bridging the Gap between Ecology and Economy. Resources for the Future, Washington, DC, USA, 2005.

Both benefit transfer and contingent valuation methods were used in the financial assessment of the value of air filtration. In the case of such services, where the financial value of the service depends on the number of people per unit of area (population density), benefit transfer methods should be viewed especially critically, because the automatic transfer of data to other circumstances can give wrong results by orders of magnitude. Also, when assessing pollution in the environment, the law of marginal utility must be taken into account, according to which the damage caused by each additional unit of pollution depends on the pollution units already present in the environment. The last fact makes it particularly difficult estimate the impact of pollution in the environment.

Using the critical benefit transfer method, it was found that total monetary value of Estonian ecosystem ability to deposit PM2.5 is 1 284 237 EUR in 2020. There is no objective basis for validating the monetary expression of a specific value, but considering the health hazard of PM2.5 particles, it is rather a modest monetary assessment. In the case of environmental pollution, a general methodological problem is linking it to human health data and medical costs. It is also not easy to distinguish between health damage caused by the environment and lifestyle.

In addition to the benefit transfer method, the air cleaning service was also evaluated using the contingent valuation method, which belongs to the group of stated preference methods.

Estimated with the contingent valuation method, the annual value of the air filtration service of Estonian ecosystems was 2.5 million euros. However, this result is not necessarily due to cleaning the air of PM2.5 particles. Air pollutants, such as bad odors or smoke, are more important for an individual and are perceived by the senses and therefore directly affect welfare. But in any case, the CVM study shows that air quality plays an important role in people's welfare and that there is a significant demand for it. The monetary assessment of the air cleaning service of Estonian ecosystems deserves to be continued.

Local climate regulation

According to the definition of the proposal for the amendment of Regulation (EU) 691/2011, the ecosystem service local climate regulation is defined as the ecosystem contribution to reducing concentrations of greenhouse gases in the atmosphere through the removal (net sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. It shall be expressed and reported as the reduction of temperature in cities, due to the effect of urban vegetation, in degrees Celsius on days exceeding 25 degrees Celsius.

In Statistics Estonia’s Report Estonian Ecosystems' carbon sequestration in 2020 was 52,212 tons of carbon (C). For monetary valuation of carbon sequestration was chosen European Union (EU) Emissions Trading System. In 2020 the monetary value of carbon sequestration service of Estonian ecosystem 4.8 million euros. Using the market price of ETS is a good approach to finding the financial equivalent of a carbon sequestration (climate regulation) service, because it links the ecosystem service in physical units to the market and market price of ETS.

In the Statistics Estonia’s Report the monetary equivalent of local climate regulation service was estimated using contingent valuation method. People estimated the value of the service as 0,84 million euros per year as an aggregated willingness to pay, which shows that this service is also considered important as a determinant of subjective welfare. The methodology for monetary evaluation of local climate regulation ecosystem services needs further development.

Nature tourism-based service

The Regulation (EU) 691/2011 defines nature-based tourism-related services as the ecosystem contribution, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. These contributions shall be reported in number of overnight stays in hotels, hostels, camping grounds, etc. that can be attributed to visits to ecosystem.

The EU's recommendation to consider only overnight stays in nature as the statistical basis of nature tourism narrows the concept and nature of nature tourism. Undoubtedly, overnight stays are a good basis for statistics, because in this case it is not necessary to do additional work to collect data, but conclusions can be made on the basis of overnight stay statistics. However a big part of recreational activities in nature are not reflected in the statistics, and the increase in individual`s welfare arising from contact is not taken into account in the value of the ecosystem service.

Statistics Estonia has developed also a detailed nature recreation service evaluation method, which was based on a special survey[80]. A representative survey was used to find out the time people spent in nature during the year and the different ecosystems they came in contact with, which was 102 hours per year. The volume of the nature tourism ecosystem service evaluated in this way is significantly higher compared to the situation where only overnight visits to nature are taken into account. The monetary value of the ecosystem's nature tourism service was attributed using the time consumption method, which is similar in nature to the revealed preference method, because people have actually used the time.

In addition to the survey, which requires a relatively large-scale special study, the value of the nature tourism service in Estonia has also been studied using the data from the counters on the hiking trail of the State Forest Management Center.

In conclusion, it can be stated that no ecosystem service valuation is good or bad in itself, but it all depends on methodology and framework applied. Environmental economic accounting imposes limitations on the methods for evaluating ecosystem services that environmental economics does not. The question is how to overcome this contradiction. The difficulties that arise between ecosystem provisioning services that have a market value and regulating and welfare services that do not have a market value are different. In the case of services having market value, the isolation of the contribution of the ecosystem is more of a technical (double description of turnover) or a philosophical nature (is the ecosystem service included in the price of the product). In the case of non-market services, however, the problem is the missing of the statistical concepts regarding simulated markets and the measurement of changes in the well-being of individuals. The economics of non-market values is a generally recognized branch of economics but the standards of non-market values for environmental goods has yet to be developed in order to allow the comprehensive valuation of ecosystem services and its reflection in environmental accounting.

Discussion on the evaluation of the trends of the ecosystem services

When accounting for ecosystem services, it is important to determine whether and to what extent provisioning, regulating and cultural services compete with each other or even exclude each other. When evaluating ecosystem services individually (i.e. in isolation from each other), it can easily give the impression that an ecosystem can provide different services simultaneously and evenly over time. In fact, this may not be the case. The discussion of evaluating ecosystem services has so far ignored the problem of competition and exclusion, how the supply of services changes when there is an interaction between them. If any category of services can be highlighted separately in this context, it can be said that it is ecosystem provisioning services that often compete with other services such as pollination of agricultural production, air filtration, global climate regulation, local climate regulation, flood mitigation and wildlife tourism. Other ecosystem services are strongly influenced by the largest provisioning services, such as the provision of agricultural production by agricultural ecosystems and wood (timber) by forest ecosystems.

The provisioning services of agricultural ecosystems have been evaluated in various ways, which have been analyzed in more detail in the Estonian Statistics grant report[81], where the rental price method has been considered most appropriate for determining the monetary value of the service.

However, The Guidance Note on Accounting for the Crop Provision Ecosystem Service [82] (version February 2023) (hereinafter Guidance Note) suggests defining crop provision as *„the ecosystem contributions to plant growth as approximated by the amount of harvested crops for different uses. This includes food and fibre production, fodder and energy, and grazed biomass“,* as set out under Annex III [of Regulation (EU) 691/2011 on European environmental economic accounts.[83]

[80] Ehrlich, Üllas (2023). Valuation of ecosystem non-market services: Recreational service in Estonia. Estonian Discussions on Economic Policy, 31 (1-2), 95–113. DOI: 10.15157/tpep.v31i1-2.23581.
[81] Grant Agreement no NUMBER — 101022852 — 2020-EE-ENVACC
Development of environmental accounts. Activity 2. Developing and refining ecosystem accounts
D1.8 Description of the methodology for advancing ecosystem accounts, methodology. Methodological report.
[82] Crop Provision Ecosysten service- Guidance Note. Doc. ENV/EA/TF/2023_1/2
Item 2 of the agenda, Eurostat – Unit E2, 2023
[83] Regulation (EU) 691/2011

So, in any case, the content of the provisioning service of agricultural ecosystems is agricultural production. And the more production, the greater the monetary value of the service. But this is precisely where the competition with other agricultural ecosystem services lies, and in addition the impact on many services of other ecosystems.

Higher agricultural output per unit area is achieved by increasing agricultural intensity, which means more fertilizers, more pesticides and herbicides, larger fields, fewer habitats within the ecosystem, etc. In addition, the chemicalization of agriculture has a negative impact on the services of neighbouring ecosystems and also affects other ecosystems through polluted water. Therefore, it can be said that the volume of production is inversely proportional to the other services of agricultural ecosystems and negatively affects neighbouring ecosystems and their services. In addition, overly intensive agriculture also threatens the sustainability of agricultural ecosystems due to soil degradation and erosion, calling into question the most important economic criterion of sustainability - the ability to provide stable or increasing benefits over the long period.

Economic measures to compensate for the damage caused by intensive agriculture to other ecosystem services would be easily feasible (at least within the EU). Given that agricultural production is in large part carried out with the contribution of EU agricultural subsidies, the provider of the subsidy could in principle choose production technology by requiring the beneficiaries to implement environmental friendly agricultural practices, organic farming, which does not use fertilizers and pesticides (or uses significantly less). In practice, however, this is hardly possible for political reasons. It is also practically impossible to internalize the damage (external costs) caused by intensive agriculture into the price of agricultural products.

However, organic agriculture (organic farming) could be useful in the monetary valuation of the provisioning services of agricultural ecosystems. Thus, organic production without the use of fertilizers and without the use of insecticides and weed control provides much better information about the contribution of the ecosystem itself than does production from intensive agriculture. Monetary valuations of the provisioning services of agricultural ecosystems, which use market prices for agricultural products, should rather operate with organic agricultural products, in the price of which the contribution of the ecosystem itself is proportionally much higher than that of conventional agricultural products.

If we try to evaluate in practical terms how to account for the negative impact of agricultural ecosystem services on other ecosystem services, it must be acknowledged that this is difficult, as the impact is large in both time and space, ranging from the degradation of soil ecosystems to the eutrophication of water bodies, which in turn affects many ecosystem services.

The impact of the forest ecosystem's provisioning service on other ecosystem services is certainly no less significant than the impact of provisioning service of agricultural ecosystems. In the case of forest provisioning services, the conflict between different services is even more acute than in agriculture. In the big picture, the types of logging are divided into maintenance logging and regeneration logging. The primary goal of maintenance logging, or intermediate logging, is to shape the species composition of the forest and create more favourable growth and light conditions for the main tree species. Regeneration logging is a final logging, the main goal of which is to generate income or create conditions for the development of a new forest culture.

The most radical method of final logging that disrupts the functioning of the forest ecosystem is clear-cutting. However, it is widely used for economic reasons. Clear-cutting is the most common types of logging in Estonian forests. Its purpose is to clear the entire forest area and sell the resulting timber. Clear-cutting is well suited for cutting young forests where the trees are of uniform age and size. Clear-cutting involves cutting down all the trees, leaving an empty area in the forest.

Clear-cutting has another important advantage over other, more environmentally friendly final felling methods. Namely, removing the forest stand all at once, leaving an open area (clear-cutting area), is the cheapest method for the forest manager, with the lowest logging costs per unit of wood. This is also the main reason why clear-cutting is preferred over other final cutting methods in practical forest management. At the same time, it is obvious that a cleared forest area (clearing), which is forest land without trees in the sense of the land cadaster, does not provide the regulating services and welfare services characteristic to the forest ecosystem.

Of the ecosystem services considered, forest clear-cutting affects negatively air filtration, global climate regulation, flood mitigation, and nature-based tourism-related services. In addition, there is an indirect impact on of agricultural production services, as the habitats of some pollinators are linked to the forest ecosystem. The non-provisioning services inherent to the forest are gradually restored after clear-cutting, reaching their full extent and volume only when the forest reaches adulthood. In the case of the habitat service of the forest ecosystem, this can even last up to a hundred years, depending on the type of forest.

Cutting can be carried out in several other ways, in which mature wood is removed from the forest gradually over a longer period of time, avoiding the need to clear-cut the entire forest area at once. Even then, the use of the timber provisioning service has an impact on other forest ecosystem services, but in this case the provisioning service is competitive with regulatory and welfare services and no longer exclusive, as it would be in the case of clear-cutting.

An important conclusion is that with approximately the same volume of provisioning service (amount of harvested wood) obtained from the forest, the total amount of ecosystem services provided by the forest during one forest generation can vary significantly, depending on the type of final felling.

A separate question is how this should be reflected in forest accounting and statistics. First of all, this would require a comprehensive approach to forest ecosystem services, where the dependencies between the different services are considered. One option is to take into account the logging method used to harvest the wood from the forest when assessing the value of the provisioning service. Although this is an economically complex problem, it is still possible to certify wood from only environmentally friendly managed forests. Generally, certification should include whether wood is obtained using clear-cutting or other more environmentally sustainable felling methods.

For forest statistics, this primarily means collecting information on the logging method used to obtain the wood. This is particularly important when evaluating the ecosystem services and service dynamics of individual forest cadastral unit or in the forest quarter.

From the point of view of economic theory, it can be argued that the lost ecosystem services due to forest clear cutting is an external cost that must be included in the price of production. It would theoretically be correct to tax the wood obtained using clear-cutting, with the amount of the tax covering the value of the regulatory services and welfare services of the forest ecosystem that are lost due to clear-cutting.

A separate issue is the habitat service provided by old-growth forests and its impact on biodiversity, which may not recover in its original form even when the trees reach adulthood. Therefore, it has been proposed to treat old-growth forests as a non-renewable resource, where use of wood provisioning service should be stopped[84].

Ecosystem services other than provisioning services also create competitiveness. For example, the ecosystem service of providing opportunities for nature tourism is not provisioning, but requires people to be physically present in nature, which in any case affects other ecosystem services. For example, the habitat service can often be disrupted.

To avoid causing damage to other ecosystem services, the carrying capacity of ecological communities must be taken into account when determining the volume of nature tourism and the number of people visiting nature must be regulated over time. Infrastructure, such as wooden paths in bogs that prevent trampling, can also help reduce the impact of nature tourism.

To internalize the damage caused by consuming nature tourism services as an external cost, visitors can be charged a tourism tax, for example, or funds can be allocated from the budget to reduce the impact (construction of infrastructure).

Ecosystem regulatory services (air filtration, global climate regulation, local climate regulation, flood mitigation) as long as natural ecosystems are not modified (monocultural fast-growing carbon capturing plants, canals and dykes etc) to increase the supply of them are generally not in conflict with each other.

[84] Joy E. Hecht. National Environmental Accounting. Bridging the Gap between Ecology and Economy. Resources for the Future, Washington, DC, USA, 2005.

Contribution to the methodological development on international level

Contribution to the thematic London Group position paper on human induced flows

The results of ecosystem accounting can also be useful in other fields. Statistics Estonia (Kaia Oras and Kätlin Aun) contributed the work on UN London Group of Environmental Accounting on how the results of ecosystem accounting can also be useful in the area of climate change mitigation. For example, within the framework of ecosystem accounting, the ecosystem service of carbon sequestration and the account of ecosystem extent, along with its ownership dimension, can provide data that allows for the distribution of carbon sequestration among economic activities. This was done based on land ownership. made a presentation at the London Group meeting. Use of the ecosystem account data for the allocation of the land use related sequestration data to economic sectors was tested. Sequestration of CO2 from land use, land-use change, and forestry, one of the important human induced flows in nature can be accounted was demonstrated in a frame of the position paper "Accounting for Human Induced Flows in Nature", Matthew Chambers , Nils Brown , Kaia Oras , Aldo Femia , and Sjoerd Schenau" . [85]This study was done in an SEEA ecosystem accounting context, but the data sources (LULUCF, ownership data) can also be adapted to the strictly SEEA CF context. The need of this work is urged by the fact that emissions and sequestration from land use, land-use change, and forestry (LULUCF) are not currently included in the air emissions accounts (AEA) of the SEEA the need for their inclusion has been emphasized by users in Estonia. The topic is also ib the scope of SEEA CF revision. Estonia's climate policy aims for climate neutrality by 2050, with specific targets. Under this umbrella sustainable forest management sets also a priority to maintain forests as carbon sinks. This involves reducing logging activities, promoting reforestation, developing financial instruments, and managing land use changes to minimize greenhouse gas emissions. Monitoring these goals requires comprehensive data on CO2 emissions and sequestration, integrated with socio-economic data.

SEEA EA chapters 3.85 and 4.40 highlights the importance of integrating extent accounts and economic data for policy purposes. Statistics Estonia suggests linking ecosystem and air emission accounts to provide more policy-relevant data.

Study showed how spatial data from the ecosystem accounts for carbon sequestration ecosystem service can be linked to air emissions accounts (AEA) by connecting carbon sequestration data with economic activities via land ownership . Via this bridge carbon sequestration and emissions can be further linked to other socio-economic data. The proposed framework is the first step in extending the accounts, and this example showcases current testing on integrating information from ecosystem accounts and land ownership in Estonia. Slides are available on demand.

Contribution to the London Group issue paper on ecosystem accounting

Statistics Estonia's team (Kaia Oras, professor Üllas Ehrlich and Aki Kadulin) contributed to the thematic London Group with the issue paper "Monetary values connected to ecosystem services[86]. Paper asks how the frameworks and semantics on valuation methods of ecosystems accounts could be taken further. The ecosystem services parallel valuation methods were analysed, and the semantics of the single services were interpreted. With the approval of the ecosystem accounting as a statistical concept (and partly also as a standard), a need for a new stream of statistical literacy has appeared. The purpose of the ecosystem services account is to connect ecosystem services to the economic accounts used by economists and financial analysts in their tools and models. The definitions, valuation methods, semantics and communication have been considered important as the concept of ecosystem accounting is new and the knowledge on methods and how to use the information is not yet widespread. The concept of connected and related values was analysed and the Estonia's single studies were set into the context of the framework.

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[85] "Accounting for Human Induced Flows in Nature", Matthew Chambers , Nils Brown , Kaia Oras , Aldo Femia , and Sjoerd Schenau" , London Group, 2024. "Accounting for Human Induced Flows in Nature", Matthew Chambers , Nils Brown , Kaia Oras , Aldo Femia , and Sjoerd Schenau" . "Accounting for Human Induced Flows in Nature", Matthew Chambers , Nils Brown , Kaia Oras , Aldo Femia , and Sjoerd Schenau" .

[86] Issue paper: Monetary values connected to ecosystem services. UN London Group on Environmental Accounting, 2024. A. Femia, I. Grammatikopoulou, K. Oras, Ü. Ehrlich, A. Kadulin, S. Schürz, A. Capriolo, M. Udugama. https://seea.un.org/sites/seea.un.org/files/session_5_issue_paper_connected_values.docx

Contribution to Ecosystem Services Partnership conference

Statistics Estonia (Kätlin Aun) presented some of the results on the interpretation of the valuation methods on the ESP 5 Conference (ESP Europe 2024 - Homepage), session 17a on Natural Capital and Accounting in Economy and Finance "Options to determine ecosystem contribution in the valuation of timber and crop provisioning ecosystem services" [87]. The presentation (other authors: Kaia Oras, Üllas Ehrlich, Grete Luukas) addressed parallel methods for the assessment of the ecosystem service of crop provision and timber provision ecosystem services. Different methods express ecosystem contribution to the service in various degrees. Similarities and differences were discussed and the communication issues regarding the results of the alternative approaches for given ecosystem services were described and links to expected users and applications were considered. The selection of the valuation methods for ecosystem services were based on the suggestions outlined in UN SEEA EA and Guidance Notes on accounting for ecosystem services by Eurostat relevant to the implementation of the regulation of European environmental economic accounting. The work was based on efforts carried out in the framework of Eurostat grants "Development of the land account and valuation of ecosystem services regarding grassland ecosystem" (831254-2018-EE-ECOSYSTEMS), "Development of the ecosystem accounts" (881542-2019-ENVECO), "Development of the environmental accounts" (101022852-2020-EE-ENVACC) and "Development of the forestry, environmental subsidies and ecosystem accounts" (101113157-2022-EE-EDG). Statistics Estonia is planning further work with the T17a group and is prepared to be engaged in further networking and collaboration on the issues of the valuation and interpretation of the ecosystem services and benefits.

Contribution to Eurostat TF ecosystem accounts and feasibility study on valuation of ecosystem services

Statistics Estonia has contributed to the work of the Eurostat workstream on Ecosystem Accounts and especially on the Task Force activities in various ways, for example: developing of the guidance notes and testing of the extent account compilation and methodological approaches for the services and condition. This work is outlined under respective chapters of ecosystem extent, services and condition accounts. Participation on TF webinars and the preparation of the contributions was also part of the workstream foreseen.

Consultation was arranged with Estonian experts where relevant in order to involve best knowledge regarding the methods and principles. If in 2024 the work on "Feasibility study on valuation of ecosystem services flow" was launched in TF, the proposed methods and principles were also consulted nationally and handled on a second methodological seminar (minutes of a seminar: Annex V). This work is still underway. The Estonia's proposals as a results of discussions will be reported back to Eurostat TF asap. The feedback to Ecosystem Accounts TF is still in process.

The discussion highlighted key points regarding the financial assessment of ecosystem services:

- Different methods can yield varying results, raising the question of how to determine the most suitable approach. - Challenges arise when financial assessments show only a specific number, often overlooking underlying doubts and restrictions.

- Ecosystem services differ significantly from other goods and services, also from non-market goods and services.

- Main threats include low values compared to other, economic values; lack of consensus on methods, and potential misrepresentation of substitutability.

- Why only market prices may not accurately reflect ecosystem service values

- Single ecosystem services often have low representation and are not addressed within a coherent framework.

- The impact of changes in ecosystem service status and the direction of change in indicators are not always agreed upon.

[87] FSD Team Site - EE_Aun_Options to determine ecosystem contribution in the valuation of timber and crop provisioning ecosystem services_ 18112024 - Copy.pdf - All Documents

The group discussed also the experience gained in Estonia while comparing two valuation approaches leading to very different results (presented in this report, chapter 3) and hence also the central role of semantics playing in the interpretation of the results.

Despite the fact that selecting only a few services may undervalue other important services, the experts proposed selecting fewer than ten ecosystem services for future analyses and mapping their values comprehensively. Preferred assessment methods would include observable prices, market prices for similar goods, market transactions, expenditures, and willingness to pay.

Emissions, Capture and Utilisation: Principles and frameworks for Ulva

Statistics Estonia (Kätlin Aun) gave an overview on ecosystem accounting work carried out in Estonia at the conference: ULVA: Participation on the marine "Emissions, Capture and Utilisation: Principles and frameworks for Ulva" taking place in Kuressaare, Estonia during the dates May 13-14 2024, organized in the framework of the COST Action CA20106 - TOMORROW'S 'WHEAT OF THE SEA': ULVA, A MODEL FOR AN INNOVATIVE MARICULTURE (SEAWHEAT).

INSPIRE conference 2023 "Green data for all"

Statistics Estonia (Kätlin Aun) gave a presentation "Country perspective (Ecosystem Accounting)" on ecosystem accounting and work carried out in Estonia with the main focus on using geospatial data at the INSPIRE conference 2023 in session 15: Statistics in support of Green Deal.

The aim of the session was to share knowledge developed in the networks of the National Statistical Institutes (NSI) and National Mapping & Cadastral Agencies (NMCAs) towards stronger implementation of geographical information together with statistical applications, supporting the European Green Deal and the digital transition. Presentations will touch upon several themes – from European down to national perspective.

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

ANNEX 2. Study visit

Development of the environmental subsidies and ecosystem accounts

April 16-17, 2024
Statistics Netherlands

April 16th

Ecosystem accounts

Ecosystem condition

Participants: Shaya, Patrick, Kätlin, Kaia

Discussed condition indicators: forest and farmland bird indexes, tree cover density, urban green, soil organic carbon, dead wood.
NL has not yet developed condition account further than described in 2023 report (Statistics Netherlands, 2023, Development and improvement of the Dutch SEEA EA condition account).

1. Tree cover density
   NL applied several methods
   - Dutch National Forest Inventory (NBI) is done every 5 years, not spatial data and difficult to extrapolate because forest parameters of the plots are not known.
   - Copernicus Land Monitoring Service.
   - National Flora Monitoring Scheme, not a spatial data.

   Copernicus Tree Cover was found the most suitable but it also has its drawbacks. The results were analyzed by forest type (natural, production forest) which gives more meaning to the results and it was found that the condition indication is more relevant for natural forests. Tree cover density values are rather stable. IUCN GET used in SEEA EA do not match with forest types in EU typology, NL has tied to apply both typologies. Regarding the value of the indicator it is a misconceived understanding that the higher value is better and means higher naturalness of the forest.
   EE subcontracted the assessment of tree cover density where data from LiDAR was used. LiDAR data is updated regularly by Estonian Land Board and in every 4 years Estonia is fully covered. Testing Copernicus Tree Cover layer was not tested and comparisons were not made.
2. The new and upcoming Forest Monitoring Regulation is set out to assess several ecosystem condition indicators in spatial scale (10x10 m), incl. tree canopy cover. This can be additional and useful data source.
3. Urban green
   NL used city limits instead of LAU as the latter in case of big municipalities includes rural areas besides city area, EE has the same case. Now it is more firmly described in the guidance note (GN) that LAU has to be used.
   NL used data from extent data and planned to analyze vegetation data (NDVI). Extent map doesn't include small areas of green and how green the area really is – satellite data (10x10m) could be used to determine it. Temporal resolution is also a question regarding vegetation period.
   Using high-resolution aerophotography with its possibilities and problems was discussed, but it was not applied as a method in NL.
   EE distinguished green ecosystem types on extent map and then found the share to all area in cities. EE also included urban blue, which is now out of scope according to GN. It was discussed however that some urban blue (ponds) is already included in urban green, especially when spatial resolution is smaller and raster maps are used.
4. Soil organic carbon in toplayer
   Different types of measurements are relevant: soil organic carbon, soil organic matter, carbon content of organic matter, particulate organic matter, mineral associated organic matter. "Soil organic matter" would be more meaningful for soil quality indicator than "soil organic carbon", also soil experts use the first term.
   NL tested using data from Soil Sampling Program which was combined with soil map and LUCAS data. Map of soil organic carbon was once provided made by Wageningen university for soil Survey but it will be repeated regularly in the future because there is a monitoring program for soil quality where soil organic matter is included. The map was overlayed with extent map. Data is provided for top 30 cm, also for top 20 cm. Other

data source LUCAS was found to have scarce data and issues in spatial details (some provinces didn't have data points) and the previous LUCAS also considered first 20 cm, now first 30 cm.
EE used a detailed soil map which is available but it is not updated regularly, which is an issue. Estimation was made that on grasslands and croplands organic carbon deposit is only in the toplayer. In the future Soil Project in Estonia can give good data but it is still unknown which data and when will become available as a result of the project. It was found previously that also for EE Lucas don't have enough data points to give a good representation.

5. <u>Dead wood</u>
   NL found that dead wood, even though it is internationally reported indicator, was the most difficult one to analyse in the sense of ecosystem condition account. Data comes from National Forest Inventory which is not spatial data. CBS was given plot data in a square (km2) from the institute that carries out NFI. The data was difficult to extrapolate because plot conditions were not known. Simple national average was calculated. Also NFI is made available every 6 years but dead wood is calculated every year which introduces delays in the data.
   EE also used data from NFI and the whole calculation was done by Environmental Agency which is responsible for NFI. The data is not spatial but extrapolated to cover all forest using underlying data.
6. <u>Bird indeces</u>
   Common farmland bird index and the newly added forest bird index are available data from other reportings both in NL and EE.
7. NL experience showed that remote sensing data can improve the available data, especially when using and analysing raw data and not products, but it is time consuming and in many cases plans to incorporate these methods in testing could not be fulfilled.
8. EE is currently testing additional condition indicators: forest bird index, area of wetlands influenced by drainage, forest connectivity, butterfly index.
9. **Can NL share slides shown during the discussion?**

Ecosystem services 1

Participants: Jocelyn, Marjolein, Kätlin

Discussed services: pollination, microclimate, carbon sequestration and retention, flood mitigation, air filtration.
Marjolein works with regulative, Jocelyn with provisioning services.

1. <u>Pollination</u>
   NL has not yet included all the new changes of GN to their pollination model (short and long range pollinators, flower and nesting suitability separately) but plans to do so.
   NL has looked into JRC model for pollination and found that totals for the whole country give a similar result but spatial distributions from the models are totally different.
   EE used NL methodology and help with its implementation in the past but could not apply the code directly because EE map was not in raster and workarounds for tabular data needed to be invented. Now EE has a raster map and would like to test the model on spatial data. **EE asked Marjolein to share the code for assessing pollination (new code is fully in Python) and help with application. It was agreed to discuss further via mail.**
2. <u>Local climate (microclimate)</u>
   NL has previously run the model for heatwaves, now it is for every day where temperature is over 25 degrees C.
   NL has updated their model regarding microclimate assessment, methodology is the same as in EU guidance.
3. <u>Carbon sequestration and storage</u>
   NL had at first only carbon sequestration model and is now discussing how to apply guidance in GN to calculate net carbon sequestration and carbon stock. NL prefers using 30 cm depth threshold which is corrected for previous year by the amount of lost carbon due to emissions. The approach is good for showing carbon emissions from peatlands as the thickness of the layer of peat soil decreases year after year due to oxidation. However interpreting the values of stock using the same threshold is tricky because when the stock is deeper than 30 cm then the changes in stock are not actually reported. Another option is to report the stock for the whole depth and then the loss is absolute from the whole stock. The number for emitted carbon can be really small compared to the whole stock then. EE prefers using total stock without depth threshold. Because the concept of changing thresholds is difficult to comprehend and data for total stocks is available in Estonia. In the last version of the draft of amended regulation the depth limit has been removed for reporting this service so changes in the GN may also be forthcoming regarding the issue.

NL considers using LULUCF data. There are ongoing plans to make LULUCF spatial and to include more land use types other than forest that store and sequestrate carbon. Estimations were done based on NFI (forest) and literature data (other ecosystems) which is not regularly updated data. Using average sequestration values and adding these to stocks can result in ever-growing stock but in reality an equilibrium should be achieved. In LULUCF some land use types are assigned 0 to show that the equilibrium has been reached.
Reporting data provided in GN was discussed. Carbon sequestration (primary net carbon sequestration), Net carbon sequestration, Carbon storage at the end of the reference year are mandatory reporting items, other are additional info but helpful to put the whole picture together. It remained unclear whether latest GN allows reporting negative values.

4. Flood protection
   NL has looked into infiltration (rain) and coastal protection services (dykes are replaced by built dunes acting as protection barrier) but not flood protection. Flooding by the rivers is usually protected by dykes and there is no ecosystem service there.
   Eurostat released GN for flood protection in the autumn as voluntary reporting item. EE is testing the service using the following indicator: area of the ecosystems that buffer waterflows resulting in protection of downstream ecosystems that are economically significant from flooding. JRC has also created a model for the service.
5. Air filtration
   Air filtration is assessed similar to GN methodology relying on lookup tables of deposition velocity by ecosystem types. There are some conceptual issues. NL does not apply the GN directly. It can be argued that the concentration of PM2.5 that is measured cannot be treated as amount from which vegetation can further reduce pollution but rather that the capture by vegetation has already happened when concentration is measured. Therefore the calculations should be done backwards.
6. Soil retention service
   NL has not considered soil retention service. Soil retention is a voluntary item, GN was provided in the autumn and JRC has created a model.

Ecosystem extent automatization

Participants: Argo, Kätlin, Shaya, Patrick

Argo Ronk presented the steps of the compilation of extent account and overview of the process of automatization of the account in Estonia. Extent account has been compiled for 2018-2021 and we have the logic and methodology for the account. Currently extent of 2022 is being compiled according to EU GN methodology and typology and automatization work for fetching input data and data pre-processing is underway. Work is done in Python and using ArcPy libary.

1. NL stores their input files in geospatial database or as .shapefiles on the server. This is a separate server with enough space (10 TB) that is available on network. With each new data update new files are added to the server. EE does not have as much experience with spatial data storing and Argo is pioneering how to store and access the data. It was suggested by colleagues working with databases in SE to first gather data to Oracle database and then access it in Python through FME. Storing in server is not currently an option for EE. NL thinks that using FME may not be needed. **It was agreed that a separate meeting will be agreed upon in the future via mail to look NL code, that how they compile the account in Python.**
2. Marine ecosystems. NL shared EUSeaMap which is based on EUNIS. https://emodnet.ec.europa.eu/en/seabed-habitats EE is currently considering using maps produced by HELCOM, which is also based in EUNIS.
3. The efficient ways of the production of the extent account were discussed. Pros and cons regarding the institutional set up of the ecosystem accounting in Statistical Office were discussed. Statistics Netherlands emphasized the need for setting up the system in Statistical Offices if there are no other producers of official statistics in the thematic area of ecosystem mapping and accounting. In Netherlands in the beginning there were several developers of ES maps and topics. Alternatives discontinued as because they filled other purposes than ES accounting.
4. Dissemination of data. NL publishes their results:
   - as tables on CBS database (total extent and by regions), https://www.cbs.nl/en-gb/figures/detail/85835ENG
   - as maps on the dedicated platform for natural capital related data, https://www.atlasnatuurlijkkapitaal.nl/kaarten. Includes extent, some services and condition maps. Available in

Dutch, users are local. Maps can also be downloaded as .zip from webpage. Publishing on the site is financed by Agriculture Ministry.

5. EE ArcGIS Online application for ecosystem extent and services was viewed. https://experience.arcgis.com/experience/6f4d584477e8427bbb0597b03319f9ea/ (currently under development)

Ecosystem services 2

Participants: Jocelyn, Claudia, Sjoerd, Kätlin
Discussed services: crop production, nature related tourism. Timber production was agreed to be discussed in forest accounts session

Crop and nature related tourism were discussed.

1. Crop production
NL uses agriculture statistics as main data source and converts to MFA classes afterwards. Flower bulbs are important in NL but are not covered in MFA therefore agriculture statistics is preferred. Spatial distribution is found by applying average production per province (agriculture statistics data) to the plots in the province. NL no longer uses satellite data to improve spatial estimation of crops/fodder yield.
Nature's contribution to the crop production was discussed. NL has not researched it separately. In case of monetary valuation nature's contribution can be distinguished from output (e.g. using rent price) and the same share could be applied to physical amounts. EE plans to look how organic farming can give some representation.
2. Timber production was agreed to be discussed in forest accounts session. NL had the discussion how well does the increment represent the real use of the service or is fellings better indicator.
3. Nature related tourism
NL has not implemented EU guidance yet (overnight stays), focus is on daily recreation. Estimation of overnight stays is based on expert opinions which regions are visited by tourists together with data on overnight stays on province level and vacation type (nature, relaxation, business, so some types can be eliminated) from questionnaires. Also there is question on what kind of environment the stay takes place which could be used to further refine the estimation. EE has tested assessing the service according to EU GN using JRC developed INCA-tool. And tried refining the estimation with CVM questionnaire data on preferred ecosystem types to visit.

Environmental subsidies

9:30 Environmental subsidies: Julius, Marieke, Sjoerd, Raigo, Grete, Kaia (B2M1)

• COFOG – finding and classifying env. related transfers, determining transfer code, etc – SN has a strong cooperation between environmental statistics and national accounts. COFOG transfers are assigned shares of CEPA/CREMA and updated regularly in cooperation between env. statistics and government statistics. Complex databases are set up and connected to allow for smooth updates and use in environmental statistics. Furthermore, SN can make suggestions to change the classification of certain transfers in public financing records.

SN uses data on spending from ministries to assign CEPA/CREMA shares to general government COFOG data. Transfers by local governments is still a problem – there is no central database for local governments transfers and it's difficult to acquire data directly from local governments and/or the data is not detailed enough. For this, 10 largest local governments are analyzed by SN to assume local governments spendings on CEPA/CREMA activities. Similar approach is used in SE to determine local governments spending on CEPA/CREMA activities. All large transactions are complemented with description of the transaction.

For COFOG 05, its necessary to be wary of non CEPA/CREMA activities – such as road maintenance.

• The financial transparency system (FTS) – potential data source for RoW transfers? SN uses CINEA to determine the RoW transfers. This database could be used by SE to determine Horizon, LIFE, CEF transport/energy fund transfers, if they are not available from other data sources. However, the data is aggregated in CINEA and time of transfers can't be determined (the subsidy is accounted for the year project started). For more information, like the focus of programs, it is necessary to read the description of all programs and assume the main environmental focus and transfer codes.

- Discussion on methodology about which transfers to include in our ESST account, other thoughts and ideas – especially for agricultural subsidies, the CEPA/CREMA classification of transfers should be further discussed as the schemes itself are similar across EU countries. For example, transfers that are classified as CEPA 4 by SE, are classified as CEPA 6/CREMA 13 by SN. This will make the results incomparable between countries. For renewable energy production, SE should check for any possible tax abatements (netting schemes) available for the producers – right now SE is unaware of such abatements.

Further discussions should be held how to classify transfers similarly in ESST account in different countries. This applies to data for Horizon, LIFE, and other programs, but especially for subsidy schemes for agriculture. This is to assure that ESST transfers and CEPA/CREMA classification remains comparable.

13:30 – 16:00 Environmental subsidies: **Julius, Marieke, Sjoerd, Raigo, Grete, Kaia (B2002)**

- Applying CEP in future – technical challenges, ideas – it is not possible to convert CEPA/CREMA directly to CEP for all categories. This means some changes to the methodology and coding.
- SN introduced how they have used web scraping to identify EGSS producers and will send some materials about the methods applied.

Forest account

16:00 Forest accounts (NL: data sources for EFA and methodologies for the stock and output calculation): **Chantal, Roel, Grete, Kaia, Frank (B2004)**

Forest accounts methods were introduced by Statistics Estonia and the methodological and conceptual issues were discussed.

Description was given how Estonia compiled the first round of EFA in 2023 and it is described in the grant report > https://www.stat.ee/sites/default/files/2023-08/Description%20of%20the%20methodology%20and%20methodological%20issues%20for%20forestry%20account%20_101022852_2020-EE-ENVACC%20%281%29_k%C3%BClj.pdf .

Statistics Estonia has the discussions with the head of the department of policy statistics, climate ministry, stakeholders and different organizations. Also enterprises and universities. These stakeholders will also be involved in the November2024 meeting to discuss the results.

Estonia tries to map the forest sector in collaboration with Franz Muerbach (consultant) from The Swiss Federal Statistical Office. SE is going to analyze which transactions are relevant, what are the sizes of the transaction? What is happening on the forest market? What is used and how is the forest used? Those are important questions. Statistics Estonia also struggles with the taxonomy and the definitions, just like Statistics Netherlands.

Statistics Netherlands will send the actor map to Estonia and also part 2 from the last report.

Estonia has quite detailed forestry data available in national accounts, but their methodology is different from EFA. Environmental accounts team is improving the data and send it to their colleagues from the national accounts. SN is going to take the same approach

Statistics Estonia plans to cover the relations with LULUCF and air emissions in their UN London Group paper. SN will share their policy piece and report Estonia when finished. And SE will also share their paper with SN once it is finished. Tables A, B and C should be combined to be relevant for policy. Due to different opinions there is more attention also on EFA results. The EFA will be the official statistics of forest data (in 2025 it is the time that the data needs to be reported about the years 2022 and 2023 due to amendment of the regulation 691/2011).

Forest is an important share in GDP. It provides job opportunities and import/export shares etc. Official statistics is produced by the national bank and by Statistics Estonia. JFSQ is reported to Eurostat but this is voluntary. Estonia will follow the EFA handbook in 2024 and is mostly focusing on the requirements of the regulation. Statistics Estonia will compile voluntary Table C in current grant project by the end of 2024. After that it is not decided yet.

Benefit of EFA was discussed: it will contribute to giving more insights in the GDP and economic input, ecosystems and protected areas. Moreover it shows the connections between ecosystems and monetary/economic data. EFA is a framework to connect basic forest statistics and economics. This is important.

There will be a seminar in November about the EFA tables and methods applied. SN is welcomed to join. Grete Luukas will send slides and the Teams link of the forestry meeting that was held in March (3 hour meeting about introduction to the methods). Statistics Estonia also have forest sector dashboards which are based on different data > https://juhtimislauad.stat.ee/en/forestry-and-wood-industry-11. Statistics Estonia has the 'tree of truth'. The leaves show if indicators are doing better or worse. > https://tamm.stat.ee/?lang=en.

April 17th

Monetary valuation of ecosystem services

Participants: Jocelyn, Sjoerd, Kätlin, Kaia, Üllas, Grete

NL gave an overview on new developments in ecosystem valuation in Statistics Netherlands and in EU and UNSD.

1. NL currently focuses on the work related gross ecosystem product and semantics behind monetary values and valuation. NL will publish report on GEP in May (in Dutch). One core indicator for each account (monetary value of services, physical value of services, condition) for easy understanding for the users.
2. NL will publish 2013-2021 ES values in database soon (crop, timber, water provision, air filtration, carbon sequestration and storage, pollination, water regulation, heat islands, coastal protection. It will be published every year. It is necessary to add accompanying document that explains the content of the account and values. Previously results were published in reports.
3. NL and EE monetary valuation methods mostly coincide. We have found the best approaches to give the best results using the data that is currently available. NL methods: crop: rent price, timber: stumpage price, water provisioning: replacement cost, air filtration: health cost, avoided death, global climate: social efficient price (EE EU ETS) pollination: avoided damage cost, coastal protection: replacement cost, nature related tourism: expenditures. No monetary valuation for local climate yet.
4. Discussion on C stock values. Depending on the purpose of the account the stock may be converted to yearly flow using net present value calculations (reversed, 100n years lifetime). Currently in EU GN storage service is considered a stock that isn't transformed to a flow, so caution is needed when summing the services. When producing a total value like GEP all service values should be on the same level (real supply and use of yearly flows). NL carbon account is updated but focus is on the economy.
5. Üllas gave presentation on the differences of the results between ELME (MAES project in Estonia) and Statistics Estonia previous work with focus on differences in values and methods. One of the findings was also that several services were accounted for potential stock rather than real flows.
6. No plans to revise or update SEEA EA chapter 8-11 on monetary values. Eurostat is carrying out a feasibility study on monetary valuation, which results should be presented in May in WG.
7. EE contribution to the thematic London Group paper on ecosystem accounting. Further collaboration was agreed upon.
8. **Follow up meeting on semantics and monetary values 24.05.2024**

New emerging needs: climate related investments, links to environmental subsidies account

Participants: Sjoerd, Raigo, Olaf, Kaia, Grete

Also climate related investments as a new emerging need under EGSS (and EPEA) was discussed. SN already calculates some climate related investments (related to resource efficiency and energy savings) and Olaf will send their report on the topic to Statistics Estonia. As the topic is new and not completely agreed then hope is to get more information on environmental accounts working group in May. SN agreed to cooperate with arising questions in the future.

Attending of the SEEA CF Revision committee work as listeners

Sjoerd was chairing the SEEA CF Revision committee meeting which gave EE an opportunity to attend the meeting.

Follow-up activities

1. Can NL share slides shown during the ecosystem condition discussion? (Shaya)
2. EE asked Marjolein to share the code for assessing pollination (new code is fully in Python) and help with application. It was agreed to discuss further via mail (Marjolein, Kätlin, Argo)
3. It was agreed that a separate meeting will be agreed upon in the future via mail to look into the code for ecosystem extent with the purpose to optimize (Patrick, Argo)
4. Follow up meeting on semantics and monetary values 24.05.2024 (Kaia, Sjoerd)
5. Regarding environmental subsidies the continuation is foreseen in near future on CEPA/CREMA classification of transfers

List of participants:

Statistics Estonia

Name	Position, function
Ms Kaia Oras	Lead expert of environment statistics and accounts in Environment Economic Statistics Service, responsible for environmental accounts compilation;
Ms Grete Luukas	Leading analyst, responsible for the compiling of the monetary environmental accounts;
Mr Argo Ronk	Leading analyst, responsible for ecosystem extent account and for a certain selection of services
Ms Kätlin Aun	Analyst, responsible for ecosystem extent account and the selection of services
Mr Raigo Rückenberg	Analyst, responsible for the compiling of the environmental subsidies accounts

Statistics Netherlands

Name	Position, function
Mr Sjoerd Schenau	Project leader Environmental Accounts (physical and monetary)
Mr Patrick Bogaart	Researcher in ecosystem accounts
Ms Jocelyn van Berkel	Researcher in ecosystem/ environmental accounts
Mr Julius Hage	Researcher in environmental accounts
Ms Marieke Rensman	Researcher in environmental accounts
Ms Shaya van Houdt	Researcher in ecosystem/ environmental accounts
Mr Frank Prins	Researcher in ecosystem/ environmental accounts

ANNEX 3. Development of the ecosystem accounts in co-ordinated manner.

Comparison of the Extent Maps of Ecosystems by Statistics Estonia and Estonian Environment Agency (KAUR)

Participants: Krisela Uussaar, Madli Linder, Hanna Kaarin Hermlin, Sander Ahi, Kätlin Aun, Kaia Oras, Argo Ronk
Date: 04.11.2024

Estonian Environment Agency (KAUR) conducted a comparison between the extent map by Statistics Estonia (10x10m raster) at the first level of the EU (European Union) ecosystem typology (the most aggregated level), which includes 12 ecosystem types, and the base map of ELME by KAUR (5x5m raster) at the most detailed level, which includes 62 ecosystem types.

KAUR: Why wasn't the extent map sent at the third level of the EU typology? Also, transitions are missing.

Statistics Estonia: The third level of the EU ecosystem typology is defined by the countries themselves, specifying which classes to use. It is important that these nest within the second and first levels of the EU typology, which are fixed and not defined by the countries. Statistics Estonia uses mapping units from the used registers as the third level and distributes them according to the first and second levels of the EU typology. The transition file will be sent later as the corresponding email was not received earlier.

KAUR's presentation:

- When transferring the ELME base map to Eurostat's L1 level, it is not possible to distinguish water bodies (classes: 8. Rivers and canals, 9. Lakes and reservoirs, 10. Marine inlets and transitional waters (lagoons, fjords), and 12. Marine ecosystem).
- The largest differences between the maps occur in the classes: 1. Settlements (Statistics Estonia definition) and other dry grasslands (ELME definition), 2. Settlements (Statistics Estonia's definition) and other wet grasslands (ELME definition), 3. Grasslands (Statistics Estonia's definition) and Deciduous swamp forest (ELME definition).

Statistics Estonia's comment: Eurostat has its own methodology (followed by Statistics Estonia) for determining settlements/urban areas. The ELME base map uses its own methodology for determining settlements/urban areas, and for the comparison of the two maps, Eurostat's methodology for determining urban areas was not applied separately. Hence, the differences arise from the methodologies used.

KAUR's presentation highlights specific location-based examples (larger "patches") where there are differences between the two maps and explains the reasons for these differences.

Settlements (Statistics Estonia's definition) and other dry grasslands (ELME definition) Settlements (Statistics Estonia's definition) and other wet grasslands (ELME definition)

It was concluded again (with these two combinations) that these differences arise from the different methodologies used to compile the maps (see above). This means that it is currently not possible to determine how large the differences would be if ELME urban areas were determined using Eurostat's methodology.

KAUR: ELME developed a methodology for defining urban areas, but the base map uses detailed units even within urban areas, meaning each 10x10 m pixel is classified as a substantive unit. Statistics Estonia, however, uses an approach based on Eurostat's methodology, where urbanity is determined by the percentage of artificial infrastructure within a specific grid size. This means that a grid with 51% artificial infrastructure and 49% natural habitat is classified as an urban unit. In ELME, it is also important to distinguish natural habitats within urban areas at the pixel level, as these areas provide significant ecosystem services. The approaches are not comparable because the levels of generalization are different.

Examples of differences in infrastructure: For instance, airports and railways are classified as infrastructure (Settlements) by Statistics Estonia, but according to the ELME map, these areas are often classified as either dry or wet grasslands if natural habitats are present. KAUR: These are so-called other grasslands, as they could be classified as grasslands based on the data layers used. It is important that these areas function as natural ecosystems and provide ecosystem services, which ELME scientists have repeatedly emphasized, and therefore they are distinguished in the ELME methodology, although in general terms, they are indeed infrastructure areas like airports or railways.

Grasslands (Statistics Estonia's definition) and Deciduous swamp forest (ELME definition).

KAUR's examples show striped areas (tree lines), for example, along ditches. But there are also larger areas.

Since the comparison was made using the first level of the EU typology (grassland), it is difficult to determine the exact reason for such differences without a more detailed view/comparison at the third classification level.

KAUR: It is possible to look closer into the layers, but in such cases, it can generally be said that these are overgrown swampy grasslands. The stripes are ditches and tree-shrub lines visible in the orthophoto. According to ELME, the area qualifies as a forest due to the height of the trees (>5 m, international definition), and the grassland definition by Statistics Estonia should be further investigated (KAUR's assessment is that it cannot be a heritage meadow, both due to its appearance and because it would be classified as a heritage meadow on the ELME map as well).

KAUR will send a layer of major differences so that the specific reasons for the differences can be identified based on location. Statistics Estonia will send a map layer where each polygon indicates the source of the specific data.

Discussion on the percentage of forest according to the ELME map, which is 58% of the entire Estonia. ELME forests include some extent of wooded bogs, and other overgrown open habitats are sometimes classified as forests. Differences arise from different forest definitions, both in ETAK and according to the international definition. In ELME, areas outside the forest register are generally classified as forests if the height of the woody plants exceeds 5 m (international definition) according to the LiDAR-based vegetation height model.

Currently, under the leadership of the forestry department at KAUR, a separate forest mask is being developed for Estonia (based on remote sensing) using the international definition (5 meters and coverage to define a forest). This could be used in the future.

Settlements (Statistics Estonia's definition) and boreal forest (ELME definition).

There was no major discussion, it was pointed out that forests should still be identified as forests, not as settlements.

KAUR: The reasons are the same as above – EUROSTAT's Settlements is a generalized approach.

Forest and woodlands (Statistics Estonia's definition) and yards, roads, wastelands, non-coastal sandy and gravelly areas (ELME definition).

The difference mainly comes from small strips of roads, but there are also some larger areas. The reason for the difference may be due to outdated data from the Forest Register.

Conclusions/agreements:
- Statistics Estonia: The differences were largely expected.
- Statistics Estonia will send a map layer where each polygon indicates the source of the specific data.
- Statistics Estonia will make a presentation on the map comparisons on 15.11.24.

15.11.24

Statistics Estonia conducted a comparison between the extent map by Statistics Estonia (5x5m raster) and the base map by ELME (5x5m raster) at two different levels: 1) at the first level of the EU typology (the most aggregated level), which includes 12 ecosystem types, and 2) at the most detailed level of both maps (so-called III level), where the extent map by Statistics Estonia distinguishes 130 different mapping units (~200 if marine areas are included) and the base map by ELME distinguishes 62 different ecosystem types.

Statistics Estonia presentation:

Detailed level

At the most detailed level (III level), a pixel-by-pixel comparison was made between the two maps, and the result was presented (a table of different combinations between different mapping units, totaling ~4000 combinations). The combinations with the largest area (the first 100 entries in the table) were examined in more detail. These cases cover 92% of the total area of Estonia. The two maps matched the most in the distribution of spruce forests. The largest differences at the III level were: 1) Other bare (Statistics Estonia's definition) and other dry grasslands (ELME definition), 2) Other bare (Statistics Estonia's definition) and other wet grasslands (ELME definition), and 3) Grassland (Statistics Estonia's definition) and Deciduous swamp forest (ELME definition).

KAUR's comment: In fact, Other bare and dry/wet grasslands also match each other, the ELME map simply further subdivides other bare areas into other classes if it was possible to identify them as meadow-like habitats (i.e., areas providing meadow ecosystem services).

The difference arises because other bare is classified as settlements according to the extent map by Statistics Estonia, and other wet/dry grasslands are classified as grasslands according to the ELME map.

The two maps overlapped by 87.6% and had a 4.1% difference.

PRIA data contains differences (one of the main sources of differences), with the extent map by Statistics Estonia using 2022 data and the ELME map using 2021 data. This could be the main reason for the differences in this case.

ETAK fields (Statistics Estonia's definition) and boreal forest (ELME definition) likely result from the use of the vegetation height model in ELME's work. If the vegetation height is over 5 m, the area is generally (with some exceptions, such as heritage meadows) classified as forest (the specific forest type is determined by the soil map). A similar reason likely applies to the change of ETAK grassland (Statistics Estonia's definition) to forest (Boreal forest, ELME definition).

The difference between ETAK grasslands (Statistics Estonia's definition) and Fens (ELME definition) likely comes from the soil map, where the soil map indicates the area should be a fen.

Statistics Estonia has refined ETAK forests using only the soil map (at the forest habitat type level).

Comparison at EU Level I

When transferring the ELME base map to EU Level I, it is not possible to distinguish water bodies (classes: 8. Rivers and canals, 9. Lakes and reservoirs, 10. Marine inlets and transitional waters (lagoons, fjords), and 12. Marine ecosystem).

At EU Level I, the largest differences (by area) come from the Forest and woodlands class (31.8%), Settlements and Other artificial areas class (31.1%), and Inland wetlands class (19.9%). Water bodies were not considered in the differences because they are not classified in the ELME map at EU Level I.

Differences in Settlements arise from different methodologies (see above). In the Statistics Estonia's map, natural ecosystems are included in settlements both within urban areas and at the borders (e.g., if 30% is infrastructure, then

70% must be something other than infrastructure). In the methodology for assessing ecosystem services, additional layers (such as urban areas) are used, which can include separate green areas, tree lines, or hedges.

For forest areas, the ELME map has the highest estimate (2.51 million ha) compared to Statistics Estonia's (2.38 million ha), SMI (2.32 million ha), LULUCF (2.44 million ha), ETAK (2.34 million ha), or MAH (2.33 million ha) (source: ELME2 report).

KAUR comment: This likely results from the use of the vegetation height model outside the forest register (overgrown fields, grasslands, edges of bogs – which are reclassified as forests). There are also often different thresholds for defining a forest (tree height) in different datasets. Transition areas (e.g., swamp forests) are also included in forest accounting.

In the Inland wetlands class, the ELME map includes 6450 floodplain meadows and other wet grasslands, which are classified as grasslands in the Statistics Estonia's extent map.

KAUR: Other wet grasslands received an incorrect classification in the initial transition table (where each ELME class was assigned a corresponding EUROSTAT class); they should generally be classified as grasslands. KAUR is investigating the matter.

Review of Questions/Examples from the Previous Session:

- Example from Saue, where a forest/park is classified as Settlements in the Statistics Estonia's map. Explanation: At Level III, it is also classified as forest in the Statistics Estonia's map, but since it is a forest within an urban area, at Level II it is classified as urban greenspace, which at Level I falls under the Settlements class.

Questions arose about the horticultural land in the same area, which is classified as forest in the ELME map.

KAUR comment: This is likely a case of "filling gaps," where the ecosystem is combined with the adjacent ecosystem.

- Example from Tapa, where grasslands are classified as Settlements in the Statistics Estonia's map. Same situation as the previous example, at Level III these areas are grasslands, but since they are grasslands within an urban area, at Level II they are classified as Urban greenspace, which at Level I falls under the Settlements class.

Questions arose about the railway in Tapa, which is partly classified as grassland and partly as Yards, roads, wastelands, non-coastal sandy and gravelly areas.

KAUR comment: It is possible that the other part of the railway is a railway station.

- Question about the railway again, why it is classified as Settlements in the Statistics Estonia's map, while it is classified as Other wet grasslands in the ELME map.

In Statistics Estonia's map, railways are treated as part of infrastructure, which is one of the classes under Settlements.

- Ämari airport is classified as Settlements in the Statistics Estonia map, while it is classified as Other wet grasslands in the ELME map.

In Statistics Estonia, airports are treated as part of infrastructure, which is one of the classes under Settlements.

- Example from Veibri, where there was a discrepancy between grassland (Statistics Estonia's definition) and Deciduous swamp forest (ELME definition). In this example, no detailed dataset (e.g., PRIA, Forest Register, Natura 2000, ELF, etc.) contains information about this area, so the information on the Statistics Estonia's map came from ETAK, where the area is classified as grassland. **KAUR:** Deciduous swamp forest likely results from a combination of >5 m tall woody vegetation + fen soil.

Conclusions/Summary

- A question remains whether a height model is used in compiling ETAK.
- It was concluded that the main sources of differences are the use of the vegetation height model, the methodology for determining urban areas, and the use of the soil map (for determining grassland and bog types).
- The Other bare class causes differences because it is specified in the ELME map.
- The use of different years of PRIA data causes differences between the two maps.

Agreements:

- We will summarize the meeting and send it to KAUR for further input.
- An indicative meeting was agreed upon before the 12.12.24 seminar to determine the next steps. The meeting will be held on 09.12.24 from 09:30-10:30.

ANNEX 4. Final consultation on ecosystem accounts

November 29, 2024, Statistics Estonia

Summary

Kaia Oras, Kätlin Aun, Grete Luukas, Argo Ronk, Aki Kadulin (Statistics Estonia); Sjoerd Schenau, Patrick Bogaart (Statistics Netherlands)

Issues on extent account

- Argo Ronk provided an overview of the work completed this year, focusing on the compilation of ecosystem accounts and the automation of certain processes. This included:
  - Automation: Using ArcGIS and Python for map automation, particularly for the decision tree process. This involved creating a main script and several smaller scripts to handle specific tasks.
  - The workflow was divided into four parts: acquiring data, preprocessing data, merging/analyzing data, and final steps to clean or improve the data.
  - Marine Areas: Integration of data for marine areas, with the help of local marine experts to transition to EU topology.
  - Future Plans: Further refining these processes, automating the determination of discontinuous settlement areas, and applying EU topology. Additionally, plans to automate some ecosystem service calculations, e.g as crop production.

Feedback on the methodology for assessing local climate regulation

- The document describing the methodology for assessing local climate regulation was sent for consultation beforehand. The methodology was created by Estonian Environment Agency following the instructions given in repective Eurostat guidance. Second opinion was asked, but Statistics Netherlands have no experience assessing local climate regulation ecosystem service as of now.
- Patrick Bogaart raised issues about the approach that was chosen by Eurostat. The input data for the model is important, e.g in case of evapotranspiration, emphasizing the need to distinguish between actual and potential evapotranspiration. Actual evapotranspiration: is crucial for understanding local climate regulation, as it directly impacts cooling effects. The cooling effect of evapotranspiration only occurs if there is water available to evaporate. During prolonged droughts, the lack of water can lead to heat buildup. Potential evapotranspiration represents the maximum possible evapotranspiration under ideal conditions, which may not reflect actual conditions.
- The importance of understanding the contributions of tree cover density and evapotranspiration to local climate regulation was also highlighted. Patrick suggested:
  - Statistical Measures**:** Computing R-squared and P-values to better understand the significance of these contributions.
  - Multiple Parameter Regression**:** To get a better understanding of how each parameter influences the results.
- Water bodies contribute to cooling through evaporation, which should be considered in the models. In guidance note waterbodies are excluded by default. The results obtained in Estonia show considerable cooling effect from water bodies. Patrick agreed that the current models might not fully account for this.
- The limitations of satellite data were discussed, with a consensus on the need for more ground-based measurements to improve accuracy. The team acknowledged the difficulty in validating these models without sufficient ground truth data.

- Kaia Oras raised the topic of presenting their work at an upcoming conference in January, discussing the maturity of current data and methodologies.
  - The importance of presenting their work at a conference to share their findings and methodologies with a broader audience.
  - The need to include experts from urban and macro-environmental fields in future discussions to ensure comprehensive coverage of the topics.

- Patrick and Sjoerd agreed that presenting at the conference would be an excellent opportunity to share the findings with a broader audience and to gain feedback.
- Patrick suggested that the presentation should focus the advancements made and the challenges overcome. It should highlight that even though the topic is relevant regarding climate change but the approach and definitions are not yet mature and there is robustness in the methodology.
- Sjoerd recommended including real-world examples would make the presentation more engaging and relatable for the audience.

Ecosystem services and condition indicators

- Kätlin Aun gave an overview on condition account, including new condition indicators. The work to develop the methodology for condition indicators: forest bird index, butterfly index, forest connectivity and share of wetlands influenced by drainage was subcontracted from Estonian Environment Agency.
  - Forest bird index is: an already reported index, additional analysis was done.
  - Butterfly index was developed as a new indicator based on the data of monitoring butterfly populations.
  - Maps of drainage systems were analysed to determine the area of wetlands affected by drainage.

Validation and quality checks

- The importance of having robust validation processes for maps and data was discussed.
  - Statistics Estonia currently uses a method of taking random subsets of polygons and comparing them with aerial or satellite photos to validate their results. However, the need for more systematic validation processes was recognized.

Further actions

It was agreed that Statistics Estonia’s methodological document will be shared with Statistics Netherlands.

ANNEX 5. Final seminar on ecosystem accounts

December 12, 2024, Statistics Estonia

Draft minutes as of 27.12.2024

Participants:

Kaia Oras, Kätlin Aun, Grete Luukas, Argo Ronk, Aki Kadulin, Anne-Mari Muru, Kaire Raasik (Statistics Estonia); Madli Linder, Krisela Uussaar, Sander Ahi, Hanna Kaarin Hermlin, Kairi Vint, Olev Märtens, Meelis Leivits (Estonian Environment Agency); Eve Veroman, Kalev Sepp (Estonian University of Life Sciences); Kadri Möller, Hedy Eeriksoo, Margit Tennokene, Eleri Pulk, Mart Kiis, Ayrton Hüüs (Ministry of Climate); Tiina Köster, Maris Kruuse (The Centre of Estonian Rural Research and Knowledge); Andres Levald, Birgit Pai (Ministry of Regional Affairs and Agriculture); Üllas Ehrlich, Aija Kosk (Tallinn University of Technology); Aveliina Helm (University of Tartu)

Overview of ecosystem accounts project activities, international developments, Regulation on European Environmental Accounts EU 691/2011 (Kaia Oras)

Kaia Oras gave an overview of the framework of the ecosystem accounting beginning with UN SEEA to the current state of the new proposed modules of regulation EU 691/2011, including ecosystem accounting module. The legislative text was adopted on December 6th 2024. The first data transmission is in 2026 on the account for year 2024. Statistics Estonia will have a new grant during the period January to December 20205 for the development of accounts including data production, metadata and testing the reporting for Task Force. The definitions of the Regulation 691/2011 and Nature Restoration Law are slightly different and need to be harmonised in the future. The feasibility study concerning monetary valuation is under discussion in discussion. It is important to get the feedback that represents the view of the state, not only the view of Statistics Estonia in the matter.

Upcoming/planned reporting in CBD and introduction to the Nature Restoration Law (Kadri Möller)

Kadri Möller as a representative from Ministry of Climate, gave an overview on Convention of Biological Diversity and Nature Restoration Law and the indicators used to monitor ecosystems. CBD is the largest and most important global biodiversity convention. At the end of 2022, the Kunming-Montreal Global Biodiversity Framework was adopted, agreeing on four long-term goals (by 2050) and 23 specific targets to be achieved by 2030. Additionally, principles for a global monitoring plan were agreed upon to continuously and standardly measure progress towards the goals and targets. The methodology for the indicators is still being developed. The goals and targets related to ecosystem accounting include (restore, conserve, and enhance nature's contributions to people) and indicator B1 (ecosystem services) in the monitoring framework. The CDB regulation allows for narrative reporting, but numerical indicators (e.g., areas) are still necessary.

Nature Restoration Law was adopted on 18th August 20204. The objective of the regulation is to restore 20% of European seas and land by 2030, and almost all degraded ecosystems by 2050. Countries have to create and submit a restoration plan to meet the targets, the deadline for fist plan is 1.09.2027. Monitoring every 6 years is applied to habitat, species habitats and urban green areas. Data on urban areas would require cooperation with Statistics Estonia. NRL includes indicators that are also included in ecosystem accounting such as pollinators, organic carbon stock farmland bird index, forest bird index, deadwood, etc.

Overview of activities by Estonian Environment Agency (KAUR) related to ecosystem accounting (Madli Linder)

Madli Linder gave an introduction of ELME I (2020/2021, Nationwide assessment and mapping of the condition of ecosystems and ecosystem services.) and ELME II (2023, Socio-economic assessment of ecosystem services) activities. The projects focused on 4 terrestial ecosystems: grasslands, forests, wetlands, croplands, additionally other areas and coastal areas were mapped. Examples of projects using ELME results were given: environmental impact assessments, general and national planning (including green networks), conservation planning and effectiveness assessment, environmental accounting, agri-environmental subsidies, issuance of mining permits, wind farm development, restoration projects, scientific research, ecological indexing, Rail Baltica analysis, public use of mushroom and berry maps, sustainable planning tools, pollinator action plan, upcoming sustainability reporting and land use hierarchy.

Creation of extent account (Argo Ronk)

Argo Ronk gave an overview about compilation of extent account for the year 2022. Also, previous years' work was highlighted, methodology used (methodology was developed in previous projects) and challenges which have been addressed. There were three main aims which were fully fulfilled during the project: compile the extent account based on Eurostat guidance note on ecosystem extent accounts, inclusion of marine ecosystems into extent account and automate at least some of the steps in compilation of ecosystem extent account workflow. Biggest change compared to previous years in compilation of the extent account was using EU ecosystem typology to classify the Estonian ecosystems. For example, methodology was introduced for distinction between continuous and discontinuous settlement areas. Also, during the project, the guidance note on ecosystem extent accounts was successfully tested and results and feedback was sent to Eurostat. For marine ecosystems HELCOM HUB spatial data was used and with the help of experts from Marine Institute was cross walked into EU ecosystem typology. ArcPy (Python module) was used in order to partially automate the workflow in compilation of ecosystem extent account. A general scheme was presented outlining how the automation works and identifying tasks to be addressed in the coming years. Overall, it was concluded that all goals set were fulfilled.

Comparison between Statistics Estonia's and Environmental Agency ecosystem extent maps (Argo Ronk)

Argo Ronk presented an overview of the joint progress and results achieved by Statistics Estonia and the Environmental Agency in comparing their respective ecosystem extent maps for Estonia. Primary aim was to identify the differences between two maps and understand the underlying causes for these. Comparisons were made on two different levels: 1) comparison in most detailed map level and 2) comparison on EU typology level 1. As this work is still ongoing, ~92% of total Estonia area was covered by these analyses at the moment. In most detailed map level, it was found that 87.6% of the total area, both maps were similar and 4.1% of the area there were differences in sense of ecosystem type. Eight percent of Estonia area still needs to be analysed although it could be expected that orders of magnitude will be similar to what was found. On EU typology level 1, biggest differences (in sense of area) were between Settlements and artificial area, Forest and Woodland area and inlands wetlands classes. For settlements and artificial area class, causes for differences are due to use of different methodology too determine these areas (continuous, discontinuous areas, infrastructure, urban green, other artificial areas). Area differences in forest and woodland class are multifaceted as it in one hand it reflects the incompleteness of national datasets (Forest registry, topographic database) and in other hand use of different definition of forest (what classifies as forest) between two maps and use of LIDAR data in compiling Environmental Agency ecosystem extent map. Causes of differences in inland wetlands class areas is currently in works, but likely the differences are not that big as initially found.

Ecosystem services account and results (Kätlin Aun)

The assessment of ecosystem services included both biophysical and monetary evaluations. The services were chosen based on the amendment to EU Regulation 691/2011. The methodologies for biophysical assessment are derived from the guidance notes prepared by Eurostat. The methods for biophysical and monetary valuation and the results for 2022 were introduced. Additional ecosystem services (flood regulation and distinguishing the contribution of ecosystems to crop production) based on national interest were assessed.

- Crop production: Physical quantities of used crops were derived from MFA, with cropfields and grasslands being the supplying ecosystems. Monetary valuation is based on rent prices, with input data derived from agricultural statistics.
- Crop pollination: This service is calculated as the increase in the yield of crops that require pollination, attributed to the ecosystems providing the service through pollinator insects. The calculation uses GIS data, including crop maps, ecosystem extent maps, and crop yields by county. For monetary valuation, unit prices for specific crop types were used in addition to crop yields.
- Wood production: The physical indicator is net increment, input data is from Environmental Agency. Monetary valuation is based on stumpage prices of increment and harvest. The service indicators should align with the data in forest account, which are also in development.

- Air filtration: The Estonian Environmental Research Center conducts the work in biophysical units based on Eurostat's guidance material. For monetary valuation, a benefit transfer based on the external costs of air pollution is used.
- Global climate regulation: Data on CO2 removal was obtained from the National Inventory Report of greenhouse gas emissions. Monetary valuation is based on EU ETS prices. The assessment of stored carbon is based on carbon stock maps created in ELME2 project. For monetary valuation of carbon storage, EU ETS prices are used.
- Nature-based tourism services: The physical indicator is overnight stays attributed to ecosystems. Input data is from accommodation statistics, and the contribution of ecosystems was done in INCATool which is developed by JRC. Monetary valuation is based on travel costs.

Local climate regulation (Madli Linder)

Madli Linder gave a brief overview of work done and results on assessing local climate regulation ecosystem service. The assessment uses instructions from Eurostat guidance note on the assessment of the service. Estonian Environment Agency has previously published work on heat islands. Current work built upon the previous experience on assessing heat island. Main input data are satellite images for obtaining land surface temperature but satellite overflight times and suitable weather conditions (without clouds) may not coincide with occurring heatwaves which makes analysis more difficult.

Input data for finding the cooling effect of vegetation in urban areas include Landsat 8/9 level 1 data over which Land Surface Temperature was found. Copernicus Tree Cover Density and Evapotranspiration from Google Earth Engine platform. The results show estimated daily cooling effect for the entire period (May-September) in Tallinn 2022, according to tree cover density and total evaporation from plants.

Kätlin Aun: How to interpret the results in the presented table? Madli Linder and Olev Märtens: The results are calculated within the municipality (LAU) and by ecosystem types. In the case of this service, the maps give a better understanding of the service than the final numerical values. It was found that for clearer interpretation, the discussion on the specifics of the service continues after the seminar between Statistics Estonia and Estonian Environment Agency.

Flood regulation (Hanna Kaarin Hermlin)

The input data for the work done on flood regulation ecosystem services were ELME2 ecosystem extent map, ELME2 water flow regulation capacity volume map, flood maps in 2018-2023 by Estonian Environment Agency. The ability of the ecosystem to regulate flooding depend on soil layer thickness, soil permeability, and relief. The indicator of the service was the area affected by floods (110 thousand ha of which 42,7% were areas of economic importance), the volume of water flow regulation was assessed to be 157 million m3. As a monetary valuation method, replacement cost of storing the same amount of water in an artificial reservoir, was calculated. The theoretical demand of this service by population was found by using the map of demand of ecosystem services developed in ELME2 project. It was noted that because data on real flooding incidents was used to identify the flooded areas, the analysis does not include areas where the waterflow has already been buffered, therefore the service is likely underestimated.

Kätlin Aun: Did you also consider using data on the probability of floods, e.g flooding event in 1-, 5-, 10- year time? Madli Linder: The data used for this calculation is obtained from lidar data and it is the most accurate available. The data of probability of flooding events is not really used, insurance companies do not use it either.

Kaia – Eurostat Feasibility Study on valuation of ecosystem Services

Validation of data and valuation methods was conducted by comparing the results of ecosystem services assessed by Statistics Estonia with those from the nationwide research projects ELME 1 and ELME 2. Overview presented and compared the assessment methods from Statistics Estonia’s earlier grant report and the ELME 2 report in both physical and financial units. Each ecosystem service is discussed. The assessments of physical units and monetary values by Statistics Estonia and ELME 2 were discussed and commented. A summary table of the physical and financial evaluation results was displayed. The comments overviewing the methods were asked for and were briefly discussed.

Comparing the approaches, Statistics Estonia follows Eurostat and UNSD standards, making clear distinctions between ecosystem extent, condition, and services, and between stock and service. ELME's approach is more flexible, sometimes valuing stocks as a precondition for service provision.

It was brought that different factors collectively influence the valuation outcomes: variations in data sources, assumptions, and the scope of the studies contribute to differing values.

Statistics Estonia emphasizes ecosystem services and their monetary valuation, making clear distinctions between ecosystem extent, condition, and services. In contrast, ELME work places greater emphasis on ecosystem mapping and condition assessment, which may lead to different valuation outcomes.

Statistics Estonia has used standardized methods that align with certain international practices, while ELME may have incorporated different scientific suggestions and methodologies, leading to variations in the results. Differences in how ecosystem services and stocks are defined and categorized has also impacted the valuation results.

Kaia – Eurostat Feasibility Study on valuation of ecosystem Services

Statistics Estonia contributes to the work of the Eurostat Ecosysem Accounts Task Force. After the launch of the analyses of the feasibility of the valuation of the ecosystem services, the respective consultation among Estonian scientists and stakeholders was initiated. Written comments were collected and the results of the study were analysed on a methodological seminar 2. The knowledge gained and analyses compiled in a frame of the work on comparing the analyses and quality were aligned with the project goals and in another hand feeding back into the TF work.

The presentation of the Eurostat feasibility study on valuation of ecosystem services made by Kaia Oras. She highlighted that the financial assessment of ecosystem services intends to bring visibility to services that are otherwise overlooked in the economic framework. By assigning financial value estimates, these assessments have the potential to enhance decision-making and ecosystem management across various levels of governance and policy-making.

It was proposed in a study that consolidating different services produced by the same ecosystem asset into a single unit (euro) is targeted to provide a possible measure of the value of the underlying asset (the ecosystem service asset? ecosystem itself?). For example, forests produce wood (m^3), sequester carbon (tonnes of CO_2), and support tourism (number of visits). It was discussed that this consolidation must provide a comprehensive valuation of the ecosystem.

Additionally it was acknowledged that there is an attention of developing environmentally-adjusted indicators of income, GDP, and wealth, as recommended by Dasgupta (2021). Financial ecosystem accounts can support macroeconomic modelling of the links and dependencies between the economy, ecosystem, and biosphere. As it has been suggested that at the local level, these accounts can provide insights into the total value of ecosystems and benchmarks for assessing ecosystems in project evaluations, as part of a broader set of diverse and pluralistic values and more broadly, monetary values and their changes offer an opportunity to combine use value, scarcity, demand, substitutability, etc., on a single scale, these aspects were handled on a seminar.

Discussion: The discussion highlighted several key points regarding the financial assessment of ecosystem services. Different methods can yield varying results, raising the question of how to determine the most suitable approach. Challenges arise when the actual financial assessment begins, as only a specific numbers finally could be used/shown, and the underlying doubts and restrictions could be often overlooked.

It was noted that ecosystem services differ significantly from non-market goods and services reflected in national accounts. For non-market goods, it is reasonable to assume that their market value should at least equal the sum of the costs incurred by their producers. However, this might not be the case for ecosystem services.

The group discussed the need to define criteria for selecting feasible and relevant valuation methods. Semantics play a crucial role in valuation results as well. Main threats include low values compared to other SNA values, lack of consensus on valuation methods, and potential misrepresentation of substitutability. It was noted that market prices may not accurately reflect the value of ecosystem services, as the economy is integrated into the wider biosphere.

The group discussed that ecosystem services often have low representation and are not addressed within a coherent framework. Selecting only a few services may reduce the value of other important services. The impact of changes in the state of ecosystem services is not addressed, and the directions of change in individual indicators (whether more is better or less) are not agreed upon, as exemplified by wood provision service.

Hierarchy for ecosystem services methos was discussed. Since there are no market prices for public goods by definition, the general hierarchy of valuation methods as presented currently would not yet be very helpful.

The proposal was made to select fewer than ten ecosystem services for future analyses and to map the values related to single ecosystem services in a comprehensive framework. Preferred assessment methods include directly observable prices, market prices for similar goods, market transactions, certified expenditures, and willingness to pay. It was suggested to first distinguish between assessment methods for private and public goods and discuss these separately in future.

Aveliina Elm proposed that: 1. Fewer benefits, 2. focus on regulatory, 3. widely open aspects. As main concerns have already been highlighted, Estonia's position is to be careful. Monetary assessment may not always be valid, it would be better to move towards physical accounts. Fewer benefits but more detailed, focusing on regulatory benefits. Supply benefits are already somehow included. Emphasize regulatory or cultural benefits. Considering the important role of nature, we should focus on regulatory benefits and very thoroughly. Non-monetary units are also important, e.g., connections with other benefits. Estonia is among the countries that think ahead and work proactively.

Kaia Oras: Which regulatory benefits should be described? We need to move forward with specific regulatory services, otherwise, the topics have become very abstract.

Aveliina Elm: pollination is certainly very important, climate regulations too, air filtration is not so important, maybe not put effort there. Wood and food do not need to be highlighted.

Eve Veroman: Concerns and weak points were and need to be highlighted. Liked the idea of creating a concept that highlights the "most important" benefits where the ecosystem contribution is well demonstrated. Fewer benefits but detailed analysis, emphasizing that these are just a few of many. This is better than doing all of them poorly. Pollination and natural pest control are important regulatory benefits that can be accompanied by monetary figures. The primary role of insects is not to make money for the producer or save costs, it is just one aspect. Annual figures should not be based on one year's numbers, as years vary so much in agriculture and horticulture, an average of years should be taken to reduce the impact of fluctuations.

Kaia Oras proposed to work on the mapping tables of the services and relevant methods together, not sticking to one or two parallel value tables as currently was created and presented in earlier session regarding the methods applied by ELME and Statistics Estonia? Yes, agree to help fill the table.

Eve Veroman: it would be good to show the results obtained by different methods and then compare them. What is the contribution? An online table will be created where assessment methods can be added and then the results. ELME and Statistics Estonia methods can already be added there. Madli: this is still a big job. KAUR cannot guarantee how much we can fill, but we are interested in being involved.

Kaia Oras: by the end of the year, still in December, we plan report back to Eurostat on feasibility study and then proceed with the mapping of the ecosystem service values only in January. The emphasis would be on what a particular methodology means and interpreting the results to avoid having just one number that lives its own life.

Condition account (Kätlin Aun)

The methods for condition indicators and the results for 2022 account were introduced. The condition indicators were chosen based on the amendment to EU Regulation 691/2011 and assessed based on the suggestions in the respective guidance notes prepared by Eurostat.

Mandatory indicators include green areas in cities and adjacent towns and suburbs, concentration of PM2.5, soil organic carbon stock in topsoil for grasslands, soil organic carbon stock in topsoil in croplands, common farmland birds index, deadwood in forest, forest tree cover density, common forest bird index, share of artificial impervious area cover in coastal areas.

Additional ecosystem condition indicators based on national interest were introduced. Forest connectivity, inland wetlands influenced by drainage and forest bird index and butterfly index were indicators that needed further analysis which was carried out by KAUR. The experts from KAUR introduced their work in following sessions. Other proposed additional indicators were obtained by queries or calculated in-house.

Forest bird index and Butterfly index (Meelis Leivits)

Meelis Leivits introduced multi-species indices on which bird and butterfly indeces are based on.

Overview on the included butterfly species and results of grassland butterfly index was given. Species choice for grassland butterfly index is based on 10 species which 5 are listed in EU grassland butterfly index species list (European Environment Agency, 2024) and additional 4 species were included to improve the representativity of common grassland butterflies. 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. Several issues were identified with the sampling and monitoring intervals, which give concerns that the indicator lacks representativity in national level.

Overview on the calculation, included bird species and results of forest bird index (FoBI) and Estonian forest bird index (EST-FoBI) was given. Estonian forest bird index is based on expert choice and includes almost all abundant forest specialists (53 species) in Estonia. In the calculation of the Estonian FoBI, it was possible to use the data of 24 species, 7 has declining, 9 stable, and 1 increasing population trends.

Kätlin Aun asked who does the monitoring and calculations in Estonia. Meelis: KAUR does the calculations and coordinates the monitoring which is based on volunteer observers.

Forest Connectivity (Sander Ahi)

The calculations for the indicator were made based on data that was also used in ELM1 and ELME2. Areas from Forest Registry, as well areas outside of it, which were detected based on vegetation height model (LiDAR data, where on an area with a minimum size of 0.05 hectares and vegetation height greater than 5 meters were considered as forest), were included in the analysis. The connectivity was calculated in two ways: using 10 ha window size and 314 ha window size for all of the forests and for forests in good condition. It was concluded that the size of the window and the condition of the forest play an important role in the results. A smaller window size highlights stepping stones, while a larger window emphasizes larger support areas, with the connectivity of stepping stones being low. The condition of forests are important to consider as it helps to distinguish the connectivity of all forests or forests in better ecological condition.

Wetlands influenced by drainage (Madli Linder)

The indicators were: 1) Area of wetlands affected by drainage (ha) 2) Percentage of wetlands affected by drainage (%). The calculations were made based on data that was also used in ELME project to assess the condition of wetland ecosystems as drainage is the most important factor affecting condition of wetlands. Insight into the creation of condition classes of wetland ecosystems in ELME project was given. Besides drainage (distance of drainage ditch), factors like status of protection, impact of human activity, restored or potential for restoring were considered to determine the condition. The data on drainage infrastructure is based on Estonian topographic map (ETAK) and land improvement (maaparanduse) database was used. Results show that 53 % on the wetlands are not influenced by drainage, whereas 31% are moderately or strongly influenced.

Future Plans (Kaia Oras)

- For the new grant the initial plans have been made.
- From 2026 onward when regular reporting of ecosystem accounts is foreseen,
- There are 5 main goals and workflows in progress.
    - Development of ecosystem extent accounting, data compilation, meta-information and communication.
    - Development of accounting for ecosystem services and compilation of data, meta-information and communication.
    - Development of accounting for the state of the ecosystem and compilation of data, meta-information and communication.
    - Development of an inclusive system of partners for ecosystem accounting.
    - Methodological development and communication at the general level of ecosystem accounting.
- Automation is a priority topic. Statistics Estonia will follow EU regulation 691/2011 as the main guidance in a work.

- In January, there will be a kick-off meeting of the new project. Methodological seminars will be held in April and November.
- The 31st London Group will be held on September 22-25, 2025, in Tallinn. Local experts are invited to contribute. The details and the topics will be discussed in coming months.

ANNEX 6. Statistics Estonia and ELME2 ecosystem services valuation results summary in physical units and in monetary units

Ecosystem service	Indicator (regulation 691/2011), chapter 4.1	Statistics Estonia, physical units	Statistics Estonia, monetary units	ELME2, physical units	ELME2 monetary units	Nature of difference	Method according to Eurostat upcoming Feasibility study for the valuation of ecosystem services	Proposals from consultation:
Provision of agricultural production	Amount of harvested crops for different uses, in tons	4554 thousand tonnes (crops + fodder, annual)	72 million euros (rent price method, annual)		41 300 million euros (replacement cost method for soil)	STAT: revealed preference ELME: value of the stock of soil	Link to the indicator, preference to use values from existing markets (Figure 2.3)	Market value of crop yield? Land rental price? Product or service related to ecological nature?
Pollination of agricultural production	Amount of the of pollinator dependent crops in tonnes	75 thousand tons (avoided production reduction, annual)	29 million euros, annual(market value of crop yield requiring pollination)		63,1 million euros (contribution of pollinators)	Similar methods, differences in prices	Link to the indicator, preference to use values from existing markets (Figure 2.3)	Market value of crop yield requiring pollination? Product or service related to ecological nature?
Wood provision	Net increment of timber as defined in Annex VII in over-bark, in thousand m3	11,78 million m3 over bark (annual)	238 million euros (stumpage value, based on net increment, annual)		15 000 million euros (total value of wood stock)	STAT: revealed preference ELME: value of the stock	Stumpage value of net increment Land rental price Residual value of the activity (resource rent)	Increment? Logging? Timber stock? Other product or service related to ecological nature?
Air filtration	Amounts of particulate matter, PM2.5, abdsorbed in tonnes	554 tonnes PM2.5 absorbed (annual)	1 million euros (annual, adjusted benefit transfer)	1180 tons PM2.5 (removal, annual)	21 million euros (saved health costs, annual)	STAT: benefit transfer ELME: health costs	link from the physical unit (tonnes of PM absorbed) and health effects (e.g. life years lost) which can be expressed in terms of the area (i.e., hectares of woodland) or individual (i.e., per individual, or per worker). 1)market benefit associated with better health, 2) revealed avoided treatment costs	Is there a threshold where impacts occur, and service provision begins
Global climate regulation	tonnes of net sequestration of carbon and tonnes of organic carbon stored in terrestrial ecosystems, including above ground and below ground stock	52 thousand ton of carbon (annual sequestration	5 million euros (EU ETS price based calculation)	Carbon stock in soil and biomass is calculated	The EU ETS value of soil organic carbon stock (1,158,498 million euros), social cost (2,437,493 million euros), avoided damage (1,938,278 - 78,966,892 million euros). The EU ETS value of biomass-associated carbon stock, social cost...	STAT: revealed preference ELME: various stock valuation approaches	Link to the indicator, preference to use values from existing markets (Figure 2.3)	What is the price of carbon. EU ETS Social cost of carbon
Local climate regulation	Reduction of temperature in cities, due to the effect of urban vegetation, in degrees on days exceeding 25 degrees Celsius	Not quantified	1 million euros (annual, CVM)	Relative regulative ability of different ecosystems	Not estimated		Link to the indicator, preference to use values from existing markets (Figure 2.3)	Parallel with air filtration. Relationship with health impacts. Is there a threshold where impacts occurs, and service provision begins?
Flood control	-	Not evaluated			4000 million euros (annual, soil buffering capacity, replacement cost)		Link to the indicator, preference to use values from existing markets (Figure 2.3)	Tourist expenditures Product or service values related to ecological nature?
Nature related tourism	Number of overnight stays in hotels, hostels, camping grounds, etc. that can be attributed to visits to ecosystems	1,46 million overnight stays (annual)	353 million euros (tourists' expenditures)		425 million euros (annual, tourists' expenditures)			Substitution costs?

ANNEX 7. Appendices for local climate regulation

Appendix 1. Examples of the LST maps, TCD, Evap. and 3 types of cooling maps.

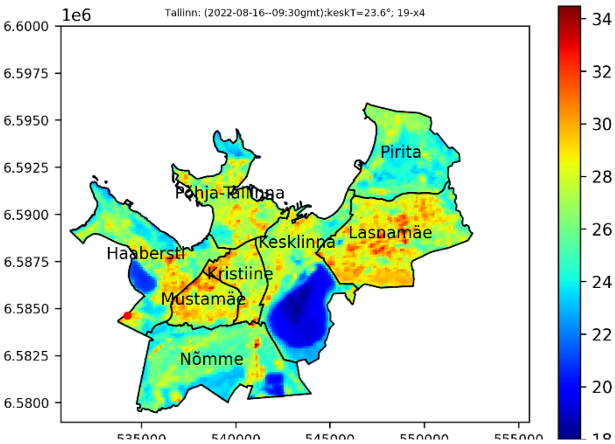


Fig 1 Tallinn LST map – from 18 to 34°C

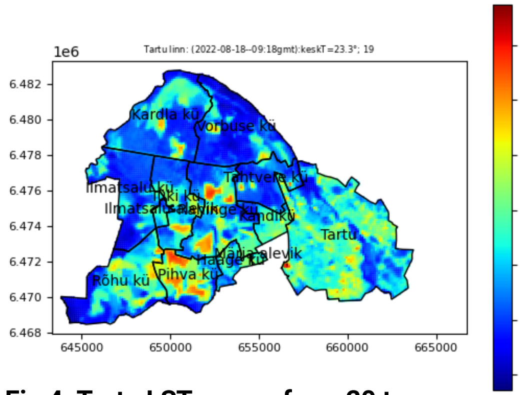


Fig 4. Tartu LST map – from 20 to

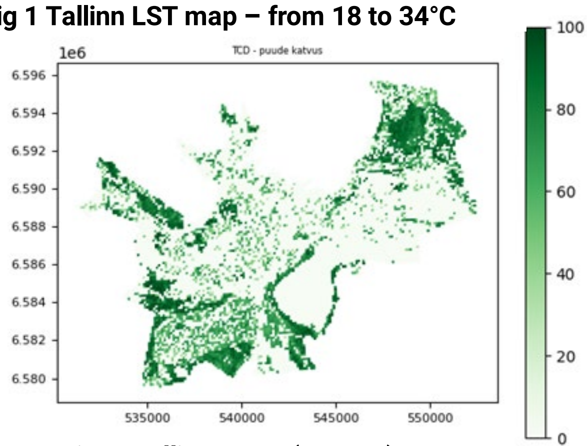


Fig 2. Tallinn - TCD (0-100%) map

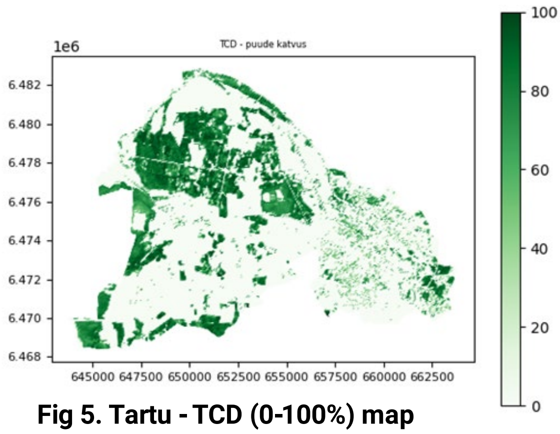


Fig 5. Tartu - TCD (0-100%) map

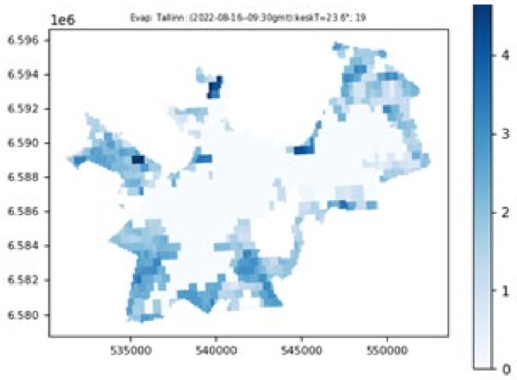


Fig 3 Tallinn- Evap. (0-4.2%)

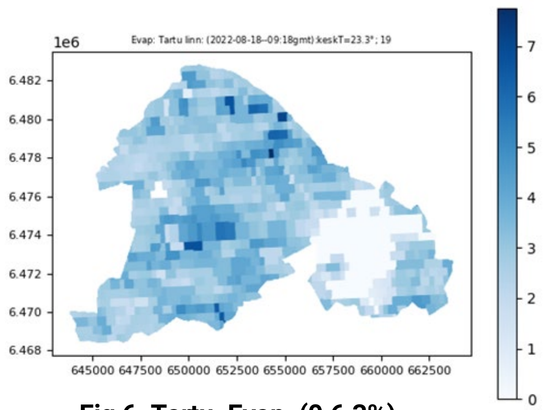


Fig 6. Tartu- Evap. (0-6.3%)

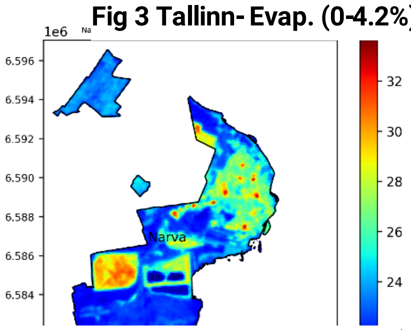


Fig 7. Narva LST map – from 20 to 33°C

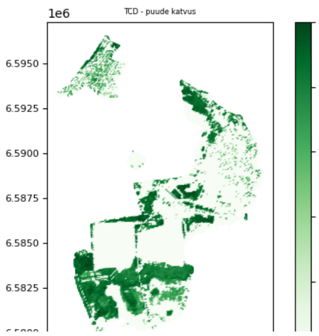
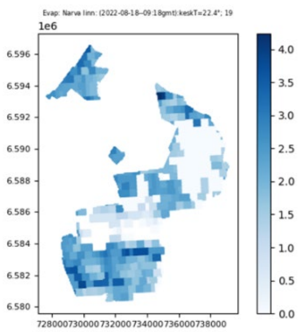


Fig 8. Narva- TCD (0-100%) map



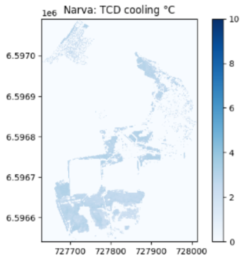


Fig 10. Narva TCD-cooling map

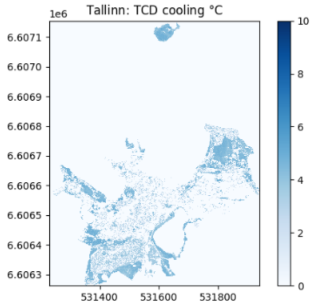


Fig 11. Tallinn TCD-cooling map

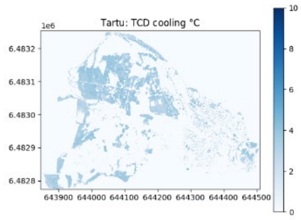


Fig 12. Tartu TCD-cooling

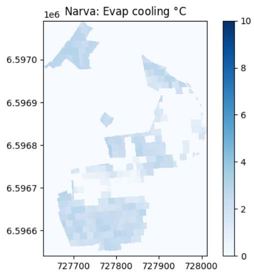


Fig 13. Narva Evap. cooling map

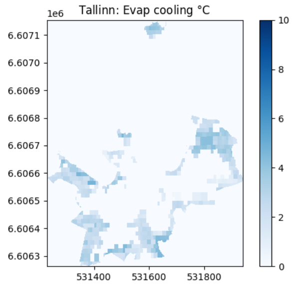


Fig 14. Tallinn Evap. cooling map

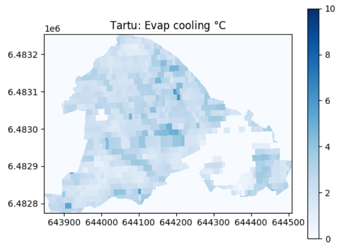


Fig 15. Tartu Evap. cooling map

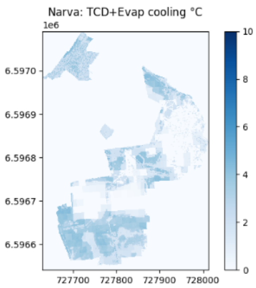


Fig 16. Narva TCD+Evap cooling map

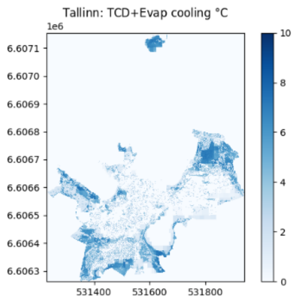


Fig 17. Tallinn TCD+Evap cooling map

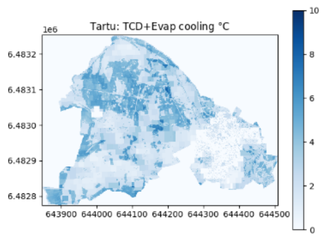


Fig 18. Tartu TCD+Evap cooling map

Appendix 2. Proposed alternative methodology to evaluate the cooling effect by area classes of the *Guidance*

1. Cooling effect calculation (accounting), to fill the table - EU guide "Table 2. Supply table…", its mandatory line " Reduction in heat exposure, expressed as average temperature reduction on days with maximum temperature exceeding 25°C.

1.1. Used input data

a) Landsat-8 (and -9) (abbreviated as *LS8/9*) available (and without significant clouds) datasets for municipalities of interest, 2019-2024 data, in a reasonable (at least several per summer) quantity.

b) Map of Estonia with the terrain type classes, provided by Estonian Statistics authorities (version of 30.04.2024, *as Stat_Extent_22.zip – geo-TIFF file, 10x10 m pixels*). See table in the Appendix 1 to see how data could be aggregated into terrain categories for EU reporting.

c) Basemaps of the Estonian Land Board (*'ETAK'*-map) with the geo-location and borders of municipalities to perform the analysis in the administrative boundaries of municipalities.

2. Suggested cities of Estonia for analysis could be (but not limited to) the largest cities, like Tallinn, Tartu and Narva with about 400, 100 and 70 thousand citizens respectively.

3. Calculation process for evaluating the effect of cooling:

a) Over the year of interest (e.g. 2022) - heat maps of the city are calculated from *LS8/9* data, for each *LS8/9* dataset (of 30x30m pixels) within the municipality (*LAU*) of interest. The currently used algorithm is the land surface temperature (*LST)* calculated from LS8/9 raw (*'Level 1'*) data from bands B4, B5, B10, as proposed in several papers and used in the previous 2020 work of O. Märtens et al, for evaluating Estonian urban heat islands (*UHI*).

b) all estimated pixel temperatures of the obtained heat map in the limits of LAU are grouped according to the corresponding surface classes, first according to the types of the Estonian Statistics authorities map (1-29).

c) The temperature pixels of these 29 subclasses are grouped to 1-12 surface classes of the *guideline.* And mean temperatures and the number of pixels (representing area of the corresponding class, each *30x30m pixel =900* m^2) are calculated for each of 12 classes: $temp_1 ... temp_{12;}\ count_1 ...\ count_{12}$

d) mean temperature over all LAU pixels is calculated; can be also found as the weighted sum of temperatures over the classes:

$$count_{total} = count_1 + count_2 + ... + count_{12,}$$

$$temp_{mean} = (temp_1 * count_1 + temp_2 * count_2 + ... + temp_{12} * count_{12})/count_{total.}$$

e) The total cooling effect from classes 2-12 is calculated as: $temp_{coolingTotal} = temp_{mean} - temp_1$,

where $temp_1 = temp_{base}$ is the first base class (*settlements and other artificial areas*).

The first class is taken as base ("zero") value, as it is considered – the other land area classes- forests, rivers, lakes, grasslands etc. are giving the major contributions to the cooling effect to the otherwise totally urban environment of the cities.

f) This total cooling effect would be distributed for each class 2 to 12 proportionally by the corresponding class size and temperature difference from the mean value:

$$temp_{cooling2} = (count_2 / count_{total}) * (temp_2 - temp_{mean}),$$

$$temp_{cooling3} = (count_3 / count_{total}) * (temp_3 - temp_{mean}),$$

....

$$temp_{cooling12} = (count_{12} / count_{total}) * (temp_{12} - temp_{mean}).$$

4. Results for the summer 2022 according to this proposed approach

Alternative approach: estimation of the cooling effect for Tallinn, Tartu, Narva, for 2022

	Settlements and other artificial areas	Cropland	Grassland	Forest and woodland	Heathland and shrub	Sparsely vegetated ecosystems	Inland wetlands	Rivers and canals	Lakes and reservoirs	Marine inlets and transitional waters	Coastal beaches; dunes and wetlands	Marine ecosystems
Tallinn	0	0	-0.2	-0.1	0	0	0	0	0	0	0	-0.2
Tartu	0	0	-0.1	-0.03	0	0	0	0	-0.01	0	0	0
Narva	0	0	-0.1	-0.29	-0.02	0	0	0	**+0.03**	0	0	0

Appendix 3. Land coverage (and terrain) classes - *EU Guide about climate accounting* vs coding of the map of *Estonian Statistics*

	Classification of the EU *Guidance*	Land classes on the map of *Estonian Statistics (10x10m pixels)*
1	Settlements and other artificial areas	Other artificial areas Infrastructure and industrial areas Continuous settlement area Discontinuous settlement area
2	Cropland	Annual croplands Permanent crops Mixed farmland
3	Grassland	Sown pastures and fields (modified grasslands) Natural and semi-natural grassland Urban greenspace
4	Forest and woodland	Broadleaved deciduous forest Coniferous forests Mixed forests
5	Heathland and shrub	Heathland and (sub-) alpine shrub
6	Sparsely vegetated ecosystems	Semi-desert, desert and other sparsely vegetated areas
7	Inland wetlands	Inland marshes and other wetlands on mineral soil Mires, bogs and fens
8	Rivers and canals	Canals, ditches and drains
9	Lakes and reservoirs	Lakes and ponds Artificial reservoirs Rivers and streams
10	Marine inlets and transitional waters	Estuaries and bays
11	Coastal beaches, dunes and wetlands	Coastal dunes, beaches and sandy and muddy shores Bare rocks Subtidal sand beds and mud plains Coastal lagoons Rocky shores Subtidal rocky substrates
12	Marine ecosystems	Marine ecosystems (coastal waters, shelf and oceanic areas)

ANNEX 8. Visualization of the results of ecosystem accounts using ArcGIS Online

Interactive maps have evolved into powerful tools for data visualization. Technological advances have made data presentation more readable, incorporating analytics and aggregated information. This allows users to compare, analyze, and draw conclusions based on their specific needs and interests.

In this project, illustrative interactive maps were produced for ecosystem extent and ecosystem services. Two spatial levels were used – local municipalities and 500x500m square grids. The local municipality level provides an overview within administrative divisions, while 500x500m square grids offer more specific distribution compared to a municipality, allowing users to see more precise data. It was decided to use 500x500m square grids instead of, for example, more precise 250x250m square grids mainly for performance reasons. The use of local municipalities is vital since local governments want and need to know what and how services are present within their territory. Users can select a service and further refine the selection by ecosystem types to see the corresponding values of the ecosystem service. These dashboards are combined into a single application (ArcGIS Experience), which is available here:

https://experience.arcgis.com/experience/3a23e1d85fc64189ac8c123cc3c37d96

As the interface is aimed mainly for experts of national audience, the user language is Estonian. An introductory prompt introduces the user to the application and explains the data and use cases behind the application. It also guides the user in using the application.

The ecosystem extent is visualized by a 500x500m square grid covering the whole of Estonia. Mandatory ecosystem service according to EU regulation 691/2011 are included. Each of the ecosystem services, with the exception of one, is visualized both with local municipalities and 500x500m square grids spanning the whole country. The only exception is Local Climate Regulation ecosystem service, which is limited to the three biggest cities in Estonia – Tallinn, Tartu, and Narva. These cities are covered only with 500x500m square grids up to their administrative (LAU) limits.

For each visual layer, a legend is shown, explaining the contents of the map. Texts further explaining the content of each service are also available. The whole application is in line with Statistics Estonia's Corporate Visual Identity (CVI) and adheres to the internal user experience guidelines.