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Empirical insights into the multiple economic values of ecosystems: applications and reflections[1]

UN London Group on Environmental Accounting, 2025

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Questions to the London Group

How could this multi-layered approach to monetary values connected to ecosystems be further developed and implemented to help bridge gaps between ecology, economics, and governance in ecosystem services assessment?

What values should be included in a dashboard of indicators on the economic importance of ES, as to represent the whole range of actual transactions, embodied values, values at risk, opportunities…? How should this dashboard be arranged?

What practical steps are needed to scale this approach to national ecosystem accounts or regional decision-making tools?

[1] This work was supported by Eurostat grant for environmental-economic accounting „ Development of the environmental accounts 101197994 — 2024-EE-EGD"

Introduction: Dealing with ecosystem services' values in official statistics

Ecosystem services link ecology and economy. To ensure impact, transparency and clear narratives it is essential to acknowledge diverse value perspectives and avoid miscommunication across disciplines. As demand grows for ecosystem valuation and accounting in policy, data and indicators must be tailored to different stakeholders and appropriately communicated.

Due to these needs, some statistical offices have started to provide monetary values associated to ecosystem services and assets, and to communicate the semantics of such valuations to wider audiences. Among these, Statistics Netherlands[2,3], Statistics Estonia[4,5,6], Istat[7] and Italian Natural capital Committee, 2024[8]).

While monetary values are often expected, they're not (yet?) part of the SEEA EA international statistical standard. Important aspects to consider are:

- ecosystem services are a bridge between ecology and economy and data inform decisions. Since decisions may be based also on monetary values, it is of paramount importance to deal with them in the most precise way possible;

- for the same reason, it is essential to build transparency around the meaning, interpretation and limitations of monetary values;

- it is also fundamental to avoid miscommunication across disciplines (economics, ecology, policy);

- there is a need for clear narratives to support the wide applicability of the results;

- physical and qualitative indicators remain essential tools for policy and planning (see next section).

This work is part of a broader initiative launched by the UN London Group on Environmental Economic Accounting, contributing to the development of methods for reflecting ecosystem values (see UN London Group *Connected Values Issue Paper*, 2024[9]). It also serves as an empirical complement to the theoretical treatment of multiple economic values associated with ecosystems (*Femia et al., 2025: Treatment of Multiple Economic Values Connected to Ecosystems – Methodology*).

Empirical work has been carried out in close collaboration between national statistical offices (Statistics Estonia, Statistics Netherlands, Istat) and academic experts. The overarching goal is to develop the semantics behind ecosystem values, support a clearer articulation of diverse value perspectives, and in particular of the historical and prospective monetary costs of ecosystem's degradation („cost of inaction"[10]) and of the historical and prospective monetary flows related to ecosystems protection[11].

A collaborative methodological mapping of valuation methods and monetary values calculation exercises' results has been carried out and is ongoing. This effort is grounded in the UN SEEA Ecosystem Accounting (SEEA EA) framework, Eurostat's regulation on environmental-economic accounting, the concept of connected and plural

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[2] Statistics Netherlands and WUR (2024), Natural Capital Accounting in the Netherlands – Technical report. Statistics Netherlands (CBS) and Wageningen University and Research (WUR).
[3] The use value of nature in the Netherlands | CBS, 2025
[4] Oras *et al.*, Two Languages or Two Narratives: Comparison of the Selected Market Price and Revealed Preferences Valuation Methods to the Stated Preferences Method, 2020; Oras, *et al.* Comparison of methods for the valuation of the nature education ecosystem service, 2021; Oras *et al.* Recreation ecosystem service, calculation of the contributions from different ecosystems, UN London Group on Environmental Accounting, 2022: Oras *et al.* Chance for Better Policy: Can Ecosystem Account Provide a Missing Link between the Services Provided by Ecosystems and the Land Owners, 2020; Oras *et al.*, Comparison of methods for the valuation of the nature education ecosystem service, 2021; Oras *et al.*, Aggregation of the ecosystem service values in urban ecosystem account, application of the principles of gross ecosystem product (GEP), 2021; Oras *et al.*, Comparison of crop provision and wood provision ecosystem services, 2023.
[5] "Development of the forestry, environmental subsidies and ecosystem accounts", Project number: 101113157, D1.9 Description of the methodology and problematic issues for ecosystem accounts https://stat.ee/sites/default/files/2025-01/D1.9%20Description%20of%20the%20methodology%20and%20problematic%20issues%20for%20ecosystem%20accounts_0.pdf
[6] Oras *et al.* Valuing Nature's Contributions: Mapping and Semantics of the Methods for Ecosystem Service Valuation.
[7] Femia A., A proposal for going beyond valuation in sight of the UNSC discussion on the SEEA E(?)EA – Presentation, 2020; Femia A., Beyond valuation: monetary aggregates for the SEEA EA, 2021. https://www.istat.it/produzione-editoriale/ambiente-e-territorio-strumenti-e-metodi-per-unanalisi-del-consumo-di-risorse-e-degli-ecosistemi/
[8] https://www.mase.gov.it/portale/quinto-rapporto-sullo-stato-del-capitale-naturale-in-italia-2022
[9] 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
[10] It is is important with regard to „cost of incation", to highlight the distinction between *economic* costs, which can be measured in monetary terms, and *ecosystemic* costs understood from an ecological standpoint: once thresholds are crossed, ecosystems may collapse irreversibly, meaning that services cannot be restored regardless of future investments. The consequent, undisputed, urgency of integrating ecological (i.e. physical) evidence into economic accounting frameworks is not the topic of this paper but a fundamental element of its context, pointed out in the next section.
[11] We deliberately left out of the list the *opportunities* of ecosystem degradation, as these largely coincide with actual economic activities and business-as-usual scenarios.

values, and existing practices in Estonia and the Netherlands. The present paper illustrates the applied part of the work, providing empirical data for the concept as asked by the London Group at its 30th meeting in Washington.

The multiple values of ecosystems and their services

From an ecological perspective, it is crucial to recognise that ecosystem functions cannot be reduced to easily measurable indicators or expressed in monetary values. Ecosystems sustain life through complex, interconnected processes. Intermediate services and complex dynamics such as soil formation and fertility, nutrient cycling, natural pest control networks remain invisible in accounts, yet they are fundamental to the functioning of ecosystems, to the provision of final ecosystem services, and ultimately to human well-being. Ecosystems' capacity to provide services depends on their ecological integrity and resilience, which must be monitored with biophysical indicators, and cannot be inferred from monetary proxies. An accounting framework must therefore attempt to make ecological integrity and system resilience explicit alongside economic measures. Although not addressed in this article, it is important to acknowledge these fundamental premises, and frame all reasoning about economic values and their role in policy-informing data and accounts within the ecological perspective.

Ecosystem service values, in the broadest sense of the word 'value', emerge along a layered continuum from the natural functioning and equilibria of ecosystems to the benefits people experience. At the foundation are ecosystem processes and functions such as primary production, soil formation, nutrient cycling, hydrological regulation, pollination, and climate regulation. These underpin the services that humans recognise and use.

Building on these functions, values emerge at different levels:

- Direct ecosystem contributions to people (final ecosystem services): use values of ecosystems represented by measurable non-monetary indicators, such as the number of people visiting natural areas, the hectares of cropland dependent on pollinators, pests' natural enemies controlling their population sizes, or the tonnes of atmospheric PM10 removed by vegetation[12].
- Societal benefits of ecosystems' existence and use: often less visible, but no less important. Recreation, for example, contributes to mental well-being, reduces healthcare costs, and strengthens community cohesion.
- Economic values: observable economic activity, usually measured in monetary terms: for instance, what people pay to experience nature (entrance fees, transport, guided tours) or what they are willing to pay to replace or restore an ecological function[13].

This progression reflects a layered understanding of value, where each step captures a different aspect of the relationship between nature and human well-being. In this landscape of plural values, monetary values connected to, or dependent upon, ecosystem services can be powerful - and therefore also dangerous – tools for decision-making. They must be handled with care. Only if we are clear about *what exactly* we are valuing and *how*, can they be used appropriately. Without careful interpretation, numbers can easily mislead. For instance, if we say that an ecosystem service is worth €300 million, what does that mean? Is it the exchange value of what nature provides? Is it the amount that people actually pay for its protection? Is it the amount they are willing to pay? Or is it a synthetic measure of overall well-being the society gains from using it? These are fundamentally different interpretations. Moreover, an equally important question is *whether this service is even replaceable or repairable if it disappears*. A figure of €300 million may give the illusion of substitutability, but in reality, many ecosystem processes, such as soil formation, pollination, or the carbon storage capacity of old-growth forests, cannot simply be recreated once destroyed.

In such cases, the monetary number does not represent an actual "price tag" but rather a warning signal of the *scale of dependence and potential loss*. Treating it as if ecosystems could be bought or rebuilt at will, risks obscuring the ecological reality that some functions are irreplaceable and that crossing ecological thresholds may lead to irreversible collapse. However, properly interpreted, valuations can illuminate hidden dependencies and strengthen the case for safeguarding ecosystems.

More generally, to avoid oversimplification and misinterpretation, it is important to map the different semantic layers embedded in the calculation of ecosystem service monetary values. The concept of *plural values* has been elaborated

[12] It is questionable whether certain cultural, religious, or even mystic, attachments of peoples to nature (living: ecosystems, but non leaving as well, e.g. a sacred mountain) can be represented at all in the „nature's contributions to people" framework, let alone in the „ecosystem services" framework, as both are based on a utilitarian perspective (Muradian R. and E. Gomez-Baggethun. „Beyond ecosystem services and nature's contributions: Is it time to leave utilitarian environmentalism behind?", Ecological Economics, Volume 185, July 2021. https://www.sciencedirect.com/science/article/pii/S0921800921000963). However, indicators can be conceived for the existence and extent of these phenomena.

[13] Monetary units express pure exchange value. Therefore, even welfare values, being expressed in monetary terms, are ultimately expressed in terms of exchange value, They reflet the pure exchange value equivalents of peoples' preferences given their budget constraints.

in SEEA Experimental Ecosystem Accounting Revision Expert Consultation Working group 5 Valuation and accounting treatments (Discussion paper 5.1: *"Defining exchange and welfare values, articulating institutional arrangements and establishing the valuation context for ecosystem accounting"*[14]). The layered approach to the monetary values associated to ecosystem services' presented there has been followed and taken further. Our current work builds on the same understanding that ecosystem service values are not static or singular — as said, they emerge along a continuum that begins with the natural functioning of ecosystems and extends to the benefits directly experienced by people and society. This plurality of modes in which ecosystems' values emerge is partly reflected in the wide variety of monetary values connected to ecosystem services, each of which tells a different part of the story, and which offer a more holistic and credible understanding of what is at stake if taken together as a well-interpreted set, rather than used for pricing ecosystem services.

In addition, the integration of ecology and economics is not only a technical task but also a normative one: it requires us to decide what we choose to measure, and how. Ecosystem accounting must therefore recognise that some values are beyond monetisation, yet essential for long-term sustainability. Ecosystem accounts framework therefore needs to safeguard space for plural values — ecological, cultural, and social — to prevent narrowing nature's meaning into numbers alone.

Multiple monetary values connected to ecosystem services and their emergence: a semantic lens with reference to prior work

To make ecosystem service "valuation" more useful and to better capture a wider subset of the values we test the semantic structuring approach described in Femia *et al*. 2025[15]. For this purpose, we use a semantic matrix to map and communicate different layers of value, each capturing different aspects of the ecosystem service-economy relationship (Femia and Capriolo, 2022[16]). This approach offers some basic perspectives from which the multiplicity of monetary values connected to an ecosystem service can be understood in relation to their origin and implications, based on the setting from which the values are derived. It acknowledges the fact that some monetary values are calculated based on *scenarios* ("experimental situations").

So, one of the first things considered is whether a monetary value is actual or 'hypothetical'. The first distinction is between monetary (exchange) values that exist in reality, and may be directly or indirectly[17] observable, and those that in valuation are assumed to "appear", or "disappear", under certain conditions.

Scenarios are static mental constructs — hypothetical situations that may differ from reality. For instance, a scenario might assume that an ecosystem service ceases to exist. In such cases, existing economic activities or assets may be assumed to disappear (as they depend on the service), or new alternative economic activities may be imagined to appear as substitutes (e.g. replacements, avoided damage). Though we use terms like "appears" or "disappears," these should be understood as shorthand for "exists" or "does not exist in the hypothetical scenario".

Monetary values become visible and measurable either because the ecosystem service itself is assumed to appear under those conditions, or because the way the ecosystem is accessed or used is assumed, in the valuation exercise, to be different than what it actually is (and economic flows appear as a consequence in the hypothetical situation that are not supported by the current conditions). Further, some valuation experiments deal with the values that would disappear, e.g. because ecosystems are degraded). Existing values often include market-based benefits; values that would appear are latent or policy-dependent, while those that would disappear signal risks of loss. This structure aims to prevent oversimplification and reduce the risk of miscommunication, especially when working across different disciplines.

Therefore, at the most basic level, we ask whether in the reference scenario of each valuation exercise an ecosystem service is assumed to exists or to disappear, and what the surrounding conditions of access, use, or management are or would be. This dual perspective reflects the intersection of a fundamental ecological condition and a fundamental socioeconomic one: if the underlying service is lost, all dependent values collapse. An income directly linked to the use of ecosystem services will only arise if control over their use is clearly defined and exercised and when products are derived from them, while other connected monetary values, such as e.g. the cost of potential

[14] 1 Plural values in the system of ecosystem accounts. Source: adapted... | Download Scientific Diagram
[15] Femia et al., 2025: Treatment of Multiple Economic Values Connected to Ecosystems – Theoretical aspects
[16] Femia AM, Capriolo A (2022) Beyond valuation. Monetary aggregates for the SEEA-EA. The Italian proposal. One Ecosystem 7: e84689. https://doi.org/10.3897/oneeco.7.e84689.
London Group 2024 Issue paper: Monetary values connected to ecosystem services (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
https://seea.un.org/sites/seea.un.org/files/session_5_issue_paper_monetary_values.pdf
[17] An indirectly observable phenomenon is for instance the value added of an economic activity. Another such is the resource rent.

replacements or the damage suffered by infrastructure when an ES is lacking, depend largely on real markets and the prevailing economic and regulatory context in which related goods and services are produced and traded.

The reference scheme

The following scheme displays the semantics of the applied connected ecosystem services monetary values framework and provides a general reference characterisation/classification of the values, based on the scenarios that are assumed in their calculation, i.e. on the methods used for their computation.

In the first column (1) we have the cases where the service exists in the scenario, including all the values based on direct or indirect observations and those whose "appearance" or "disappearance" in the scenario depends on institutional, rather than on physical/ecological, changes; in the second (2) we have values based on hypothetical scenarios where "the service does not exist" ("would disappear": risk of loss)[18]. "The service does not exist in the scenario" is always related to counterfactuals that "appear" or "disappear" in the economic world. These values are therefore not related to economic activities, transactions, economic flows or stocks that do exist in reality but only in the hypothetical scenarios in which their value becomes visible.

In the rows, we have, at the first level: (A) actual situations, where the connected value exists (as an actual economic value), are observable and directly referred to ES or "stocks" thereof. Since these depend on the ES existence, they are not related to an hypothetical scenario; (B) hypothetical scenarios where connected values appear, connected mostly to the case of decrease in the availability of the ES (latent economic potential of ecosystem degradation), and (C) hypothetical scenarios where connected economic values, not directly referred to ES actually exist but would disappear (risk of loss) in case of ES's loss.

So there are six main kinds of 'value categories' in the table, but only four main blocks of cells can be populated: 1A – reality: actual flows and reserves of exchange value that can be directly or indirectly observed; 1B – institutional change: "privatisation" of the (whole) ES; 2B – adaptation: the loss of the ES sparkles "alternative" or "reparatory" economic activities; 2C – cost of inaction: what we lost or risk losing. Of course, all figures in 1A could also be placed in 2C. The difference is that 2C figures are either historical estimates of damages actually suffered (no-longer-existing values) or prospective forecasts that would not make sense out of the "loss of ES" hypothesis, differently from 1A cases. These four main cases can be further articulated according to the specific characteristics (additional scenario hypothesis, e.g. concerning "what is exactly put in place instead of the ecosystem service" in the "ecosystem service does not exist" hypothesis) of the methods used to derive the connected value. Moreover, not all four cases are relevant for all ecosystem services, according to the empirical analysis of case studies described in the next section.

The first main row of the table, "Connected monetary value/ transaction/asset exists in the scenario" has four sub-cases:

i. "ES are traded as private usage right to use": this is the case of rent on land as in the national accounts, PES (if PES is not a given as a subsidy but as a payment measured on a physical quantity of the ES actually provided), the volume of actual transactions in tradable emission permits;

ii. "ES are potentially traded as private usage right to use": some ecosystem services are to a certain extent institutionally dealt with as a private kind of asset. This is the case of the actual stock value of potentially-for-sale actually tradeable emission permits, and to that of all the standing timber that is potential wood supply. These quantities differ from the total quantity of the respective ecosystem services "measured" by the non-monetary indicators of SEEA chapters 6-7.

iii. "the ES is used as an input for producing other goods or services[19]": Resource rent, Residual value, Hedonic pricing... fit in the "ES exists" column, but they are embodied in other transactions' values, not directly observable as actual transactions. Even if they look for the price at which the ES would be traded on its own, which is not the current situation (so from this institutional point of view the scenario is hypothetical), they

[18] In principle, three kinds of scenario can be defined as for the existence of the ecosystem service: it exist both in the reality and in the scenario; it exists in the reality, but not in the scenario ("is lost"); it does not exist in the reality, but it does in the scenario ("appears"). The latter case did not show up in the applications we considered, so we did not include it in the scheme. Framing the economic aspects of ecosystem services' enhancement, however, would also be very interesting: when ecosystem services are gained, and their unmet demand is satisfied, new economic opportunities arise and some existing activities are threatened (e.g., how much air filtration devices manufacturing would be an unnecessary cost to society if more natural air filtration was available?).

[19] This is a way to appropriate ecosystem services and get an income from that, if there is rivalry in their use. If there is none, probably there is no edge for the user who produces goods or services by using the ecosystem service to charge more than its costs of production. E.g. all production activities use oxygen for free, and no one would be able to charge more its clients for that.

intend to capture a share of existing monetary flows that is supposed to represent the contribution of the ES to its users' income.

iv. "Other (transactions recorded in SEEA CF and/or SNA that are related to ecosystem services)". Under this category fall empirically observable transactions or asset values that depend from or are related to the ecosystem service, which can be found e.g.in: production and value added of industries that heavily depend on ecosystem services, actual biodiversity protection expenses from EPEA, taxes linked to ecosystems use (from ETEA) or earmarked for use for ecosystems' protection, subsidies, some EGSS items... . Also actual historically borne observable travel costs are connected monetary value/ transaction that exist in the reality scenario. Of course, all Ai and some Aii cases could be placed here as well, but this is a residual category.

As said, all the connected values belonging to these "reality" values would of course disappear if the ES disappears, but we do not need to make this hypothesis to calculate them, unlike other connected values whose existence is conceptually linked to the ecosystem service *not* being available, such as e.g. those of substitutive activities. These are placed in the second main row, while the third main row we have the connected values that exist in reality but need, in order to be estimated, the hypothesis that an ecosystem service that supports them is not available (anymore), such as the damages that the loss of the ecosystem service would cause.

The second main row of the table is for the cases where a connected monetary value does is not observable in reality, but is hypothesised to exist in a hypothetical scenario. In comparative static terms, "Connected monetary value/ transaction would appear in the scenario". We identified three types of these cases, so we have the following three sub-rows:

i. "Economic activity that avoids the need for the ES, or substitutes it with something else". E.g. technologies are put in place to abate carbon emissions to zero, and economic activities exist which provide those technologies (cars retrofits are an example). Actual historical expenses on retrofits are values included in row 4. above. Prospective estimates of the cost of further abating carbon emissions belong here[20]. The global climate regulation ES would not be necessary in such a scenario, and this is why we use the second column for these cases. Another example is hand pollination as a substitute for pollinators. This latter example points to a kind of values that would exist in an economy adapted to be disappearance of some ES, important to consider for a society resigned to their perspective loss, and which sees business and employment opportunities in it.

ii. "ES restoration as an economic activity". When ecosystems are lost, and all of its ES with them, there sometimes is the possibility to put in place human actions (economic activities) that locally reverse the ticking of the clock, and help nature to recover. Planting trees and purifying the water from the nutrients that cause oceans' eutrophication are actions that have costs which, when quantified ex-ante in relation to the "ES is lost" hypothesis, provide hypothetical connected values.

iii. "Marketisation" of the ES" (with or without perfect price discrimination). When a payment for a well-specified, existing, quantity of ecosystem services is done to the owner of the supplying ecosystem, where there was no payment before, an institutional arrangement arises, that recognises economic ownership and monopoly rights on the use of the function of nature represented by the ES. The value of actually paid PESs belongs to row 4 of block 1, and this is recorded under "subsidies" in the national accounts if paid by government units. However, if the unitary "price" used for the PES is applied to the whole existing flow of the ES, we get an estimate of how much would ecosystems' owners earn by cashing it. A common good becomes private and property income flows appear. A similar kind of hypothesis underlies questions such as "if you had to pay for this ES, how much would you like to?", with the only difference that the aggregation of willingness to pay across individual gives a measure of the whole area under the demand curve, i.e. what the ecosystem (service) owners would get in the case of prefect price discrimination. These mental experiments do not need that existing ES be imagined to disappear, so they are found under the first column.

[20] It is important to keep in mind that every monetary cost is the dual expression of some economic activity's output value. In this block of rows the emphasis is on the emerging activities.

Figure 1. Semantics of the applied connected ecosystem services monetary values framework

REFERENCE SCHEME FOR THE CLASSIFICATION OF VALUES CONNECTED TO ECOSYSTEM SERVICES ACCORDING TO THE FEATURES OF THE CALCULATION SCENARIO

			Ecosystem service in scenario	
			Ecosystem service exists	Ecosystem service does not exist hypothesis
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	Ecosystem services are traded as private usage rights	Rent of the land, directly observable prices applied to actually traded volumes, observed value of actually observed transactions in tradable permits	
		Ecosystem services are potentially traded as private usage rights	Directly observable prices applied to potentially for sale permits of using the ES	
		ES is used for producing other goods or services	Resource rent, Residual value, Hedonic pricing	
		Other (outside or inside of SEEA-EA, within SEEA CF, other satelllie accounts or SNA)	Travel cost method, effective carbon rates	
	"would appear" (does not exist in reality, does in the scenario)	Economic activity that avoids the need for the ES		Abatement costs, substitution costs, averting behaviour
		ES restoration as economic activity*		Restoration costs
		Marketisation of the ES (with or without perfect price discrimination)	Prices applied to quantities of ES not actually traded or tradable under current institutional arrangements, WTP for maintaining ES	
	"would disappear" (exists in reality, is lost in the scenario)	Existing economic activies can no longer thrive, and/or assets are damaged («other negative changes in value») because of the lack of the ES		Social cost of lacking ES, expected damages

* Restoration costs usually refer to the restoration of whole ecosystems. It is however possible to think about the restoration of a single ES, that leaves the rest unchanged. E.g. if an area is made suitable (e.g. reclaimed from venoms) for wild animals and/or these are reintroduced in the area. Pollinators could be one case

The third main row of the table, for each service, is the "Connected monetary value/transaction/asset would disappear" scenario. This reflects a hypothetical situation in which existing economic activities can no longer thrive, and/or assets cannot stand in their current state (are damaged: «other negative changes in value of assets» in the SNA) because of the lack/disappearance of the ES. This row is not split further. We allocate here all value based on emerging economic and "social" cost kind of estimations, even if these are often based on the value of activities that try and restore the damaged values (repair works after a flood, additional healthcare needs of air pollution…), which would suggest allocation in the second block of rows, because the emphasis is on the damage suffered and the objective of the estimations is to quantify it independently from any hypothesis that the reconstruction costs be actually sustained by someone (and, certainly, that the deceased could be restored to life). But it is clear that, not differently from war destruction, even ecological catastrophes are economic opportunities for some, and social costs for others. As said above, all figures in the 1A block could also be placed in 2C, as they would be lost under the "ES does not exist (anymore)" scenario, or the C row could be dealt with as a fifth sub-case of A, the only one where the activities exist and their quantification requires the explicit hypothesis of the ES disappearing.

A very important feature characterising different scenarios is the quantity to which unitary values are applied: if applied to actually traded quantities of private usage rights on ESs, we have observable values (1Ai); if applied to quantities "in stock", that could be traded under the current institutional arrangements, we have the value of existing assets (1Aii); if applied to quantities of ES that are not subject to alienable property rights, we have values that may appear under a "marketisation" hypothesis (1Biii), or potential costs connected to losing the ES (2Bi and 2Bii).

Multiple economic values connected to ecosystems: empirical insights

By tracing the layers of values as seen above, we try to allow for more inclusive, multi-stakeholder handling of values. Different actors — whether policymakers, businesses, or the public — can better understand how ecosystem services affect them, even if they view value differently.

This structure is meant to – and has been used to – build a shared language between ecologists, economists, and policymakers, just because it has the precision and specificity that the pricing approach does not have. For instance: ecologists can show where services exist and are at risk. Economists can identify where the different values dependent from them might be captured. Policymakers can understand where market failures or governance gaps exist. By linking "what exists in nature" with "what exists or could exist in markets, public budgets or accounts" the matrix would improve cross domain alignment.

Monetary values connected to ecosystem services found in valuation exercises for the case studies of Estonia and the Netherlands were mapped in the framework described above. The table below applies the semantics framework to seven ecosystem services: crop provision, crop pollination, wood provision, air filtration, global climate regulation, local climate regulation, nature-based tourism-related services.

The values connected to these ecosystem services, which we drew from statistical offices' and academic applications, are presented in EUR million, mapped by their semantic classification according to the experimental settings. The application of the framework turns the semantic framework into practical interpretation. The following tables display the allocation of the Estonian and Dutch values. In addition to currently available results, the tables also report possible additional methods that could provide useful information for policymakers and the public.

Crop provision: rent on land and products' value

The presence of „normal", observable, market transactions characterises the case of provisioning ecosystem services. The land that provides these services has a long history of private property rights enforcement, so that the rights to use it for the production of crops is normally traded on its own, e.g., through land lease arrangements. In return for letting others use the faculties of the land, e.g. to support the production of crops, its owners get a property income in return. In 2022 100 million euros[21] is the estimate of the rent actually transferred yearly in Estonia from farmers to landowners (590 million euros in the Netherlands[22]).

[21] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement no NUMBER — 101113157 — 2022-EE-EGD) https://stat.ee/sites/default/files/2025-01/D1.9%20Description%20of%20the%20methodology%20and%20problematic%20issues%20for%20ecosystem%20accounts_0.pdf
[22] Statistics Netherlands (2025). The socio-economic use value of nature in the Netherlands. Database statistics Netherlands (statline): https://opendata.cbs.nl/statline/#/CBS/nl/dataset/85854NED/table?ts=1757063343477

Figure 2. Monetary values connected to the Crop provision ES (million euro)

			Ecosystem service in scenorio	
			Ecosystem service exists	Ecosystem service does not exist hypothesis
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	ES traded as a right of private usage (observed transactions volumes)	**100** (land rent, use rights on assets)	
			590 (land rent, use rights on assets)	
		ES potentially traded as a right of private usage (observed prices applied to stocks)		
		ES is used for producing other goods or service	**14.9** (resource rent of NACE A.1)	
			959 (resource rent NACE A.1)	
		Other (outside or inside of SEEA-EA, within SEEA CF, other satelllie accounts or SNA)	**300** (crops, final product)	
			4 769 (crops, final product)	
			agricultural subsidies (organic farmic, general support scheme, etc)	
	"would appear" (does not exist in reality, does in the scenario)	Avoiding the need of the ES as economic activity		
		ES restoration as economic activity		**1500** (replacement of soil, NPV 3% DR, 50 years, total soil asset value 41300).
		Marketisation of the ES	**1.4** (WTP for maintaining supply of agricultural production)	
	"would disappear" (exists in reality, is lost in the scenario)	Existing economic activies can no longer thrive, and/or assets are damaged («other negative changes in value») because of the lack of the ES		

Estonian figures
Dutch figures
Further possible connected values

These payments are, surprisingly, much higher than the resource rents (14.9 million euros for Estonia in 2020)[23] embodied in the market value of the crops. This may suggest that the land is used also for purposes other than cultivation (e.g. cattle breeding) and that rent is paid also for these supporting activities. For the Netherlands, the resource rent for arable farming was higher (959 million euro) than the calculated rent payments, but in the years before this was also the other way around. The resource rent may fluctuate significantly over the years and is very much dependent on the underlying detailed data from the national accounts.

As crops would not exist at all without nature's contribution, their market value is a very important monetary indicator connected to (dependent upon) this ES. It amounts to 300 million euros in Estonia in 2018[24] (385 million euros in 2022[25]), 4769 million euros in the Netherlands. The resource rent is around 5% of the value of crops in Estonia, which seems reasonable, while it is 20% in the Netherlands.

Not differently from the GCR case, contingent valuation provides a very low value – 1.4 million euros in 2019[26] – as willingness to pay (WTP) of the Estonians to maintain their country's ability to supply agricultural production. In this case, however, this amount may be considered as „on top" of the money (around 300 million euros per year) they (or the importers of Estonian crops) actually pay to get the national crops output, and expect to pay for future crops, embodying actual and implicit rents. In other words, there is no utilitarian reason why this WTP should be significantly different from zero, as the consumers of Estonian crops do not get them for free and they may well assume that it is up to the ones that appropriate the economic benefit to maintain their assets' „productivity".

Finally, we provide a direct estimate of the value of Estonian's "arable land soil" – the asset delivering the ES in question – calculated as the cost of replacing the entire topsoil with an equivalent quantity purchased on the market. This amounts to 41 300 million euro[27] (an amount similar to that of the Estonian GDP). Assuming crop provisioning is the only element of economic value in the soil, so that this value would be the net present value of this ES only, and using a discount rate of 3%, and a 50 years' time horizon for the calculation, this gives a 1 500 million euro yearly flow of value. But of course, at least the carbon storage ES should be considered as well, so this value should be split between at least these two services. More in general, a prerequisite for using the replacement cost method is that the service must really be replaceable. While soil can be given a notional "replacement cost" by imagining physical import of topsoil, it must be considered that soil is not a passive medium: it is a living system shaped by centuries of biological activity, climate, and land use history. Its structure, microbial communities, and ecological memory cannot simply be reconstructed or imported. From an ecological perspective, soil functions are emergent properties of long-term ecosystem processes, and these processes are neither technically reproducible nor economically replaceable at scale. This represents the case where assigning a monetary "replacement value" risks obscuring the reality that soil degradation represents an irreversible loss of natural capital.

Wood provision: the market value of a product

The case of wood provision, like that of crops, is characterised by the presence of observable market transactions, so that all estimated connected values fall in the upper left group of cells of the reference table.

The ES is defined as „net increment", i.e. as the increase of the quantity of wood, contained forests and other land, that may be further used in the economy. Formally, this quantity is considered as used as soon as it comes into existence, given that standing timber is dealt with as an inventory in the National Accounts. This standing timber

[23] Statistics Estonia, 2023. D1.8 Description of the methodology for advancing ecosystem accounts, methodology "Development of the environmental accounts" (101022852-2020-EE-ENVACC) https://www.stat.ee/sites/default/files/2023-09/D1_8_%20Description%20of%20the%20methodology%20for%20advancing%20ecosystem%20accounts%2C%20methodology%20_101022852_2020-EE-ENVACC_k%C3%BClj.pdf

[24] 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

[25] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement no NUMBER — 101113157 — 2022-EE-EGD) https://stat.ee/sites/default/files/2025-01/D1.9%20Description%20of%20the%20methodology%20and%20problematic%20issues%20for%20ecosystem%20accounts_0.pdf

[26] 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

[27] 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), page 150

stock that is the result of the accumulation in time of the wood provision ES. The economic value and further use possibilities of the net increment, i.e. of the ES are strictly tied to those of its cumulated stock. Private or private-like property rights are usually enforced on forest ecosystems, but it is not common for the owners to rent the land for others to grow and harvest wood. In other words, the right to use the ES is normally not traded on its own. However, there is an active market in forest ecosystems themselves and, of course, in derived wood products. The existence of a stock derived from of the ES, for which a market exists, makes the economic aspects of this provisioning service somewhat different from other provisioning services and in particular from the crop provision case. In the latter we can observe the rent on agricultural land as a category of transactions that can be directly referred to the ES. In the wood provision case, we need to look for the „price" of the ecosystem service as embodied value, either within assets' values or within derived products' values. The market value of the existing stock of timber has a clear meaning: forest owners have appropriated the ES to the extent it historically occurred (or was created by making the forest available for wood supply, which is the result of institutional arrangements), and was not used already. How much would they get if they decided to transform this wealth into cash, i.e. to fell all the timber in the current year? What we measure here is the owners' wealth. The Estonian timber stock was estimated at 20 640 million euros (2022 closing stock)[28]. Of course, it is unrealistic to assume that, with such a huge amount of timber flooding the market, the price would be the same as the current one.

Starting from the market value of the asset „forest"[29], it can be considered that it is the land underneath the trees that ultimately provides the service (even though, the existence of the trees themselves is also a necessary condition). In turn, once this land's asset value is isolated, and assuming wood provision is the only value element in it (a quite strong assumption[30]), it can be converted into an equivalent income stream. This measure of the contribution to the owner's income of the right to use the ecosystems' ability to provide wood, is a measure of the „actual market value" of the ES conceptually close to that of the rent in the crop provision case.

So, the land under all Estonian forests available for wood supply (FAWS), ideally naked of the trees and everything else on it, seen as sheer natural wood-production power, valued at average land prices, would be worth 3 900 million euro. This amounts, using a 2.3% discount rate, to a current yearly income stream, attributable to the ES, of 86 million euro[31,32].

An alternative measure of the resource rent, concerning the whole of NACE A02 activities, is provided by national accounting-based figures, and assumptions on the "normal" return to capital used in production. This estimate amounts to 171 million euro in Estonia[33], and 20 million euro in the Netherlands.

Like crops, timber would not exist at all without nature's contribution, so the market value of timber felled or removed from forests is at the basis of further monetary indicators connected to this ES, and more precisely, dependent upon the actual use in current economic activities of the product to which the service contributes, cumulated in forests seen as wood inventories. The Estonian service value calculated as net increment in FAWS and harvest in FNAWS is 565 million euros in 2022 (the removals valued at stumpage prices were higher, worth 762 million)[34]. The Dutch respective value, in the same year, is 99 million[35].

Several other values connected to the wood provision ecosystem service can be thought of. The national "value chain" dependent upon wood provision could provide several relevant monetary indicators (e.g. value added and output – but also non-monetary, like employment – of the activities using national wood) could provide some. Others may be found in the world of economic incentives (subsidies) and disincentives (taxes) covered by SEEA activity accounts, such as the 1.5 million subsidies[36] given by the Estonian Government for reforestation.

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[28] Statistics Estonia, 2024. "Description of the methodology and methodological issues for forestry account", D1.1. Project name: Development of the forestry, environmental subsidies and ecosystem accounts, Project acronym: 2022-EE-EGD, 101113157

[29] A refinement of the calculations would consider how to deal with other land with trees available for wood supply.

[30] Even if the main component of forests' market value is the value of the wood they contain and may provide, this value also includes that of all other exchangeable products of the forest: mushrooms, boars, as well as of expectations, such as income that may be gained from having tourists paying entrance fees (if this kind of management is considered likely to prevail in the future), and the perspective of selling or renting the property to builders or windmill installers.

[31] Timber flows and stocks, comparison of the monetary valuation methods, Kaia Oras, Statistics Estonia, Leading expert; Professor Paavo Kaimre, Estonian University of Life Sciences; Grete Luukas, Statistics Estonia, Leading Analyst; Aki Kadulin, Estonian University of Life Sciences, researcher, Meeting of the 31st UN London Group on Environmetal Accounts, Tallinn, 2025

[32] Land value annuity method (Eurostat – Unit E2. Methodological and feasibility study on monetary valuation – Revised annotated draft (February 2025)). Average land value 2022 (ha, transaction based)*FAWS*discount rate (2.3%)

[33] Timber flows and stocks, comparison of the monetary valuation methods. See footnote 31

[34] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement no NUMBER — 101113157 — 2022-EE-EGD)

[35] Statistics Netherlands (2025). The socio-economic use value of nature in the Netherlands. Database statistics Netherlands (statline)

[36] Timber flows and stocks, comparison of the monetary valuation methods, see footnote 31

Figure 3. Monetary values connected to the Wood provision ES (million euro)

			Ecosystem service in scenorio	
			Ecosystem service exists	Ecosystem service does not exist hypothesis
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	ES traded as a right of private usage (observed transactions volumes)		
		ES potentially traded as a right of private usage (observed prices applied to stocks)	**20 639** Timber asset value - Net income (NPV) (a)	
			3 900 (land value) (a)	
		ES is used for producing other goods or services	**86** (Land value annuity method - rent on land only)	
			171 (residual value, resource rent of forest activity A02)	
			20 (residual value of forest activity A02)	
		Other (outside or inside of SEEA-EA, within SEEA CF, other satelllie accounts or SNA)	**762** Harvest at stumpage prices	
			565 Net increment from FAWS plus removals from OWL and FNNAWS in stumpage prices	
			99 (timber felled /per year and in stumpage prices - harvest)	
			1,5 (reforestration subsidy 2022)	
	"would appear" (does not exist in reality, does in the scenario)	Avoiding the need of the ES as economic activity		
		ES restoration as economic activity		
		Marketisation of the ES		
	"would disappear" (exists in reality, is lost in the scenario)	Existing economic activies can no longer thrive, and/or assets are damaged («other negative changes in value») because of the lack of the ES		

(a) the price here is not an observed, but an estimated one (resource rent by the appropriation method)

Estonian figures

Dutch figures

Pollination: dependent values, and the costs of restoring its enabling conditions

Pollination is a key regulating service that underpins agricultural productivity and biodiversity. While often taken for granted, its economic relevance can be substantial, particularly in agricultural landscapes dependent on insect-mediated pollination. The dataset examined presents a variety of approaches, capturing both direct market transactions and broader economic implications.

From a market perspective, pollination is reflected in small-scale payments for ecosystem services, such as subsidies to promote beekeeping by establishing additional food resource in the agricultural landscape. In Estonia, these amount to approximately 0.57 million euros, representing direct, observable transactions within the System of National Accounts (SNA) made to support and increase the existing ecosystem service[37]. While relevant for tracking current economic flows, such figures capture only a fraction of the real importance of pollination for the economy.

A more substantial perspective comes from production change estimates based on the dependency of crop production from pollination, which assess the contribution of pollinators to crop yields. These estimates range from 62.4 million euros in Estonia[38] to 134 million euros in the Netherlands[39] in 2022. This method calculates how much of the total crop yields' market value is pollination-dependent, using the "pollination dependency" rates of the individual traded crops and their market prices. As such, it provides a direct link between pollination services and agricultural output, making it highly relevant for both agricultural policy and national accounting. This interpretation remains consistent with the market-based valuation of crops. This figure reflects the potential economic loss that the loss of natural pollination would cause directly to farmers. If pollination services decline—due to a decrease in insect pollinators, for example—then the associated crop yields would also drop, leading to economic losses. In scenarios where pollination is lost, valuation can be based on costs for avoiding the consequent damages or on restoration costs. Avoiding the damage, in case of wild pollinators' disappearance, refers to manual pollination or to using domesticated pollinators, which are generally expensive and less efficient.

Restoration incentives, given for creating or enhancing bee foraging habitats[40], estimated to be ca. 256 €/ha in 2024 in Estonia[41], provide a very good demonstration of how the semantics of monetary values change according to the physical entity to which unit values are applied. The actual entity of this subsidy (i.e. the per hectare rate times the area actually benefitting from it) reflects how much the Government is investing in order to restore specific ecosystems for the explicit purpose of supporting the pollination ES. There is no need in this case to assume that the subsidy be sufficient to cover the whole restoration cost. However, if this is the case, the unit rate applied to the total area actually providing the ES, would give an estimate of how much it would cost to restore the service (more precisely: the ecosystem providing it), in case of complete loss. The same cost, applied to areas that actually need to be restored (i.e. to the areas where there is an „unmet demand" for the ES[42]), would provide a figure for the hypothesis "the service appears where there currently is none", and additional monetary values appear as a consequence (but this case is not included in our scheme, as we have excluded the column „ES exists in scenario but not in reality"). Additional perspective is provided by willingness-to-pay (WTP) studies, where respondents value their intended contribution to enabling pollination and honey collection at 3.3 million euros in 2019[43]. While not a direct market measure, WTP captures public perception and the perceived monetary value to the person's wellbeing by pollination, as constrained by individuals' budgets, adding depth to the overall assessment and reflecting also relatively low awareness of this important regulative ecosystem service in relation to other needs and benefits that money can buy[44].

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[37] 566 105 € was distributed by the measure to support bee foraging areas in Estonia (https://www.pria.ee/toetused/MESI-2024, €255.80/ha in 2024). The purpose of the measure is to establish a pollinator-attractive fields (costs include soil preparation, seed costs, labour costs, and foregone income from cash crops minus the state support; rate is €255.80 per hectare)

[38] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement NUMBER 101113157 — 2022-EE-EGD)

[39] Statistics Netherlands (2025). The socio-economic use value of nature in the Netherlands. Database statistics Netherlands

[40] Measure to support bee foraging areas (€255.80/ha in 2024) refers for the establishing a pollinator-attractive field for nearby bumblebees (costs include soil preparation, seed costs, labour costs, and foregone income from cash crops minus the state support of €255.80 per hectare)

[41] Only the agricultural support measure is included. Also grassland restoration and preservation that also restores and maintains nesting possibilities and wide diversity of plant species needed to maintain diverse population communities should be considered.

[42] "The absence of ecosystem able to provide the services" (https://ecosystem-accounts.jrc.ec.europa.eu/about-inca)

[43] Statistics Estonia, 2021. "Development of the ecosystem accounts" (881542-2019-ENVECO)

[44] Sandel, Michael. 2013. *What Money Can't Buy*. Harlow, England: Penguin Books.

Figure 4. Monetary values connected to the Crop pollination ES (million euro)

			Ecosystem service in scenario	
			Ecosystem service exists	**Ecosystem service does not exist hypothesis**
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	Ecosystem services are traded as private usage rights		
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	Ecosystem services are potentially traded as private usage rights		
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	ES is used for producing other goods or services		
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	Other (outside or inside of SEEA-EA, within SEEA CF, other satelllie accounts or SNA)	**0.57** (payment for ecosystem services, subsidy on establishing fields that are attractive for foraging to pollinators) **256 €/ha** (restoration subsidy), if applied to actually benefitting areas	
Connected monetary value (transaction/asset, etc.) in scenario	"would appear" (does not exist in reality, does in the scenario)	Economic activity that avoids the need for the ES		Hand pollination/designated pollination by domesticated bee species (substitution cost - averting behaviour)
Connected monetary value (transaction/asset, etc.) in scenario	"would appear" (does not exist in reality, does in the scenario)	ES restoration as economic activity*		**256 €/ha** (restoration cost), if applied to areas providing the service
Connected monetary value (transaction/asset, etc.) in scenario	"would appear" (does not exist in reality, does in the scenario)	Marketisation of the ES	**3.3** (WTP for enabling pollination and honey collection)	
Connected monetary value (transaction/asset, etc.) in scenario	"would disappear" (exists in reality, is lost in the scenario)	Existing economic activies can no longer thrive, and/or assets are damaged («other negative changes in value») because of the lack of the ES		**62.4** (production change - dependency rate) **134** (production change - dependency rate)

Estonian figures

Dutch figures

Further possible connected values

When compared side-by-side, these approaches reveal that market-based policy measures vastly underrepresent pollination's true contribution to the economy. The dependency-based estimates alone are over 100 times higher than current subsidies, indicating a large gap between market-based policy signals and agroecological reality. Restoration costs further demonstrate that conserving pollination is more cost-effective than trying to restore it once lost. This striking gap reveals a core ecological blind spot in agricultural policy: the economy is heavily dependent on a service provided for free by ecosystems, yet financial flows to maintain the ecological conditions for pollinators are vanishingly small. Pollinators require diverse habitats, continuous floral resources, and freedom from pesticides. Subsidies that target only narrow aspects, such as temporary forage strips, cannot secure the resilience of pollination in intensively managed landscapes. Here, evidence is clear: prevention is far cheaper and more effective than restoration. Once pollinator populations collapse, replacement by manual pollination or domesticated bees is not only economically costly but ecologically insufficient, as wild pollinators sustain biodiversity far beyond agricultural fields

From an accounting standpoint, the dependency-based values provide the most compelling case for integrating pollination into environmental-economic accounting, as they link directly to agricultural outputs and not policy-dependent. Restoration and substitution costs are essential for cost-of-loss scenarios, while WTP values highlight societal rather low recognition of the service.

In conclusion, pollination is a vital yet under-recognised component of the economy. Highlighting the dependency of economic value from it into national accounts and co-measuring subsidies with its real contribution could strengthen agricultural resilience, biodiversity, and long-term food security.

Global climate regulation: unpacking latent, appearing and risk-based economic values

Among the ecosystem services analysed, Global Climate Regulation (GCR) most clearly exemplifies the semantic complexity of ecosystem-related monetary values. While ecosystems' contribution to climate regulation is undisputed, most of the monetary estimates associated to it in the available applications fall into the category of "values that would appear" — indicating latent or hypothetical values that depend on future regulatory, fiscal or market developments.

According to the European legal definition of this service, "the ecosystem contributions to reducing concentrations of greenhouse gases in the atmosphere" have two components: "the removal (net sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems". The two components are dealt with together, with no distinction as for the unitary values applied, in the exercises we analysed.

Several valuation perspectives have been devised by researchers to illustrate the diversity of meanings and interpretations.

From a market perspective the Global Climate Regulation ecosystem service is reflected in small-scale payments for emission permits. Each year, a number of emission permits are surrendered or sold by their holders to other economic agents. This flow is known from ETS registers. Actually observed transactions in tradable permits was 249 million euros in Estonia in 2022[45]. This figure tells how much „financial traffic" is connected to the ES, which relates to the attractiveness of this kind of financial investment, its weight in financial markets, the discrepancy between the initial allocation of the permits and enterprises' need to surrender them as well as to the possible influence of speculative movements.

If the average price at which market exchanges take place is applied to the stock of emission permits held by economic agents, then we have the estimate of an asset, which is dealt with in the 2025 SNA in Ch. 27. This stock is an asset for the holder (advance payment of taxes) and a liability for the government. It can be noted that "freely provided emission permits have zero value" in there (§27.81). Such values provide information of actual financial movements and positions connected to private-like management of the GCR ES.

Total accumulated abatement costs (EUR 1 681 788 million in 2022)[46] estimate what it would cost the economy to reduce emissions in case of Estonia by the same amount that ecosystems currently have sequestered (referring to the stock) — offering insight into the economic resources ecosystems help to conserve, but also highlighting how difficult it is to assign meaning to these numbers outside of pricing logic. The hypothesis and question behind this valuation seems to be "let us assume the carbon retained is emitted, and this is compensated by abatement… what

[45] Statistics Estonia, KK37: Environmental tax reveneu by Environmental tax and Year.
[46] 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), page 100

would it cost?" Considering that Estonia's CO2 emissions in 2022, including from biomass, are less than 18 500 thousand tons (AEA Estonia)[47], i.e. around 5 000 thousand tons C, and the carbon stock valued is of 4073 million tons, the abatement hypothesis is equivalent to that of a complete halt of emissions from the Estonian economy for 800 years... a fully hypothetical and unrealistic experimental setting.

EU ETS market prices applied to existing Estonian ecosystem's carbon stocks (1 259 420 million EUR in 2022) and net sequestration flows (154 million EUR in 2022)[48] offer a more tangible perspective. This reflects a hypothetical market scenario: "If all carbon retention were monetised under today's permit prices, what would Estonian ecosystems carbon storage ability be worth?". Yet the result depends entirely on the assumption that such a massive sale would not influence the price, which is a major simplification. Most importantly, this estimate embodies an institutional change hypothesis that is particularly inappropriate for national statistical offices to use as reference, as it may seem as an implicit promotion of the privatisation of such a fundamental common good, conveying the idea that it would not be worth preserving the existing ecosystem carbon stock if economic agents interested in emitting an equivalent quantity of C were willing to pay the sum. Under such an institutional setting, the C stock would be preserved only if people were willing to pay for it not to be emitted (i.e. if they would buy the emission permits and destroy them)

Contingent valuation opens another perspective regarding the willingness to pay to maintain ecosystem carbon and continue benefitting from this service. The value obtained for capture (EUR 13 million in 2019)[49] is much lower than that given by the application of EU ETS prices, which reflects the public's limited awareness or valuation capacity. Individuals may assign such low values to such critical services just because they do not know how fundamental these services are, or because of the well-known discrepancy between societal collective goals and the sum of individual preferences and strategic economic behaviour (tendency to free-ride)[50].

For the Netherlands a carbon price was applied that is linked to meeting a specific policy-defined goal for reducing CO2 emissions (efficient carbon price). This goal is in turn set on the basis of the constraint that certain damage costs should be avoided. By assigning a monetary value to carbon sequestration in biomass at this established economic-modelling-based carbon price, we can quantify the costs the Dutch economic system would have to bear in order to meet the net emissions target, in case there was no contribution of ecosystems toward meeting the policy target (i.e. in the no-carbon-sequestration hypothesis). This results in a carbon value for carbon sequestration of 134 million euro (2022)[51].

Unit social cost of carbon applied to C stock values (EUR 2 514 829 million in case of Estonia in 2022)[52] are meant to represent the projected damages avoided by keeping carbon in ecosystems, offering a stark contrast to the relatively modest market-based figures. Social cost of carbon approximated by sequestration (36-186 million in case of Holland for 2010-2017)[53] are lower expectedly. Both values, though powerful, rely on global models and assumptions about future damages — and are often overlooked in national economic statistics. They are questionable as they often imply monetisation of non-monetary values such as that of human and animal life, houses and places to which people have an existential attachment... but the figure (57 times the Estonian GDP) at least conveys a sense of urgency of ecosystems' conservation (which is the ultimate purpose of valuation according to policy intentions).

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[47] Statistics Estonia, KK31: Air emissioon accounts by Year, Source of air emissions / Economic activity (EMTAK 2008) and Pollutant,

[48] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement no NUMBER — 101113157 — 2022-EE-EGD), page 41

[49] Statistics Estonia, 2021. "Development of the ecosystem accounts" (881542-2019-ENVECO), page 104

[50] See Elinor Olstrom *Governing the Commons: The Evolution of Institutions for Collective Action* (1990) and theory of non-cooperative games.

[51] Statistics Netherlands (2025). The socio-economic use value of nature in the Netherlands. Database statistics Netherlands (statline): https://opendata.cbs.nl/statline/#/CBS/nl/dataset/85854NED/table?ts=1757063343477

[52] 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), page 100

[53] Statistics Netherlands and WUR (2020) Experimental monetary valuation of ecosystem services and assets in the Netherlands. https://www.cbs.nl/-/media/_pdf/2020/04/monetary-valuation-ecosystems-final-report-jan-2020.pdf, page 45

Figure 5. Monetary values connected to the Global Climate Regulation ES (million euro)

			Ecosystem service in scenario	
			Ecosystem service exists	Ecosystem service does not exist hypothesis
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	Ecosystem services are traded as private usage rights	**249** (Directly observed volume of actual transactions in tradable permits)	
		Ecosystem services are traded as potentially private usage rights	Directly observable prices applied to the existing stock of tradable permits held by economic units	
		ES is used for producing other goods or services		
		Other (outside or inside of SEEA-EA, within SEEA CF, other satelllie accounts or SNA)	Effective carbon rate payments, total	
	"would appear" (does not exist in reality, does in the scenario)	Economic activity that avoids the need for the ES		**1 681 788** (C stock - Abatement cost)
				184 (C sequestration - Efficient carbon rate - averting behaviour)
		ES restoration as economic activity		Cost of planting and raising trees
		Marketisation of the ES	**1 259 582** Directly observable prices (EU ETS price) of which: 1 259 427 stock, 154 sequestration	
			13 (C sequestration - Contingent valuation (WTP for maintaining ecosyst. C capture))	
	"would disappear" (exists in reality, is lost in the scenario)	Existing economic activies can no longer thrive, and/or assets are damaged («other negative changes in value») because of the lack of the ES		**2 514 829** (C stock - Social cost of having C in atmosphere)
				36.3 – 185.7 (C sequestration - Social cost of carbon)
		Estonian figures		
		Dutch figures		

This layering of valuations exposes a core tension in climate economics: ecosystems deliver global public goods that markets are not structured to recognise or reward adequately, and whose value is too big for markets to contain. The GCR ES provides one of the clearest cases where semantic structuring helps disentangle meanings: from actual transactions to fiscal proxies, from hypothetical payments to avoided catastrophe. The valuation figures do not converge on a single "price" — nor should they. Rather, they expose different dimensions of value, each with different implications for policy and accounting.

Seen through this lens, the lack of robust, observable economic flows linked to GCR is not a shortcoming, but a prompt to reconsider how society values — and plans to secure — such essential ecological functions.

Air filtration: avoiding health costs

Air filtration refers to the capacity of vegetation, particularly trees and shrubs, to remove particulate matter ($PM_{2.5}$, PM_{10}), nitrogen oxides, ozone, and other airborne pollutants from the atmosphere. This service improves air quality, thereby reducing respiratory and cardiovascular illnesses and enhancing general well-being.

From a willingness-to-pay (WTP, 2019) perspective, aggregated studies indicate an annual adjusted WTP of €5 million euros[54] for improved air quality through natural filtration in Estonia. This reflects persons' stated preferences for clean air, incorporating both health and general wellbeing. Rather low values indicate general low value allocated to the ecosystems role in contributing to clean air which could reflect either general low knowledge but also real low willingness to pay.

In terms of avoided health damage costs, pollutant removal by ecosystems reduces medical treatment needs, work absenteeism, and premature mortality. The actual economic savings from this service have not been directly assessed in Estonia as no designated study of health costs related to pollution has been carried out in Estonia.

Benefit transfer based on foreign external costs estimates annual avoided costs of approximately €1.3 million in the Estonian context in 2022[55]

International benchmark highlight the potential magnitude of this service in the Netherlands. The annual avoided health cost value of air filtration by ecosystems has been estimated at €167 million in 2022[56]. This includes two measures for avoided damage, namely avoided health effects and avoided mortality (see Statistics Netherlands, 2025 for more details). While this reflects different environmental conditions, population density, and valuation methods, it might also underscore the economic significance of this service in comparable contexts.

Other potential valuation approaches, such as substitution cost[57], could assess the expense of achieving equivalent pollutant removal using artificial air purification systems. However, no local technical or financial data on such substitutes have been analysed as of yet.

Overall, the evidence shows that air filtration delivers non-market benefits that are captured by relatively low values in monetary terms. The service directly supports public health, reduces healthcare costs, and contributes to urban liveability. In Estonia, the absence of primary local valuation studies limits the precision of estimates, but value

[54] Statistics Estonia, 2021. "Development of the ecosystem accounts" (881542-2019-ENVECO) https://www.stat.ee/sites/default/files/2021-07/D1.1%20Final%20methodological%20report_July_2021.pdf
[55] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement no NUMBER — 101113157 — 2022-EE-EGD) https://stat.ee/sites/default/files/2025-01/D1.9%20Description%20of%20the%20methodology%20and%20problematic%20issues%20for%20ecosystem%20accounts_0.pdf
[56] Statistics Netherlands (2025). The socio-economic use value of nature in the Netherlands. Database statistics Netherlands (statline): https://opendata.cbs.nl/statline/#/CBS/nl/dataset/85854NED/table?ts=1757063343477
[57] This is called „replacement cost" in the SEEA EA. We prefer not to use this term as it is at odds with its use in the SNA, as clarified in the 2024 Issue paper.

transfer results from other countries offer a reasonable starting point for inclusion in environmental-economic accounts.

From a policy perspective, avoided health damage costs offer a particularly compelling argument for maintaining and expanding vegetated areas, especially in urban and peri-urban regions with higher pollution exposure. Incorporating even conservative value transfer figures would help recognise the role of ecosystems as natural infrastructure for public health protection.

An important final consideration concerning this ES's connected values, is that when the calculated ecosystem service is very low due to low particulate matter (PM) concentrations, this reflects a favorable situation for both the environment and society. If it is low because there are no trees, however, the situation is not favourable. Even when there is high ecosystem service value the situation may not be favourable, if there is high pollution and the actual ecosystem service removes only a little share of it. Considering this kind of dependency, it is important to analyse both the monetary and the physical estimates of the service with underlying environmental parameters and conditions. The situation where an ecosystem service is lost should be understood in relation to the societal demand for that service.

As regards physical background figures, the Netherlands has a value of 15 408 tonnes[58] of adsorbed PM2.5, while Estonia has 552 tonnes[59] of adsorbed PM2.5. This indicates a relatively higher demand for and/or supply of this ecosystem service in Netherlands. Considering that PM2.5 total emissions in 2022 were 4 910 tonnes in Estonia and 14 925 tonnes in the Netherlands[60], the demand for and coverage of this ecosystem service appear significantly higher—and almost fully met—in the Netherlands. In contrast, Estonia still has some potential for saving costs by enhancing ecosystems' contribution to air filtration by meeting the currently unmet demand for this service.

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[58] Statistics Netherlands (2025). The socio-economic use value of nature in the Netherlands. Database statistics Netherlands (statline): https://opendata.cbs.nl/statline/#/CBS/nl/dataset/85854NED/table?ts=1757063343477

[59] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement no NUMBER — 101113157 — 2022-EE-EGD) https://stat.ee/sites/default/files/2025-01/D1.9%20Description%20of%20the%20methodology%20and%20problematic%20issues%20for%20ecosystem%20accounts_0.pdf

[60] https://ec.europa.eu/eurostat/databrowser/view/env_air_emis/default/table?lang=en&category=env.env_air.env_air_ai for emission data. I looked up territory-based inventories because this is what matters in relation to adsorption

Figure 6. Monetary values connected to the Air filtration ES (million euro)

			Ecosystem service in scenario	
			Ecosystem service exists	Ecosystem service does not exist hypothesis
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	Ecosystem services are traded as private usage rights		
		The ES is appropriated and potentially traded as a right to use on its own		
		ES is used for producing other goods or services		
		Other (outside or inside of SEEA-EA, within SEEA CF, other satelllie accounts or SNA)		
	"would appear" (does not exist in reality, does in the scenario)	Economic activity that avoids the need for the ES		
		ES restoration as economic activity		
		Marketisation of the ES	**5** (WTP)	
	"would disappear" (exists in reality, is lost in the scenario)	Existing economic activies can no longer thrive, and/or assets are damaged («other negative changes in value») because of the lack of the ES		**1,3** (Avoided health cost, value transfer) **167** (avoided damage: avoided health effects and avoided mortality)

Estonian figures

Dutch figures

Further possible connected values

Local climate regulation: the importance of green infrastructure

Local climate regulation ecosystem service refers to the capacity of ecosystems, particularly urban green spaces and tree cover, to moderate microclimates through shading, evapotranspiration, and wind buffering. This service mitigates heat stress, reduces cooling energy demand, and enhances urban liveability. From a market-linked perspective, local climate regulation is captured indirectly through its impact on real estate prices. Hedonic pricing studies indicate that properties in greener areas command 3–10% higher prices[61].

While these figures are not direct payments for the ecosystem service, they represent monetised value that reflects the market's recognition of its benefits. Moreover, it would be very difficult to isolate the effect of just climate regulation. However, for the current accounting exercise, no real, monetary figures are available for this service in Estonia and the Netherlands.

In replacement cost terms, the absence of natural microclimate regulation would require artificial cooling and shading infrastructure, such as air conditioning or engineered shade structures. These substitutes entail both capital investment and ongoing operational costs. Researchers' assessment includes qualitative descriptions of these artificial means, but again no local quantitative data have been observed, estimated or proposed for Estonia or the Netherlands.

Willingness-to-pay (WTP) studies in 2019 provide an additional perspective, valuing the preservation and maintenance of local climate-regulating vegetation at 1.67 million euros[62]. Although modest in scale compared to the hedonic pricing effect, WTP captures cultural and potential additional market appreciation for the service, particularly among urban residents. This figure is drawn from Estonian study. For the Netherlands specific survey results are not available.

A potentially important perspective is provided by avoided health damage costs. By reducing urban heat island effects and mitigating extreme temperature events, green infrastructure can lower rates of heat-related illness and mortality. These avoided costs, though potentially large, remain unquantified for the Estonian and Dutch context.

Overall, the evidence shows that market signals only partially capture the real economic value of local climate regulation. While property market premiums indicate a significant monetisation, operational cost savings and health benefits are excluded from accounts.

Averting behaviour costs might highlight the expense of substituting the service artificially, while WTP underscores its public recognition. The current absence of Estonian-specific figures limits the precision of national valuation, but qualitative and literature-based evidence still supports its importance.

From a policy standpoint, hedonic pricing results could be particularly relevant for integrating local climate regulation into environmental-economic accounts, as they align with observed market behaviour. Substitution cost and avoided health cost estimates are critical for cost–benefit analyses of green infrastructure investments, while WTP results strengthen the case for public funding and awareness campaigns. In conclusion, local climate regulation could provide also multi-dimensional benefits that extend beyond direct market transactions. Even without robust valuation data, its inclusion in urban planning and climate adaptation strategies would reflect its economic and social significance, particularly in rapidly urbanising or climate-sensitive areas.

[61] Trojanek, R., Gluszak, M., Tanas, J. (2018). The effect of urban green spaces on house prices in Warsaw. *International Journal of Strategic Property Management,* 22 (5) 358–371. https://doi.org/10.3846/ijspm.2018.5220
[62] Statistics Estonia, 2023. D1.8 Description of the methodology for advancing ecosystem accounts, methodology "Development of the environmental accounts" (101022852-2020-EE-ENVACC) https://www.stat.ee/sites/default/files/2023-09/D1_8_%20Description%20of%20the%20methodology%20for%20advancing%20ecosystem%20accounts%2C%20methodology%20_101022852_2020-EE-ENVACC_k%C3%BClj.pdf

Figure 7. Monetary values connected to the Local climate regulation ES (million euro)

Connected monetary value (transaction/asset, etc.) in scenario			Ecosystem service in scenario: Ecosystem service exists	Ecosystem service in scenario: Ecosystem service does not exist hypothesis
	exists (scenario coincides with reality)	Ecosystem services are traded as private usage rights		
		Ecosystem services are potentially traded as private usage rights		
		ES is used for producing other goods or services	3-10% higher real estate prices (hedonic pricing)	
		Other (outside or inside of SEEA-EA, within SEEA CF, other satelllie accounts or SNA)		
	"would appear" (does not exist in reality, does in the scenario)	Economic activity that avoids the need for the ES		Cooling, shading by artificial means (substitution cost - averting behaviour)
		Ecosystem service restoration as economic activity*		
		Marketisation of the ecosystem service	**1.67** (WTP for preservation and maintenance of urban green spaces that provide microclimate regulation)	
	"would disappear" (exists in reality, is lost in the scenario)	Existing economic activies can no longer thrive, and/or assets are damaged («other negative changes in value») because of the lack of the ES		Avoided health damage costs

Estonian figures
Dutch figures
Further possible connected values

Nature-based tourism: economic resources allocated to enjoying nature

Nature-based tourism captures the recreational and cultural benefits people derive from experiencing ecosystems directly while having overnight trips with the purpose to spend time in nature. It may include activities such as hiking, birdwatching, camping, staying in a hotel at natural area etc. These experiences generate market transactions (travel, accommodation, services) as well as non-market values linked to well-being and cultural identity.

From a market transaction perspective, nature-based tourism is reflected in expenditures on travel, accommodation, and other related costs. In Estonia, available references suggest 576 million euro[63] in direct spending in 2022, while Dutch comparisons indicate higher expenditure levels of around 4960 million euros[64]. These figures demonstrate that even if the ecosystem service itself is not traded, it supports significant downstream economic activity in the tourism sector.

In terms of opportunity cost, time spent in nature is recognised as a valuable allocation of personal resources. Alternative use of time estimates suggests values around €157 million euro in 2022[65], reflecting the implicit worth of recreational time dedicated to ecosystem-based tourism as an alternative to work (average hourly wage was used as monetary equivalent).

From a willingness-to-pay (WTP, 2022) perspective, the dedicated survey suggests that individuals would contribute financially approximately 25 million euro[66] extra per year just to maintain the infrastructure (preserving trails, signage, and other access-related amenities) necessary for ecosystem-based recreation. This reflects both cultural and recreational appreciation, even when access to ecosystems themselves remains free at the point of use.

If ecosystems degraded to the point where recreational attractiveness was lost, significant restoration costs would be required to restore their recreational function. No direct Estonian valuation of restoration costs is available, but this logic underpins the service's implicit asset value.

Overall, no comprehensive valuation study exists for Estonia. Additional methods and values can be found in literature, but these were not used in Estonia. Expenditure data capture direct economic flows, value of alternative use of time captures opportunity cost, and WTP highlights public willingness to support infrastructure and conservation.

From a policy perspective, these valuation approaches demonstrate that nature-based tourism is a critical contributor not only to cultural well-being but also to rural development and regional economies. Recognising it in environmental-economic accounts would strengthen the evidence for investing in conservation and sustainable tourism infrastructure, while also highlighting the potential losses if ecosystems degrade.

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[63] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement no NUMBER — 101113157 — 2022-EE-EGD) https://stat.ee/sites/default/files/2025-01/D1.9%20Description%20of%20the%20methodology%20and%20problematic%20issues%20for%20ecosystem%20accounts_0.pdf

[64] Statistics Netherlands (2025). The socio-economic use value of nature in the Netherlands. Database statistics Netherlands (statline): https://opendata.cbs.nl/statline/#/CBS/nl/dataset/85854NED/table?ts=1757063343477

[65] Statistics Estonia, 2024. D1.9 Description of the methodology and problematic issues for ecosystem accounts (Eurostat Grant Agreement no NUMBER — 101113157 — 2022-EE-EGD) https://stat.ee/sites/default/files/2025-01/D1.9%20Description%20of%20the%20methodology%20and%20problematic%20issues%20for%20ecosystem%20accounts_0.pdf

[66] Statistics Estonia, 2023. D1.8 Description of the methodology for advancing ecosystem accounts, methodology "Development of the environmental accounts" (101022852-2020-EE-ENVACC) https://www.stat.ee/sites/default/files/2023-09/D1_8_%20Description%20of%20the%20methodology%20for%20advancing%20ecosystem%20accounts%2C%20methodology%20_101022852_2020-EE-ENVACC_k%C3%BClj.pdf

Figure 8. Monetary values connected to the Nature-based tourism ES (million euro)

			Ecosystem service in scenario	
			Ecosystem service exists	Ecosystem service does not exist hypothesis
Connected monetary value (transaction/asset, etc.) in scenario	exists (scenario coincides with reality)	The ES is appropriated and actually traded as a right to use on its own		
		The ES is appropriated and potentially traded as a right to use on its own		
		ES is used for producing other goods or services		
		Other (outside or inside of SEEA-EA, within SEEA CF, other satelllie accounts or SNA)	**576** (travel costs, accommodation costs, other costs)	
			3 390 (travel costs, accommodation costs, other costs) of which **1150** travel costs	
	"would appear" (does not exist in reality, does in the scenario)	Economic activity that avoids the need for the ES		
		ES restoration as economic activity		Restoration of the ecosystem regarding attracative characteristics for recreation
		Marketisation of the ES	**157** (alternative use of time)	
			25 (WTP for maintaining the infrastructure necessary for recreation in nature)	
	"would disappear" (exists in reality, is lost in the scenario)	Existing economic activies can no longer thrive, and/or assets are damaged («other negative changes in value») because of the lack of the ES		

Legend:
- **Estonian** figures
- **Dutch** figures
- Further possible connected values

Discussion: making ecosystem service "valuation" more useful through semantic structuring

A central strength of the proposed reference scheme for connected ecosystem values lies in its ability to bring more clarity to the types of value being considered. It separates observed, potential, and potentially lost values further to the observed one. The method avoids collapsing complex, multidimensional value systems into a single monetary figure. Take carbon capture as an example: it can be valued through its current market price, anticipated future value under changing policies, and the cost associated with its loss due to ecosystem degradation.

This distinction is important for policy-making. Latent values — those that would appear — point to future opportunities, such as payments for ecosystem services or green infrastructure investment. Conversely, values that would disappear draw attention to the consequences of inaction, such as loss of fertile soil, declining health, or loss of biodiversity. Both perspectives are essential for designing long-term strategies and prioritizing investment in ecosystem resilience.

The approach could make ecological loss more visible — something that traditional accounting often overlooks — by using indicators like restoration costs or public health impacts. The semantic matrix could translate environmental degradation into terms that are more actionable for budgeting, and for policy to the extent that it is guided, or constrained, by strictly economic considerations. It may also provide a shared insight for ecologists, economists, and policymakers, helping to connect ecological, economic, and social perspectives for more integrated, evidence-based decisions. By highlighting which ecosystem services are being used, at risk, or hold potential, it could help set priorities and guide more effective policy and investment.

Conclusion: A semantic roadmap for smarter decisions

Within this framework, the reference scheme for connected ecosystem values presents several opportunities for advancing the use of monetary figures in decision-making, based on a sound understanding of their information content. It helps make the economic losses that may follow ecological loss more visible through measurable indicators, supporting more informed budgeting and policy responses, for instance by allowing – by keeping them distinct – to compare the economic costs of inaction to those of action, and the costs of prevention to those of repair and to those of restoration were it is possible at all. It also offers a potential shared language that connects ecologists, economists, and policymakers, opening the door to more integrated and cross-disciplinary collaboration. By suggesting to policy an identification of which potentials of ecosystems to provide services are currently used, under threat, are untapped, or are fully tapped but more is needed, the matrix fosters policy-making innovation, providing a tool to help set strategic priorities with a correct and more complete view of the economic consequences of policy action, and to direct investments and protection measures taking appropriately into account their impact on the actual economic system in several of its dimensions and facets, rather than reducing moral trade-offs to the sheer calculus, served by the pricing approach, of market-like gains and losses.

Advancing this framework will require investment in data coverage, and methods — especially to capture latent and risk-based values and to scale the further integration with SEEA EA.

Ultimately, the credibility of any valuation framework depends on recognizing that ecosystem services are inseparable from the biodiversity, ecological integrity, and resilience that sustain them. Monetary assessments may illustrate the scale of human dependence or the costs of degradation, yet they can neither substitute for ecological thresholds nor assure the feasibility of restoration. Safeguarding these ecological foundations is indispensable and usually the most cost-effective way to secure long-term value.