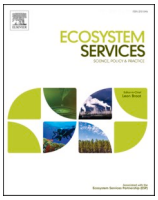
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Review Paper



A systematic literature review on the implementation of the System of Environmental-Economic Accounting-Ecosystem accounting in forests, cities and marine areas

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ABSTRACT

The System of Environmental-Economic Accounting (SEEA-EA) was set as an international standard framework for integrating and relating economic and environmental statistical data. Since its adoption in 2021, several scientific efforts have been established to operationalise it. Systematic literature reviews are essential for providing a comprehensive worldview on specific topics, exploring gaps, and defining future directions. In this study, we systematically review ecosystem accounting studies in the context of SEEA-EA and collate information on several aspects of its multiple accounts: ecosystem extent, condition, ecosystem services and assets. To narrow the scope, we focus our research on three ecosystem types: urban, forest and coastal and marine ecosystems. The results showed an increasing interest in the topic among scientists. Most of the works were published between 2014 and 2024 (75 studies – 98.68%) and conducted in Europe and Oceania (61 studies – 80.26%). Ecosystem extent and services (monetary) were the most studied aspects; however, most studies do not compile information on opening/closing tables. The revised studies covered other ecosystem types besides the target ones (e.g., croplands). Extent accounts were compiled mainly using European and National land cover datasets. Condition accounts were mostly compiled based on compositional state characteristics, especially using biophysical indicators. Most studies failed to define reference conditions. Regarding ecosystem services (ES), most studies focused on physical and monetary accounts, using mixed methodological approaches. Most works assessed one section, primarily regulating & maintenance ES. Statistical data and market prices for biophysical and economic methodologies were preferred methods. Validation and mapping were not considered in the majority of the works. Future priorities, which are also challenges, on applying the SEEA-EA include developing guidance for (1) systematically defining appropriate reference conditions, (2) validating ES modelling outputs or at least reporting uncertainty levels, and (3) making the connection, often missing, between condition and ES accounts.

1. Introduction

The importance of natural systems in supporting human wellbeing is reflected in the multiple socio-economic activities that drive national and global economic systems, which depend on healthy ecosystems (Paul et al., 2020). Natural capital is understood as "*the living and non-living components of ecosystems that contribute to the generation of goods and services of value for people*" (Guerry et al., 2015). It has been recorded at the macroeconomic level through the System of National Accounts (SNA) (Ochuodho and Alavalapati, 2016). However, only to a very limited extent, mainly focusing on marketed values. SNAs provide an internationally agreed framework to compile information on concrete material outputs (e.g., wood products) from ecosystems (e.g., forests). This allows the analysis of a country's economic performance (United Nations, 2010). Despite its importance, SNAs need to incorporate key aspects of natural capital, such as ecosystem services (ES), partly capturing natural ecosystems' true value and importance to support wellbeing (Ochuodho and Alavalapati, 2016).

In the last decades, direct (e.g., land use changes) and indirect (e.g., climate change) drivers of change have dramatically altered natural

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systems (Winkler et al., 2021), leading to dramatic losses of biodiversity and ES (IPBES, 2019) and negative impacts on wellbeing (Adla et al., 2022). Governments were encouraged to rethink how to better integrate the contribution of ecosystems into economic accounting due to growing concerns stemming from anthropogenically driven environmental degradation and the consideration of future sustainable development (Bartelmus, 2015; Ochuodho and Alavalapati, 2016). To address this need, the System of Environmental-Economic Accounting (SEEA) was developed by the United Nations (UN) in the 1990 s to complement existing economic accounting frameworks, building on the SNAs. The main objective of SEEA was to create a standardised framework to account for the relationship between the environment and the economy more comprehensively (Stahmer, 1993). From its first version in 1993, SEEA has undergone multiple iteration cycles. In 2012, the SEEA framework was revised, and a new version, the SEEA-CF (Central Framework), was developed to provide a standardised method for accounting for environmental assets (e.g., forests, water) not only in monetary but also in physical terms (United Nations, 2014a). In 2013, the UN introduced the SEEA-EEA (Experimental Ecosystem Accounting) as an experimental framework to address aspects of ecosystem services and assets, complementing the SEEA-CF (United Nations, 2014b). Finally, in 2021, the SEEA-EA (Ecosystem Accounting) was developed and recognised as an international statistical standard adopted by the UN to measure ecosystems, their condition and services (Edens et al., 2022; United Nations, 2021). Building upon the SEEA-EEA, the SEEA-EA provides a more comprehensive and detailed methodological approach to fully account for the contributions of natural environments to well-being (Edens et al., 2022). The SEEA-EA is organised into physical and monetary accounts, recorded for a determined spatial unit and time-frame. Physical accounts encompass ecosystem the extent, condition, and services, while monetary accounts include ecosystem services and assets (United Nations, 2021). Ecosystem extent accounts "*organise data on the extent or area of different ecosystem types*", ecosystem condition accounts provide "*biophysical information on the condition of different ecosystem types*", ecosystem services accounts in physical terms provide information on the "*supply of final ecosystem services by ecosystem assets and the use of those services by economic units*"; and in monetary terms provide "*estimates of ecosystem services in monetary terms are based on estimating prices for individual ecosystem services*" (United Nations, 2021). Monetary ecosystem assets account "*record information on stocks and changes in stocks of assets (…) based on the monetary valuation of ecosystem services and applying the net present value approach*" (United Nations, 2021). Due to its interdisciplinarity, the SEEA-EA methodological framework integrates geospatial, ecological, and socio-economic data to compile the accounts. Clear guidelines on applying SEEA-EA are compiled in a guidance document (United Nations, 2021).

Since the SEEA-EA was in its experimental phase, several countries have started compiling ecosystem accounts (UNCEEA, 2022). Governments initiated multiple research projects to test, apply and develop tools to support the implementation of the SEEA-EA (Edens et al., 2022; United Nations, 2021). Successful examples of such projects are the Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES),[1] the Integrated Natural Capital Accounting (INCA),[2] the Mapping and Assessment for Integrated Ecosystem Accounting (MAIA),[3] and the Wealth Accounting and the Valuation of Ecosystem Services (WAVES)[4] projects that will help develop the SEEA framework further and implement it globally. The role of academia in developing frameworks, methodologies, and indicator sets is key for a robust and scientific-based compilation to assess SEEA-EA accounts (Comte et al., 2022). Some efforts have been made to summarise the information on the countries compiling ecosystem accounts (e.g., UNCEEA, 2022), the progress towards the implementation of SEEA-EA in specific regions (e.g., Europe (Lange et al., 2022)), the efforts in specific ecosystem types (e.g., marine ecosystems (Cummins et al., 2023)), or the potential of specific methodological approaches (e.g., Earth Observation (Kokkoris et al., 2024)). However, since the SEEA-EA encompasses a broad spectrum of research topics (ecosystem extent, condition, and services), it is essential to have an overview of where and which specific ecosystem accounts have been compiled (Comte et al., 2022). This is especially important because the UN aims that by 2025, at least 60 countries will compile at least one ecosystem account.[5] This may lead to an imbalance in research efforts towards a specific account. Furthermore, it is essential to synthesise information on how the ecosystem accounts are compiled and to understand whether the methodological approaches follow a scientifically robust framework, whether the results are validated, and whether there is an uncertainty analysis. Systematic literature reviews enable the exploration and synthesis of scientific information on the current state and future research needs (Wyborn et al., 2018). The information collected enables to identify gaps and biases (e.g., a focus on ES), revealing where to direct scientific and administrative efforts for the robust and accurate implementation of SEEA-EA (Comte et al., 2022). Several systematic reviews have been conducted on the implementation of the SEEA-EA and ecosystem accounting. Rendon et al. (2019) explored the assessment of European ecosystem condition, compiling information on indicators, methods, and ecosystem services. Comte et al. (2022) focused on ecosystem accounting, exploring which accounts were compiled and which methods were used, the purpose of accounting assessments, ecosystem types and ES sections (e.g., provisioning, regulating & maintenance, cultural). Lange et al. (2022) examined the implementation of ecosystem accounting in Europe, with a focus on the types of accounts produced. Despite the previous reviews providing a good overview of the implementation of SEEA-EA on a global, but very much on a European scale, none has explored all ecosystem accounts in-depth (e.g., how were extent accounts compiled, which methods were used to assess condition, which and how many ecosystem services and methods were used).

In this study, we conducted a systematic literature review focused on the scientific efforts to implement environmental-economic accounting in the context of the SEEA-EA framework. However, since SEEA-EA encompasses multiple spatial units and ecosystem types, we focus our research on three specific types: forests, urban areas, and coastal and marine environments. We selected these types to represent different stages of ecosystem accounting implementation. Forests have long been explored in environmental and economic accounting. For example, in SNA, the contribution of timber products to economic systems is mainly due to market values (King et al., 2024). In recent years, several efforts have been made to incorporate the contributions of non-timber products and other ecological functions into ecosystem accounting. Urban areas have recently become important socio-ecologic systems where nature is essential in supporting physical and mental human wellbeing (UNEP-WCMC, 2022). Finally, coastal and marine areas have been recognised as important suppliers of ES and, for some countries, the main drivers of economic development. Here, the lack of data has always been a hindrance in the context of environmental-economic accounting (Cummins et al., 2023). The specific objectives are to identify studies that have compiled SEEA-EA accounts for the defined ecosystem types and extract information regarding (1) the year of publication, (2) the location of the study, (3) ecosystem accounts, and if opening/closing information was collected; (4) ecosystem types and ecosystem extent accounts, input data and mapping; (4) ecosystem condition accounts, typology, methodological approach, reference conditions, validation, and mapping; (5) ES (physical and monetary), ES dimensions (supply, flow, demand),

[1] https://seea.un.org/home/Natural-Capital-Accounting-Project.
[2] https://ecosystem-accounts.jrc.ec.europa.eu.
[3] https://maiaportal.eu/.
[4] https://www.wavespartnership.org.
[5] https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_implementation_strategy_march_2022.pdf.

methodologies, validation, and mapping; and (6) ecosystem assets.

2. Materials and methods

We conducted this systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021), following the workflow suggested by Koutsos et al. (2019). The workflow comprised of several steps: (1) the *scoping phase,* which includes the definition of keywords aligned with the study objectives; (2) *the planning phase*, comprising the definition of search strings to be used on defined databases and the time frame of analysis; (3) *identification and search*, including the actual search and initial identification of the articles; (4) *screening phase*, where articles were included or excluded based on defined criteria; (5) *eligibility assessment*, in which a set of defined information was extracted for each article included; and finally (6) *presentation and interpretation*, including the presentation of the information extracted in tabular and graphical formats, as well as their interpretation and discussion. This workflow has been adopted in previous works (e.g., Pereira et al., 2024; Perevochtchikova et al., 2019) and is presented in Fig. 1. The detailed PRISMA review protocol applied in this study is shown in Table S1.

In step 1 (scoping), multiple keywords were defined based on the study objectives, covering topics related to the SEEA-EA physical (extent, condition, and ecosystem services) and monetary (ecosystem services and assets) accounts. The keywords defined were: "ecosystem account", "environmental account", "ecosystem extent", "ecosystem condition", "ecosystem service", "ecosystem asset", and "monetary". Furthermore, as the study focuses on specific ecosystem types (forests, urban, coastal and marine), additional keywords were defined to narrow down the scope of the search. The additional keywords are: "urban", "city", "forest", "shrub", "coast", "marine", and "sea". Keywords were jointly defined by three researchers whose expertise covers environmental and socio-economic disciplines.

In step 2 (planning), keywords were combined using Boolean operators ("AND", "OR"). The search strings utilised are shown in Table 1. Following previous works, SCOPUS was the defined database used for searching (e.g. Pereira et al., 2024). The search covered the period from January 2000 to July 2024. It was filtered to include only articles published in English, document type classified as "Article", and source type classified as "Journal". This way, articles written in a different language than English and grey literature (e.g., book chapters, reports) were already discarded from the search results.

In step 3 (identification and search), 1298 articles were initially identified based on the above criteria. However, 808 articles were removed based on duplicate exclusion.

In step 4 (screening), the abstracts of 490 articles were screened. Articles that did not fit the study's objectives or did not focus on the defined ecosystem types were excluded. In total, 296 articles were excluded. Three reviewers performed this step. An intraclass correlation coefficient (ICC) was done to ensure that the inclusion/exclusion criteria were consistent between the three reviewers. Each reviewer analysed a sample of 100 abstracts, and the model assumed that *each subject was subjected to the same set of raters.* The results showed an ICC value of 0.66 (lower 95 % confidence interval = 0.57; upper 95 % confidence interval = 0.75), corresponding to a moderate level of agreement (Koo and Li, 2016). The ICC was calculated using JASP software (version 0.17.3 – Apple Silicon) (JASP, 2024).

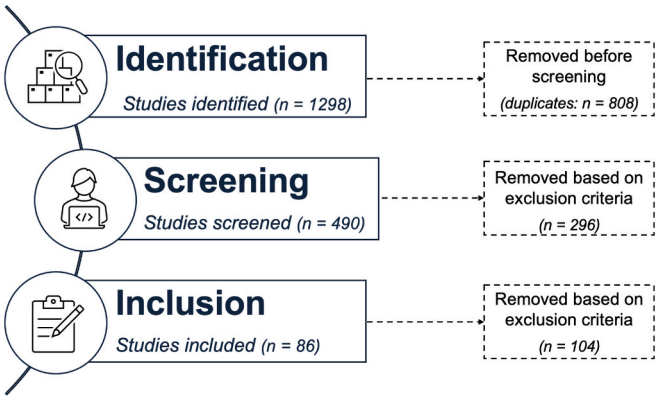


Fig. 1. Methodological framework applied in this review.

Table 1
Keywords and search strings used in this literature review, and respective number of results in SCOPUS database.

Search-strings	Number of studies
("ecosystem account*" OR "environmental account*") AND ("ecosystem service*" OR "environmental service*" OR "ecosystem condition*" OR "environmental condition*" OR "ecosystem extent*" OR "environmental extent*" OR "ecosystem asset" OR "environmental asset*" OR monetary* OR urban OR city* OR forest OR shrub* OR coast* OR marine OR sea)	489
("ecosystem account*" OR "environmental account*") AND ("ecosystem service*" OR "environmental service*")	222
("ecosystem account*" OR "environmental account*") AND ("ecosystem condition*" OR "environmental condition*")	39
("ecosystem account*" OR "environmental account*") AND ("ecosystem extent*" OR "environmental extent*")	34
("ecosystem account*" OR "environmental account*") AND ("ecosystem asset " OR "environmental asset*")	38
("ecosystem account*" OR "environmental account*") AND (monetary*)	99
("ecosystem account*" OR "environmental account*") AND (urban* OR city*)	100
("ecosystem account*" OR "environmental account*") AND (forest* OR shrub*)	137
("ecosystem account*" OR "environmental account*") AND (coast* OR marine OR sea)	140

In step 5 (eligibility assessment), 194 articles were selected for full-text screening. Conceptual articles and studies that performed ecosystem accounting but not in the context of the SEEA-EA framework were excluded from the analysis. Finally, 86 articles were selected for analysis (see Table S2). For each article, we extracted information regarding the year of publication, the location of the study (continent, country, and city), and the components of SEEA-EA physical and monetary accounts (*extent, condition, ES, and assets*).

For *ecosystem extent,* we extracted information on (1) the number of Ecosystem Types (ET) analysed, (2) ET analysed, (3) the input data utilised (e.g., national land cover maps, satellite imagery), (4) if maps were provided; and (5) if opening and closing periods were recorded. To harmonise the ET analysed in the articles, we have re-classified them following the EU Ecosystem Typology[6] (Table S3), aggregated to Level 1.

For *ecosystem condition*, we extracted information on (1) ecosystem condition typology; (2) if reference conditions were analysed; (3) methodological approach utilised; (4) if any uncertainty or validation analysis was considered; (5) if maps were provided; (6) if opening and closing accounts are recorded. Each condition indicator was classified according to the Ecosystem Condition Typology (ECT) and *Ancillary data classes* (hereafter referred to as "Other") (Czúcz et al., 2021) (Table S4).

For *ES (physical and monetary)*, we extracted information on (1) the type of ES accounts, (2) the number of ES sections analysed, (3) ES sections analysed, (2) ES classification, (4) ES dimensions (supply, flow, demand); (6) methodological approach (qualitative, quantitative,

[6] https://ec.europa.eu/eurostat/documents/1798247/12357920/Guidance-note-on-ecosystem-extent-accounts_2023.pdf/9d17c2ae-623f-9b4d-5c57-b1ea8c455f94?t=1702894975706.

mixed) and methods utilised; (7) uncertainty or validation analysis (8) if maps were provided; (9) if opening and closing accounts are recorded. The identified ES were harmonised following the CICES v5.1. Classification (Haines-Young and Potschin, 2018). Whenever possible, we identified the ES at the class level of classification; otherwise, we classified the ES according to the hierarchical organisation of CICES (Fig. S1), as described by Pinto et al. (2022). According to the SEEA-EA guidance document (United Nations, 2021), ES accounts are recorded as "flows from ecosystem assets to people" and calculated using supply and use accounts. ES supply refers to the potential and actual ES provided by ecosystem assets, and ES use refers to the actual consumption of ecosystem services by humans (United Nations, 2021). The definitions are similar to those commonly used in the context of ES. Supply was defined by Burkhard et al. (2012) as "the capacity of a particular area to provide a specific bundle of ecosystem goods and services within a given period" (Burkhard et al., 2012) and ES demand as "*the sum of all ecosystem goods and services currently consumed or used in a particular area over a given period*" (Burkhard et al., 2012). Finally, to harmonise the methodologies used to map and assess ES, we follow the typology developed in the ESMERALDA Project (ESMERALDA MAES Explorer)[7] in which methods are classified as "biophysical", "economic", and "socio-cultural" (see Table S5). We have collected information on whether asset accounts were developed or whether monetary ecosystem assets were used. Three reviewers were also involved in this step. Reviewer 1 extracted information on the year of publication and location of the study. Reviewer 2 extracted and standardised information on the ecosystem types analysed. Finally, Reviewer 3 extracted information regarding ecosystem condition and services.

In step 6 (presentation and interpretation), we georeferenced the location of each study in ArcGIS Pro software (ESRI, 2024). If studies were conducted at the local level, we mapped the exact location of the study. However, if the studies were conducted at the national, regional, or global level, respective geographical centres were mapped.

3. Results and discussion

3.1. Temporal and geographical analysis

The studies identified in this systematic review were published between 2007 and 2024. However, there was a gap between 2007 and 2014. From 2014 onward, the number of publications related to the topic has increased, with numbers oscillating between the years, as shown in Fig. 2. The highest number of studies was published in 2022 (19 studies), and the lowest number in 2007 and 2016 (1 study each). Since 2019, the number of studies per year has been higher than in previous years. The results showed an increasing interest in ecosystem accounting in the last two decades. This was also observed in previous works (e.g., Comte et al., 2022; Lange et al., 2022). The number of publications per year corresponds with the multiple iterative cycles of SEEA development. Although the number of studies related to the topic only increased significantly from 2017 onwards, the fact that the first published articles (excluding the one published in 2007) were from 2014 can be attributed to the SEEA-CF and SEEA-EEA, which were developed in 2012 and 2013, respectively. This can be linked to the scientific shift from other ecosystem accounting frameworks applied (e.g., Agroforestry Accounting System) to the SEEA-EA, as highlighted by Comte et al. (2022). From 2020/2021, there was a reduction in published articles, coinciding with the development of the final SEEA iteration cycle and the establishment of the SEEA-EA framework. In 2022, the year after the SEEA-EA establishment, the number of articles was the highest over the entire timeframe. This could be related to the case study articles applying the newly developed framework, as shown by Edens et al. (2022). The high number of articles published between 2017 and 2023 was due to a high research output on ecosystem conditions and services, as observed in previous studies (Maes et al., 2020; Li et al., 2023). Also, linking ecosystem accounting to policies and directives, such as the European Green Deal[8] or the Convention on Biological Diversity Aichi Targets,[9] may have contributed to increased research on the topic (EEA, 2019; Lange et al., 2022).

Regarding the geographical location of the studies, most were conducted in Europe (49 studies – 56.96 %), followed by Oceania (12 studies – 13.95 %). The least studied continent was South America (6 studies – 6.98 %) (Table 2). It was possible to identify 33 countries where studies were conducted, with the most studied countries being Australia (12 studies – 14.81 %), the USA (7 studies – 8.64 %), and Italy (6 studies – 7.41 %) (Table 2). Several countries only had one study, e.g., Rwanda, Russia, and the UK (Table 2). The location of the studies is shown in Fig. 3. The European Commission has been constantly involved in the development cycles of the SEEA framework, promoting projects (e.g., INCA Project (La Notte et al., 2022), initiatives (e.g., Eurostat Taskforce on Ecosystem Accounting) and policies (e.g., European Green Deal) to refine further and test the applicability of SEEA-EA (Vysna et al., 2021). This may have contributed to the high number of studies in European countries, which has also been observed in other review works related to ecosystem accounting (e.g., Comte et al., 2022). More importantly, in Europe, Member States will be required to compile ecosystem accounts in accordance with the SEEA (European Commission, 2024). In Oceania, represented solely by Australia, the high number of studies can be attributed to the country's adoption of ecosystem accounting, particularly in the context of the Indigenous perspective (Normyle et al., 2022; Vardon et al., 2019). In the study by Comte et al. (2022), Australia also appears to have the highest number of studies compiling ecosystem accounts. Hein et al. (2020) stated that several accounts have been produced in Australia at the national and local scales. Although ES studies are well developed in Asia (mainly in China) (e.g., Pereira et al., 2024), the results showed that the number of ecosystem accounting studies is still reduced. For instance, this may be related to the lack of available data and the fact that the data are organised according to administrative divisions, not by ecosystem type, as Ji et al. (2023) observed. This may limit the development of ecosystem accounting works based on ET. It is important to highlight as well that an important number of countries still have not implemented the SEEA'EA.[10] This may explain the reduced number of works. Contrary to Asia, in Africa, several revisions focused on ES showed that it is among the continents that are less studied (e,g., Pereira et al., 2024; Baltranaite et al., 2025), and this is likely a reflection of the reduced ecosystem accounting studies as it was observed in ES studies. The majority of the African countries did not fully implement the SEEA'EA[10]. This may explain the small number of works. Nevertheless, previous works highlighted that several accounts have been released in Africa (e.g., Edens et al., 2022; Failler et al., 2023). Also, some initiatives are being developed, such as the Natural Capital Accounting Community of Practice Africa.[11] At the country level, some countries launched as well the SEEA-EA (e.g., Kenya[12]). Nevertheless, compared with Europe and Oceania, it is likely to be in a primary phase. South America had the lowest number of studies related to ecosystem accounting. This can be attributed partly to the countries' capacity to integrate natural capital contribution into decision-making, which is still in the early phases (Alpízar et al., 2020). Nevertheless, some countries in Central and South

[7] https://www.maes-explorer.eu.

[8] https://commission.europa.eu/strategy-and-policy/priorities-2019–2024/european-green-deal.

[9] https://www.cbd.int/doc/strategic-plan/2011–2020/aichi-targets-en.

[10] https://seea.un.org/content/global-assessment-environmental-economic-accounting.

[11] https://ecastats.uneca.org/ncacop/Resources.

[12] https://iucn.org/story/202211/kenya-launches-implementation-un-framework-ecosystem-accounting.

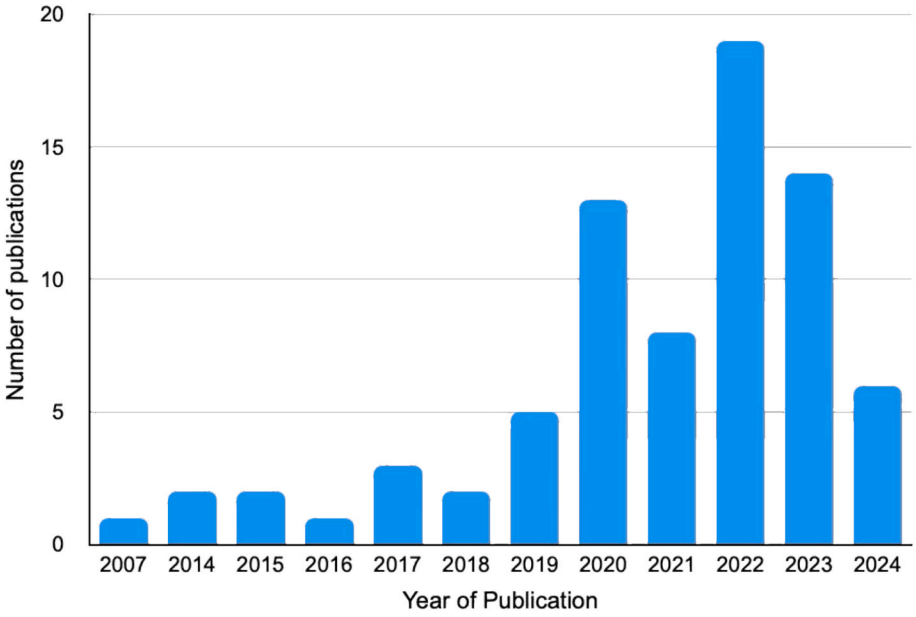


Fig. 2. Number of publications per year, from the 86 studies analysed.

Table 2
Continents and countries where the analysed studies were conducted. Each study can analyse more than one country in the same or in different continents.

Continent	Number of Studies	Percentage
Africa	7	8,14
Asia	7	8,14
Europe	49	56,98
North America	8	9,30
Oceania	12	13,95
South America	6	6,98
Countries	**Number of Studies**	**Percentage**
Australia	12	14,81
Benin	2	2,47
Brazil	1	1,23
Bulgaria	2	2,47
Canada	1	1,23
China	4	4,94
Colombia	3	3,70
Costa Rica	1	1,23
Cyprus	1	1,23
Czech Republic	3	3,70
England	1	1,23
Estonia	2	2,47
Finland	4	4,94
Germany	2	2,47
Greece	2	2,47
Grenada	1	1,23
Hungary	1	1,23
Indonesia	1	1,23
Ireland	2	2,47
Italy	6	7,41
Morocco	1	1,23
Netherlands	5	6,17
Norway	4	4,94
Philippines	1	1,23
Poland	2	2,47
Russia	1	1,23
Rwanda	1	1,23
South Africa	2	2,47
Spain	2	2,47
Sweden	1	1,23
Turkey	1	1,23
UK	1	1,23
USA	7	8,64

America have made significant efforts to implement the SEEA-EA, such as Mexico (INEGI, 2021) and Brazil (IBGE, 2021); however, the focus of these countries may still not be adequately reflected in the scientific literature. In the study by Comte et al. (2022), South America has also been highlighted as a continent with a limited number of ecosystem accounting studies. Also, according to Hein et al. (2020), only Peru and Colombia compiled ecosystem accounts. In some countries, only one study on ecosystem accounting was identified (e.g., Russia). Hein et al. (2020) highlighted the different stages of SEEA implementation globally, with countries varying in their level of advancement. They also emphasised the need to develop and implement ecosystem accounting initiatives to promote the global adoption of the SEEA-EA framework.

3.2. SEEA-EA ecosystem accounts

The results showed that all five accounts were identified in the analysed studies (Table 3). Regarding the number of ecosystem accounts analysed, 37 studies (43.02 %) focused on one account, and 23 (26.74 %) focused on two accounts. Only one study (1.16 %) has analysed all five accounts (Table 3). The most studied ecosystem account was *ES (physical)* (54 studies – 62.79 %), followed by *ecosystem extent* (49 studies – 56,96 %), *ES (monetary)* (40 studies – 46.51 %), *ecosystem condition* (28 studies – 32.56 %), and finally *ecosystem assets (monetary)* (2 studies –.33 %).

Most studies focused on either one or two ecosystem accounts. Although implementing the complete SEEA-EA framework (i.e., all the ecosystem accounts) would be ideal, this task is challenging. It depends on data availability and knowledge, which may not always be available (Hein et al., 2020). Knowing that assessing all ecosystem accounts would be challenging, the UN has set a target that by 2025, 60 countries should at least compile information for one ecosystem account.[13] Comte et al. (2022) and Lange et al. (2022) also observed the focus on one or a few ecosystem accounts. Implementing the full cycle of the SEEA-EA, including all the ecosystem accounts, would be something to envision when ecosystem accounting becomes more integrated into countries' directives and policies. For example, EU Member States (MS) will periodically elaborate and mandatorily report SEEA-EA ecosystem accounts

[13] https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_implementation_strategy_march_2022.pdf.

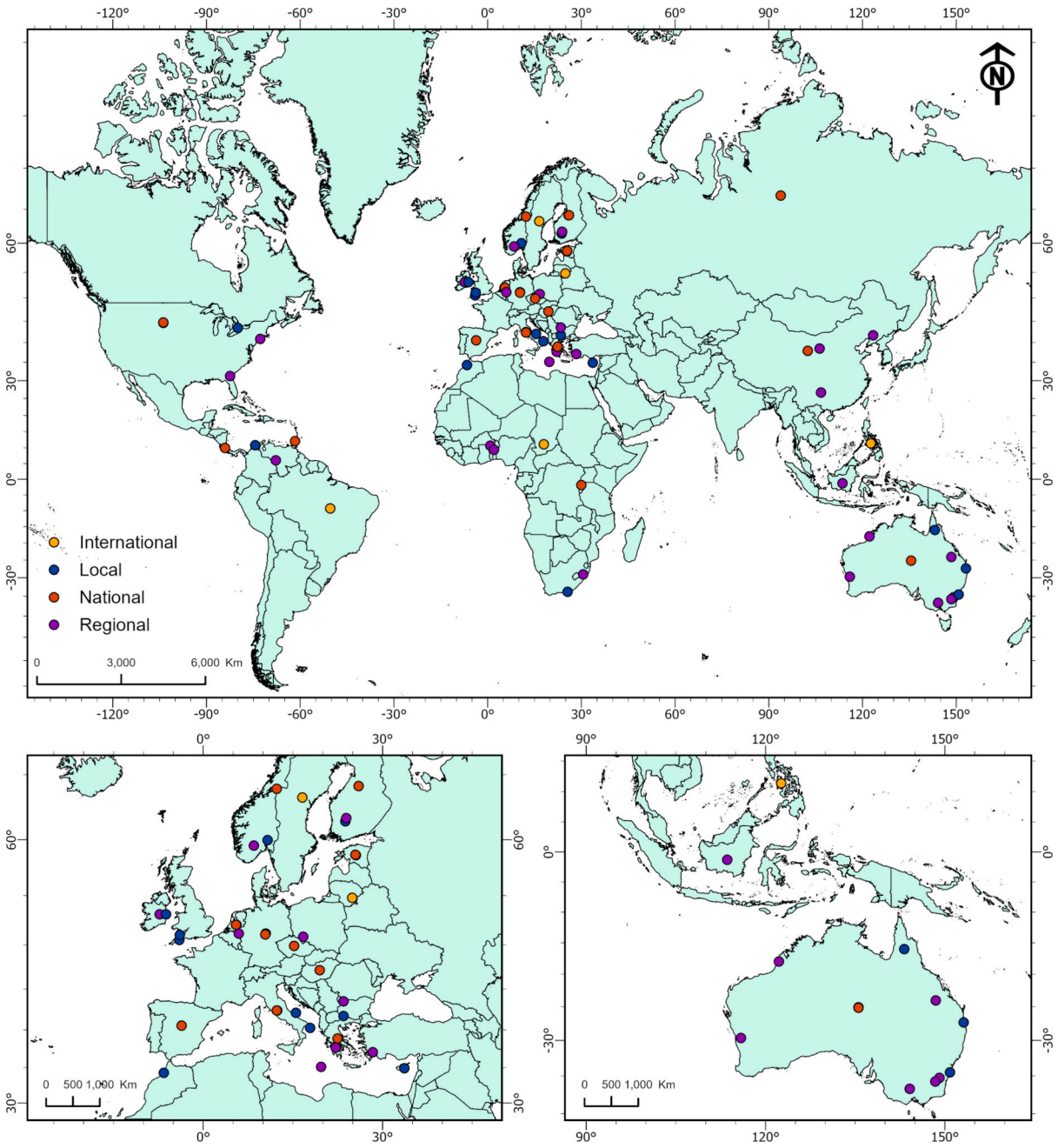


Fig. 3. Location of the studies across the globe, according to geographic scope. If studies were conducted at national, regional, or international levels, the geographical center was marked.

Table 3
Type and number of ecosystem accounts analysed. Each study can analyse more than one account.

Ecosystem Accounts *(number)*	**Number of Studies**	**Percentage**
1	37	43,02
2	23	26,74
3	15	17,44
4	10	11,63
5	1	1,16
Ecosystem Accounts *(type)*	**Number of Studies**	**Percentage**
Extent	49	56,98
Condition	28	32,56
Ecosystem Services (physical)	54	62,79
Ecosystem Services (monetary)	40	46,51
Asset (monetary)	2	2,33

in Europe (European Commission, 2024). The most studied accounts were *ES (physical and monetary) and ecosystem extent*. Other works obtained similar results (Comte et al., 2022; Lange et al., 2022). The high number of studies related to these *ecosystem accounts* is linked to the high research interest output related to ES in general (Li et al., 2023) and to the research on habitat or land cover mapping (Saah et al., 2019). Following the Millennium Ecosystem Assessment (MEA) (Millennium Ecosystem Assessment, 2005), ES have been extensively researched due to their role in demonstrating the importance of nature to human wellbeing (Sangha et al., 2022). The concept has been integrated into several policies and directives worldwide (Bouwma et al., 2018; Geijzendorffer et al., 2017), thereby further promoting research on the topic. Several literature reviews highlighted the growing trend of ES-related research in the last decades (e.g., Li et al., 2023), including for specific ecosystem types like forests (e.g., Aznar-Sánchez et al., 2018),

urban (e.g., Pereira et al., 2024) and coastal and marine areas (e.g., Buonocore et al., 2021).

Physical accounts were more studied than monetary accounts. Although the number of publications related to ES valuation has been increasing in the last decades (Tinch et al., 2019), there is still an evident focus on ES mapping and assessment (e.g., Urbina-Cardona et al., 2023). In the recent work by Costanza (2024), a literature review in SCOPUS revealed that from all the works related to ES (nearly 7000), only a fraction of those focused on valuation (a little over 2000) and economic value (nearly 1000). The developed biophysical and monetary valuation knowledge has contributed to compiling ES ecosystem accounts within the SEEA-EA framework. The many studies on *ecosystem extent* accounts can be linked to the well-developed research topic and outputs related to spatial mapping and assessment of habitats, ecosystems, landscapes, and land uses. Many sources with different spatial and temporal coverage allow to derive spatially explicit information on ET (García-Álvarez and Nanu, 2022). For example, in Europe, MS have access to the Copernicus Corine Land Cover database[14] that provides spatial information at the national scale with varying levels of detail, which can be used to assess and map the extent of ecosystem types and changes over time (e.g., Cieślak et al., 2017). Fewer studies analysed *ecosystem condition* accounts. This can be explained as an ecosystem condition, a relatively new "concept" linked with SEEA-EA. Condition measures the quality of an ecosystem based on quantitative metrics (United Nations, 2021). The concept of ecosystem condition has been widely studied in the context of marine ecosystems related to good ecological/environmental status (Smit et al., 2021). However, in the context of ecosystem accounting, its implementation and research are relatively recent (Maes et al., 2020).

From the studies that analysed ecosystem extent accounts, the majority (31 studies – 63,27 %) provided information on opening/closing accounts (Table S6). For ecosystem condition and ES accounts, most studies (19 studies – 67,86 % and 45 studies – 68,18 %, respectively) did not provide information on opening/closing accounts (Table S6). Compiling information on opening/closing accounts is essential for implementing the SEEA-EA framework (United Nations, 2021). For *ecosystem extent* accounts, providing opening and closing information requires analysing changes in ET over a period. As mentioned above, several information is available at different spatial scales, allowing for changes in ET over time. An example is the Dynamic World (Brown et al., 2022) or the ESRI Land Cover Map (Karra et al., 2021), which uses remote sensing imagery and deep learning to create a high-resolution global land cover map. These databases are essential in supporting data-poor regions in compiling information on ecosystem extent and opening/closing accounts. Most studies did not provide information on opening/closing accounts for ecosystem condition and ES accounts. Nevertheless, this is essential information according to the implementation guidelines of SEEA-EA. Compiling evidence on opening/closing accounts reveals changes in condition and ES. However, in practice, analysing changes in ES and condition is challenging due to the availability of spatial and temporal data (Erhard et al., 2016; Rau et al., 2018), especially when assessments are conducted at broader scales (e.g., national and international). Additionally, information on opening/closing accounts is likely more integrated into reports, whereas scientific publications focus on the mechanisms that explain why changes occur.

3.2.1. Ecosystem types and ecosystem extent accounts

The results of the ET analysed are shown in Table 4. Most studies analysed one ET (27 studies – 31.40 %), followed by two and three ET (11 studies – 12.79 %; each). Only one study (1.16 %) analysed all the 12 ET. The most studied ET were *4. Forest and woodland* (54 studies – 62.79 %), followed by *1. Settlements and other artificial areas* (39 studies – 45.35 %), and *3. Grasslands* (46 studies – 41.86 %). The least studied ET were *10. Marine inlets and transitional waters* (12 studies – 13.95 %), *12. Marine ecosystems* (17 studies – 19.77 %), and *6. Sparsely vegetated ecosystems* (19 studies – 22.09 %).

Table 4
Ecosystem types, and number of types analysed. Each study can address more than one ecosystem type.

Ecosystem types analysed *(number)*	**Number of Studies**	**Percentage**
1	27	31,40
2	11	12,79
3	11	12,79
4	2	2,33
5	5	5,81
6	9	10,47
7	6	6,98
8	9	10,47
9	3	3,49
10	2	2,33
12	1	1,16
Ecosystem Types	**Number of Studies**	**Percentage**
1. Settlements and other artificial areas	39	45,35
2. Cropland	34	39,53
3. Grassland	36	41,86
4. Forest and woodland	54	62,79
5. Heathland and shrub	25	29,07
6. Sparsely vegetated ecosystems	19	22,09
7. Inland wetlands	31	36,05
8. Rivers and canals	27	31,40
9. Lakes and reservoirs	26	30,23
10. Marine inlets and transitional waters	12	13,95
11. Coastal beaches, dunes and wetlands	22	25,58
12. Marine ecosystems	17	19,77

The SEEA-EA methodological framework suggests first defining a spatial unit of interest, identifying the ET and providing information on changes in spatial extent over time (United Nations, 2021). The number of ET varies depending on the administrative level (e.g., local, regional, national). Studies conducted at the local scale likely analyse fewer ET than those conducted at the national scale. Moreover, extent accounts can also be targeted for specific ET (e.g., Esen et al., 2023). Our results suggested that most studies were conducted locally, at a regional scale, or developed for specific ET. Our findings are in line with the work by Comte et al. (2022). Our study focused on specific ET: forests, urban areas, and coastal and marine ecosystems. The results identified these ET, as well as others considered in the Eurostat typology (e.g., grasslands and sparsely vegetated ecosystems). Studies conducted in broader spatial units (regional and national) will include several "non-target" ET. For example, in urban and *peri*-urban areas, besides the urban fabric, there are other ET, such as forests, grasslands, and agricultural areas (Pereira et al., 2024). According to the results, forests were the most analysed ET. This aligns with other studies on ecosystem accounting (e.g., Comte et al. 2022). Forests have an important role in socio-economic development (Li et al., 2019; O'Grady et al., 2020), and their products are an integral part of the SNA and the SEEA-CF (Niedzwiedz and Montagné-Huck, 2014). Moreover, several studies were focused on forests ecosystem extent (e.g., Almeida et al., 2024), condition (e.g., Maes et al., 2023) and services (e.g., Grammatikopoulou and Vačkářová, 2021). The second most analysed ET was urban areas. After establishing the concept of ES, these ecosystems have become increasingly critical for human wellbeing (Gómez-Baggethun et al., 2013; Pereira et al., 2024). In ecosystem accounting, urban areas have been increasingly researched (e.g., Almenar et al., 2023; Álvarez-Ripado et al., 2024; Heris et al., 2021), with a specific focus on ecosystem extent accounts (e.g., Costadone et al., 2024; Hanssen et al., 2021). The least analysed ET were coastal and marine ecosystems, as in Comte et al. (2022). Despite their importance for human wellbeing (Villasante et al., 2016), there is a notable gap in research efforts in these environments compared to the terrestrial (Sink et al., 2023). Spatial and temporal information on coastal and marine ET is lacking globally (Sink et al., 2023; Smit et al., 2022). Some authors use remote sensing imagery to analyse changes in extent over time for specific ecosystems, such as seagrasses (e.g.,

[14] https://land.copernicus.eu/.

Traganos et al., 2022) and mangroves (e.g., Wang et al., 2019). However, there is still a long way to properly operationalising ocean ecosystem accounting (Cummins et al., 2023). Initiatives like the Global Ocean Accounts Partnership (GOAP)[15] are essential in further developing knowledge (e.g., methods, databases) and guidance for compiling ecosystem accounts for coastal and marine areas.

The most utilised input data to map and assess ecosystem extent (Table S7) were *European Products* and *National Land Cover Maps* (16 studies – 32.65 %; each), followed by *Remote Sensing* products (11 studies – 22.45 %). The least utilised input data were *Historical Maps, Management Plans,* and *Statistics,* with one study (2.04 %) each. Most studies (32 studies – 65.31 %) provided information on the extent of the ecosystem in maps (Table S8). One of the most utilised input data sources was *the European Products,* primarily the Corine Land Cover database, which is derived from numerous studies applied in Europe. Corine Land Cover enables the analysis of different spatial scales (e.g., local to national) with varying levels of detail (levels 1 to 3) at a relatively high resolution (100 m) (European Environment Agency, 2021). Furthermore, it has a large temporal coverage from 1990 to 2018 (Bielecka and Jenerowicz, 2019). This information is critical to estimate ecosystem extent accounts (Petersen et al., 2022). National Land Cover Maps is another highly utilised input data to assess extended accounts. Besides being official and thus reliable, this information allows national coverage, which is important when assessing and reporting ecosystem extent accounts (Venter et al., 2024). However, these maps are synoptic or rarely updated in some countries, which does not allow for analysis of changes over time. Remote sensing is a promising approach, especially in data-poor countries (Zhang and Li, 2022), covering spatial and temporal dimensions (Saah et al., 2019). Several studies highlighted the applicability of remote sensing in ecosystem accounting (e.g., Kokkoris et al., 2024). However, regardless of which input data was utilised, it is essential to assess and report the uncertainty associated to ecosystem extent accounts (Venter et al., 2024). Several methods were developed using confusion matrices, sensitivity assessments, and statistical metrics (e.g., confidence intervals). Also, most studies provided maps of the ET analysed to translate ecosystem extent information into spatial representation. Mapping is a crucial aspect of ecosystem accounting, as visually explicit information is easily understood by many users and stakeholders (Burkhard and Maes, 2017).

3.2.2. Ecosystem condition

Regarding the ecosystem condition typology (Table 5), the most assessed types were *Other* (15 studies – 53.57 %), followed by *B1 Compositional state characteristics* (12 studies – 42.86 %). The least assessed typologies were *C1 Landscape characteristics* (6 studies – 21.43 %) and *B3 Functional state characteristics* (7 studies – 25 %) (Table 5). From the ecosystem condition typology adopted in the SEEA-EA (Table S4), the most used type was *B1 Compositional state characteristics*, which belong to the *Biotic ecosystem characteristics.* This observation was also identified by Czúcz et al. (2021), which referred to the case studies analysed by Maes et al. (2020). This ECT class relates to the "composition/diversity of ecological communities at a given location and time" (Czúcz et al., 2021). Several studies assessed this ECT type using species richness (e.g., Maes et al., 2023) or their presence (e.g., Mengo et al., 2022). This type of data is available at the global scale and collected in different databases (e.g., Global Biodiversity Information Facility[16] and Ocean Biodiversity Information System[17]), contributing as a direct input to assess this ECT class. The category *"Other"* includes all metrics utilised to assess ecosystem condition that do not fit into the five official categories and are regarded in Czúcz et al. (2021) and Vallecillo et al. (2022) as ancillary data. These include information about the environmental and ecological status of the different ET (e.g., Bekri et al., 2023), as well as the assessment of ecosystem condition based on the presence or absence of disturbances (e.g., Costa et al., 2024). In the study conducted by Czúcz et al. (2021), referring to the case studies analysed by Maes et al. (2020), ancillary data and pre-aggregated indices were also the highest in number. Although these metrics (under the category "Other") are not considered suitable for representing ecosystem condition, according to Czúcz et al. (2021), in some cases, they are the only available data that can be used to perform condition account works. Nevertheless, it would be advisable to follow the proposed methodological framework set up in SEEA-EA to assess ecosystem condition using only the five categories. *C1 Landscape characteristics* and *B3 Functional state characteristics* were the least utilised categories. *Landscape characteristics* refer to "*metrics describing mosaics of ecosystem types at coarse (landscape, seascape) spatial scales*" (Czúcz et al., 2021). This ECT class was evaluated using indicators such as tree density (e.g., Bruzón et al., 2023) and Shannon diversity (e.g., Tanács et al., 2022). This information was researched in the context of landscape analysis (e.g., Frazier and Kedron, 2017) and not for ecosystem accounting. Our results differ from those of Czúcz et al. (2021), referring to the case studies analysed by Maes et al. (2020), where *Landscape characteristics* were highly assessed. The study of Maes et al. (2020) analysed reports which were not included in this review and the difference of the different results can be explained by this methodological choice. The ECT class *Functional state characteristics* related to the "*summary statistics (*e.g. *frequency, intensity) of the biological, chemical and physical interactions between the main ecosystem compartments*" (Czúcz et al., 2021) and can be assessed based on productivity, greenness (through remote sensing products like the Normalised Difference Vegetation Indices (NDVI)), and other metrics depending on the ET analysed (Vallecillo et al., 2022). Similarly to the ECT class mentioned above, several studies on primary productivity analysis (e.g., Liao et al., 2023), exist, although not in the context of ecosystem accounting.

Regarding the methodological approach, most studies followed either qualitative or quantitative approaches (10 studies – 35.71 % each). *Biophysical indicators and Spatial proxies* (17 studies – 60,71 %) were the most used methods to assess ecosystem condition, whereas *Expert elicitation and Surveys* and *In situ data* (2 studies – 7,14 % each) were the least used (Table 6). The results generally agreed with those of Rendon et al. (2019), in which *biophysical and modelling methods* to assess ecosystem conditions, while *surveys and expert elicitation* were among the least frequently employed methods. Assessing ecosystem condition requires scientifically robust data and methods. Thus, it is essential to adopt quantitative methodological approaches. The use of biophysical and spatial indicators derived from environmental monitoring datasets (e.g., Copernicus[18]) or remote sensing databases (e.g., Google Earth Engine (Gorelick et al., 2017)) allow for the assessment of ecosystem

Table 5
Ecosystem Condition Typology (ECT), based on Czúcz et al. (2021). Each study can analyse more than one ECT.

Ecosystem Condition Typology			Number of studies	Percentage
ECT	A1	Physical state characteristics	9	32,14
	A2	Chemical state characteristics	11	39,29
	B1	Compositional state characteristics	12	42,86
	B2	Structural state characteristics	11	39,29
	B3	Functional state characteristics	7	25,00
	C1	Landscape characteristics	6	21,43
	Other		15	53,57

[15] https://www.oceanaccounts.org.

[16] https://www.gbif.org.
[17] https://obis.org/about/.
[18] https://www.copernicus.eu/en.

Table 6
Methodological approach (e.g., quantitative) and methods used to compile ecosystem condition accounts. Each study can apply only one methodological approach but several methods.

Methodological approach	Number of Studies	Percentage
Qualitative	10	35,71
Quantitative	10	35,71
Mixed	5	17,86
NA	3	10,71
Methods	**Number of Studies**	**Percentage**
Aggregated Indicators	5	17,86
Biophysical Indicators and Spatial Proxies	17	60,71
Expert elicitation and Surveys	2	7,14
In situ data	2	7,14
Literature and Statistics	6	21,43
Process-based Modelling	4	14,29
Remote Sensing	3	10,71

condition accounts accurately. On the contrary, the use of qualitative methodologies*, such as expert elicitation and Surveys* (e.g., Farrell et al., 2021) and *literature* reviews (e.g., Gomez Cardona et al., 2023), are subjective and the reliability of the results is questioned (Busch et al., 2012; Jacobs et al., 2015). Over the last few decades, there has been a shift from qualitative to quantitative approaches, enabling decision-makers to be informed more effectively (Pereira et al., 2024). However, our results still suggest that many studies analyse ecosystem conditions using these qualitative methods, which can be considered less reliable. Therefore, future works must focus on scientifically robust quantitative approaches. However, this can only be true where quantitative data is available. For example, there is likely more data and information (spatial and temporal) on forest ecosystems compared to coastal and marine ecosystems. In this case, qualitative data is also valid for assessing condition accounts as long as the uncertainty and potential biases are reported.

Most studies did not assess reference conditions when assessing ecosystem conditions (21 studies – 75 %) nor performed any validation of results (25 studies – 89.29 %). Only 11 studies (39.29 %) mapped ecosystem condition, while the remaining 17 studies (60.71 %) did not perform any mapping of ecosystem condition or their representative indicators (Table S8). According to the SEEA-EA, a crucial step in compiling information on ecosystem condition accounts is defining reference conditions, which enables the analysis of how far the current status deviates from pristine or less impacted conditions (Keith et al., 2020; United Nations, 2021). Defining reference conditions is a challenging task that requires scientific knowledge and evidence (Maes et al., 2020). Even though the SEEA-EA methodological framework guides the definition of reference conditions, our results suggested that most studies fail to achieve this. It is an important bottleneck in ecosystem accounting studies that need to be addressed. Previous studies also highlighted that reference conditions were not always defined when compiling ecosystem condition accounts (Maes et al., 2020). The lack of studies defining reference conditions can reveal two aspects: (1) there is not sufficient information (methodologies and data) to define them, and (2) it is not the main priority when implementing the SEEA-EA. More efforts should be directed to develop systematic and stepwise guidelines for defining reference conditions (e.g., using globally available databases), including local and national reports. Additionally, it is essential to emphasise the significance of compiling this information, as assessing current ecosystem condition based on reference values provides information that can be linked to the sustainable use of ES (e.g., Martini et al., 2024). The studies that defined reference conditions used multiple strategies, such as (1) based on maximum and minimum values of condition indicators to show more or less disturbed locations (e.g., forest reference levels – Maes et al., 2023), (2) based on unfavourable land use (e.g., cropland as unfavourable ecosystem condition against native woodland as favourable ecosystem condition – Parkhurst et al., 2024), or (3) based on literature (e.g., Gomez Cardona et al., 2023). Nevertheless, a range of potential strategies exists to define reference conditions (see Keith et al., 2020, for a comprehensive overview). Another crucial step in assessing ecosystem condition is to validate the results. This enhances the reliability of the results and uptake by decision-makers (Pereira et al., 2024). Unfortunately, most studies analysed omit this step in their methodological framework. Future implementation of SEEA-EA should not overlook this, and more efforts should be placed into validating the results of the ecosystem condition. However, it is essential to note that validating the results is not a trivial task, primarily due to the lack of available data. This is a recurrent problem that can only be solved by investing in field data collection efforts. Lastly, our results showed that most studies did not translate ecosystem condition information into maps. Our results align with those of Rendon et al. (2019), who found that only 20 % of the analysed studies mapped ecosystem condition. The authors argue that the low number of studies mapping ecosystem condition may be attributed to non-objective approaches, a focus on spatial representation, a lack of spatial data, or technical capabilities. As mentioned, mapping enables the translation of complex information related to ecological processes (Burkhard and Maes, 2017). Thus, we advocate to represent ecosystem condition spatially, or at least the indicators used.

3.2.3. *Ecosystem services*

Regarding the type of ES accounts (Table 7), 26 studies (39,39 %) analysed physical accounts, 12 studies analysed monetary accounts (18,18 %), and 28 studies analysed both physical and monetary accounts (42,42 %). Information on the geographical location of ES accounts is available in Fig. 4. Most studies analysing only ecosystem services' physical accounts, monetary accounts, and both physical and monetary accounts were conducted in Europe, with the fewest studies conducted in Asia, North America, South America, and Africa (Fig. 4). In ecosystem accounting, the concept of ES bridges the physical and monetary accounts of ecosystems (Edens et al., 2022). When implementing the SEEA-EA fully, it is recommended that physical accounts be assessed and, subsequently, ES valuation for monetary accounts performed (United Nations, 2021). The results of our study showed that the highest number of reviewed works record information for both physical and monetary accounts of ES, indicating an intention to implement the SEEA-EA. Comte et al. (2022) and Lange et al. (2022) also demonstrated that many studies focus on the physical and monetary aspects of ES. However, the abovementioned studies did not specify their analysis. Besides the studies compiling accounts, our results showed that 26 studies only analysed physical accounts, whereas fewer works recorded only monetary accounts. They differed from the obtained in Comte et al. (2022) and Lange et al. (2022). Comte et al. (2022) showed that articles in most world regions focus more on monetary and less on physical accounts. The study by Lange et al. (2022) showed a higher proportion of ES monetary than physical accounts. However, our study focuses on

Table 7
Type of ecosystem services (ES) accounts (physical and monetary) analysed, sections analysed (e.g., Cultural ES), and number of sections analysed per study. Each study can analyse more than one ES section.

ES accounts	Number of Studies	Percentage
ES physical accounts	26	39,39
ES monetary accounts	12	18,18
ES physical & monetary accounts	28	42,42
Number of Sections analysed	**Number of Studies**	**Percentage**
1	25	37,88
2	16	24,24
3	23	34,85
Total ES	2	3,03
ES Sections	**Number of Studies**	**Percentage**
Provisioning	38	57,58
Regulating & Maintenance	51	77,27
Cultural	37	56,06
Total ES	2	3,03

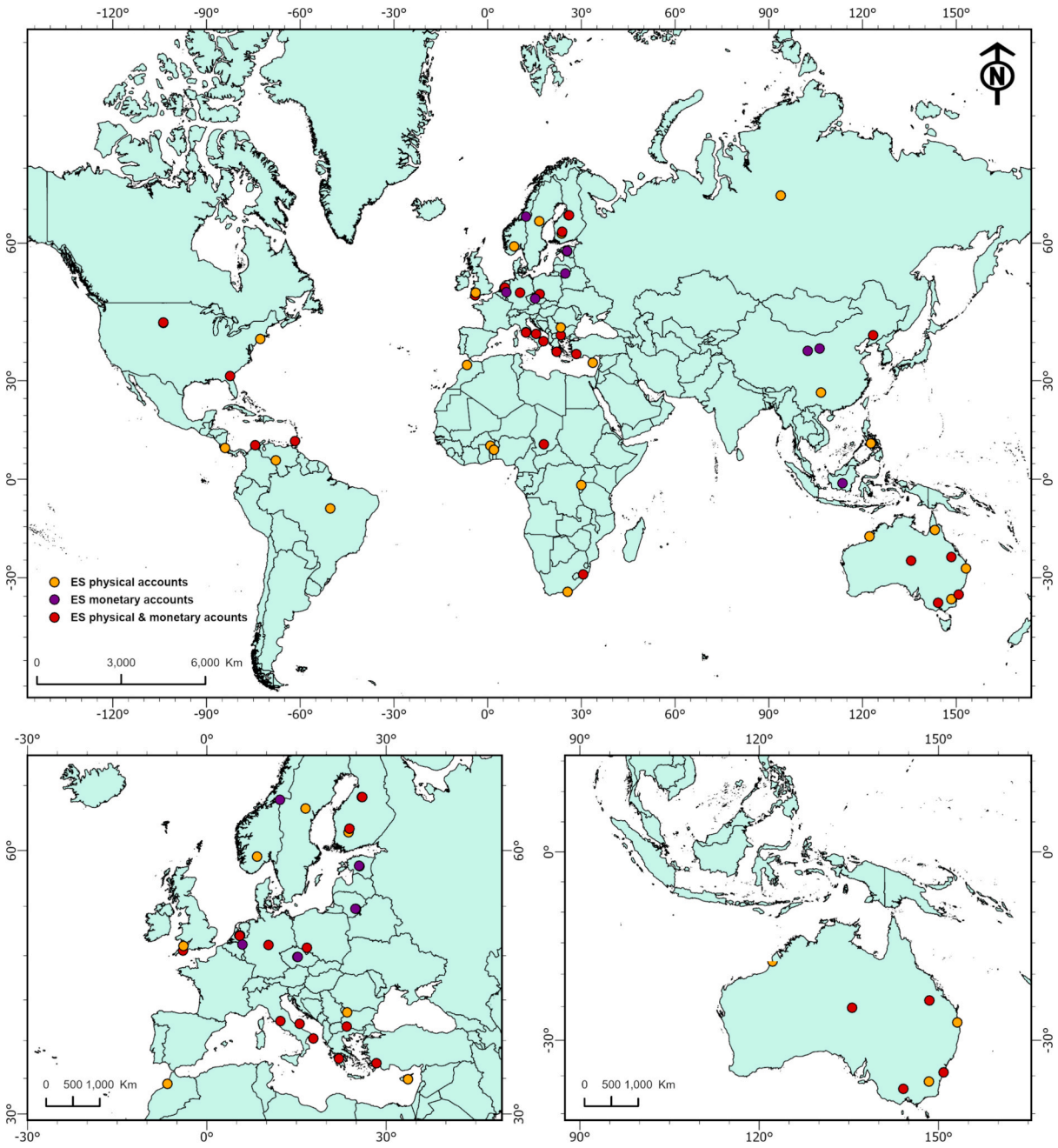


Fig. 4. Ecosystem services accounts analysed per study.

specific ET, whereas the mentioned works had a broader scope. The fact that the two accounts (physical and monetary) were the most studied within SEEA-EA reflects the development of the ES concept in physical and monetary terms (Li et al., 2023; Peng et al., 2023). The spatial differences highlighted in Fig. 4 are similar to those reported by Comte et al. (2022). Europe is the areas where most of the ES studies were conducted, while less were performed in Asia, America, and Africa.

Regarding the number of ES sections (Table 7), 25 studies (37.88 %) focused on one section, 16 studies (24.24 %) on two sections, and 23 studies (34.85 %) on the three ES sections. The most analysed ES section was *Regulating & Maintenance ES* (51 studies – 77.27 %), followed by *Provisioning ES* (38 studies – 57,58 %), and *Cultural* (37 studies – 56,06 %) (Table 7). The SEEA-EA guidance document lists ES following the CICES classification (United Nations, 2021). However, it does not concretely state the number of ES to be analysed. Therefore, studies can either focus on one (e.g., La Notte et al., 2017) or few (e.g., Vargas et al., 2017) ES within a section or multiple ES considering all sections (e.g., Tao et al., 2021). The highest number of studies analysed one ES section, e.g., nutrient regulation (La Notte et al., 2017). The focus on a single ES section was also observed in previous works related to ES (e.g., Pinto et al., 2022; Sousa et al., 2024). The second highest number of studies assessed three ES sections (e.g., Ji et al., 2023). Studies that assess multiple ES from all sections provide a holistic perspective on nature's contribution to human wellbeing. Thus, when implementing the SEEA-EA, it is important to account for more than one ES to represent all values of nature fully. The most studied section was *Regulating & Maintenance* e.g., carbon sequestration (Mengist et al., 2020). The high focus on the regulating & maintenance section in the context of ecosystem accounting was also observed by Rendon et al. (2019) and Comte et al. (2022). Previous studies on urban areas and forest ES also identify the regulating & maintenance section as the most studied (e.g., Acharya et al., 2019; Ma and Yang, 2025; Pereira et al., 2024). For

coastal and marine ecosystems, previous studies identify *provisioning* as the most analysed ES section (e.g., Campagne et al., 2023; Chalkiadakis et al., 2022). Despite the *Cultural* ES section being the least assessed, as also observed in previous studies (e.g., Rendon et al., 2019), there was an increasing focus and recognition of their importance for human wellbeing in urban areas (e.g., Tandarić et al., 2020), forests (e.g., Sutherland et al., 2016), and coastal and marine environments (e.g., Garcia Rodrigues et al., 2017).

From the 66 studies analysing ES accounts, only 19 studies (28.79 %) explicitly used ES dimensions terminology: 15 studies (22.73 %) analysed the supply, 12 studies (18.18 %) analysed the use, and 2 studies (3.03 %) analysed the flow of ES (Table S9). Although the terminology used in SEEA-EA in ES flow is derived from ES supply and use (United Nations, 2021), not all studies explicitly use these terms. The lack of concrete terminology has been highlighted as a challenge in several other ES-related works (e.g., Schröter et al., 2020). Using and stating the correct terminology is important, especially when assessing ES accounts. This is especially important since there is a multitude of ES dimension terms and conceptual definitions (Burkhard and Maes, 2017; Danley and Widmark, 2016; Villamagna et al., 2013) that may have different meanings and lead to misinterpretations. A typical example is the confusion between ES potential, supply, and use concepts (Dworczyk and Burkhard, 2021). For example, in the case of carbon sequestration ES, potential refers to the ecosystem's hypothetical maximum capacity for carbon sequestration, the supply refers to the de facto carbon sequestration and carbon storage, and use refers to the utilisation of sequestration benefits for society (e.g., carbon credits) (Hein et al., 2016). Therefore, defining and assessing ES within the SEEA-EA implementation is essential. Another aspect is related to the spatial relationship between the three dimensions, which often occur in different locations, following the concept of ES supply and benefiting areas (Syrbe and Grunewald, 2017). Failing to correctly define and assess ES dimensions conceptually and spatially can negatively impact management decisions. Barton et al. (2024) state that *"better conceptual distinction and measurement will improve understanding and management of the mismatches between what ecosystems can sustainably offer (capacity and potential) and what is required or desired by human populations (current use and future demand).",* and that by doing so decision-makers can make better decisions to ensure the sustainable supply of ES in the future and its continuous support to human wellbeing.

The most used methodological approach was *Mixed* (29 studies – 43.98 %) (e.g., Ji et al., 2023), followed by *Quantitative* (19 studies – 28.79 %) (e.g., Lai et al., 2018), and *Qualitative* (17 studies – 25.76 %) (e.g., Taljaard et al., 2023) (Table 8). Regarding the methods applied (Table 8), the most used biophysical methods are *the use of statistical and socio-economic data* (27 studies – 40.91 %), followed by *literature* (19 studies – 28,79 %), and *Spatial proxies methods* and *Process-based models* (11 studies – 28.79 % each). The least used biophysical methods were *Field observations* and *Phenomenological models* (2 studies – 3.03 % each) and *Ecological connectivity models* (3 studies – 4.55 %). The most used methods for economic methodologies are *market price* (25 studies – 37,88 %), *replacement cost,* and *damage cost avoided* (11 studies – 16.67 % each). The least used economic methods were *Choice modelling, Net factor income, Opportunity cost,* and *Defensive expenditure* (1 study – 1.52 % each). The main use of *Mixed* methodological approaches can be related to studies focusing on the different ES sections (e.g., regulating & maintenance and cultural) (e.g., Visintin et al., 2022), or in the specific case of ecosystem accounting, to studies compiling both physical and monetary accounts (e.g., Sylla, 2024). The assessment of specific ES sections is generally linked to particular methodologies, as highlighted in previous works (e.g., Kalinauskas et al., 2024; Pereira et al., 2024). For example, quantitative approaches were mainly used for regulating & maintenance sections (e.g., Horváthová, 2022), since assessing these ES relies on understanding complex ecological processes. Qualitative methods were primarily employed to study cultural ES (e.g., Scheufele and Pascoe, 2023) based on public perceptions and surveys. Studies focusing on compiling accounts of monetary ES can employ both quantitative (e.g., Horváthová, 2022) and qualitative methods (e.g., Ekinci et al., 2022). Thus, since multiple studies focus on physical and monetary accounts, this relates to the higher share of studies that employ mixed methodological approaches. *Quantitative* approaches were the second most applied, followed by qualitative approaches. Over the last few decades, an effort has been made to shift from qualitative to quantitative approaches due to their high reliability (Inácio et al., 2020). Thus, future studies should focus on compiling physical and monetary ES accounts based on scientifically robust quantitative methodologies. As mentioned previously, this recommendation is only valid if quantitative data is available. Data is lacking in many situations and in these cases, the use of qualitative information is also valid. However, it is important to communicate potential uncertainties and biases. Regarding the specific methodologies used, our results unfortunately showed a high proportion of qualitative approaches in *biophysical methods*. *Statistical and socio-economic data* (e.g., Klimanova et al., 2023) was used to get statistical information (e.g., crop statistics) to assess ES (e.g., crop production), and *Literature* information is usually applied to transfer information from one study to another (e.g., Alarcon Blazquez et al., 2023). This type of methodology and its subsequent results carry considerable uncertainty and lack robustness, which is essential in biophysical ES assessment (Comte et al., 2022; United Nations, 2022). In future, studies on ES accounting should focus on quantitative methods like *Spatial Proxies methods* (e.g., Keith et al., 2017) and *Process-based models* (e.g., McMahon et al., 2022), as well as *Field observations* (e.g.,

Table 8
Methodological approach and methods utilized to compile ecosystem services (physical and monetary) accounts. Each study can apply more than one method.

Methodological Approach		**Number of Studies**	**Percentage**
Qualitative		17	25,76
Quantitative		19	28,79
Mixed		29	43,94
NA		1	1,52
Methods		**Number of Studies**	**Percentage**
Biophysical	Spatial proxy methods	11	16,67
	Phenomenological models	2	3,03
	Process-based models (includes landscape function models)	11	16,67
	Statistical models	6	9,09
	Ecological Connectivity model	3	4,55
	Integrated modelling framework	9	13,64
	Field Observations	2	3,03
	Surveys and questionnaires	7	10,61
	Remote sensing and earth observation derivatives	4	6,06
	Use of statistical and socio-economic data	27	40,91
	Literature	19	28,79
Economic	Market price	25	37,88
	Public pricing	3	4,55
	Defensive expenditure	1	1,52
	Replacement cost (Alternative cost method)	11	16,67
	Damage cost avoided	11	16,67
	Social Cost of Carbon	7	10,61
	Opportunity cost	1	1,52
	Net factor income (residual value method)	1	1,52
	Production function	3	4,55
	Hedonic pricing	4	6,06
	Travel cost	7	10,61
	Contingent valuation	2	3,03
	Choice modelling (choice experiment, discrete choice modelling)	1	1,52
	Value transfer (benefit transfer)	7	10,61
Social	Geo-tagged photo-series analysis	1	1,52
	Citizen-Science	1	1,52

Araza et al., 2023), which were one of the least used methods. For *monetary methods,* the majority of studies followed *Market price* (e.g., Schenau et al., 2022), *Replacement cost* (e.g., Esen et al., 2023) and *Damage cost avoided* (e.g., Faccioli et al., 2023). The results are similar to those observed by Comte et al. (2022), who linked the high number of studies applying direct market prices to the recommendation of using exchange values, as done in the SNA (United Nations, 2021). *Replacement* and *Damage costs avoided* are well-known and applied methods in ES valuation (e.g., Ma and Yang, 2025).

Only two studies (3.03 %) performed a validation step when compiling ES accounts results. About mapping (Table S8), 39 studies (59.09 %) do not map the ES accounts, and 27 studies (40.91 %) do provide ES maps. Validation is essential in any ES assessment (Willcock et al., 2019), and it is necessary to increase the study's credibility (Pereira et al., 2025). It is important to include this step in the assessment framework to ensure the reliability of the results and, consequently, the uptake by policymakers (Barton et al., 2024). Validation assesses the reliability and robustness of ES results by comparing modelling outputs with field data, proxy indicators (e.g., remote sensing products), and expert opinion via questionnaires/surveys (e.g., PPGIS) (Willcock et al., 2019). Common metrics used in ES (physical) validation include the coefficient of determination (R2), Spearman's correlation coefficient (ρ), Kendall's tau (τ), or Root Mean Square Error (RMSE), as well as other strategies (Piikki et al., 2021). However, validating ES outputs is not always easy due to data availability, reliability, and accessibility. Also, several ES are more challenging to validate than others. To validate cultural ES, it is necessary to conduct surveys or questionnaires, which can be costly and time-consuming. It is not a trivial task and may not be applicable to the entire range of ES (e.g., cultural) (Pereira et al., 2025). However, despite the difficulties, an extra effort to validate ES assessment results may be a focus of future ES accounting work. For this, it is necessary to provide guidance and best practices on how to validate ES results and to highlight the benefits of validating ES results (e.g., robustness and uptake by decision-makers). This would lead to more studies in performing this step when compiling ES accounts within SEEA-EA.

For practical reasons, it is challenging to accommodate monetary values when translating ES information into maps instead of accounting tables. However, mapping physical ES accounts is essential, as highlighted by Comte et al. (2022) and envisaged in *Guidelines on Biophysical Modelling for Ecosystem Accounting* (United Nations, 2022). The lack of ES mapping is also showed by previous studies (e.g., Kalinauskas et al., 2024; Pereira et al., 2024), since in their initial search several hundred articles were discarded for not mapping ES. Future works on physical ES accounting should provide accounting tables and ES maps.

3.3. Review limitations

Our results provided useful insights on the application of SEEA-EA worldwide. Nevertheless, several limitations should be taken into consideration. We recognise that, as is the case with any reviews, some studies might have been overlooked. However, we believe that this would not affect the overall conclusions of our study. The most important limitation is the exclusion of grey literature. Several countries do not publish their SEEA information in scientific publications but rather in reports[19] and project synthesis (e.g., NCAVES[20]). Thus, a considerable amount of information was not included in this review, which may affect the assessment the implementation of SEEA-EA in cities, forests and coastal and marine ecosystems. Nevertheless, including only peer-reviewed information is common when conducting systematic literature reviews in environmental sciences. Our search was restricted to the SCOPUS database, which can also be considered a limitation. However, SCOPUS has been used as the primary database in previous systematic reviews (e.g., Pereira et al. 2024). The Web of Science (WOS) is a recurrently used search database. However, WOS is a subscription-based database with different subscription options, which may limit the reproducibility of search results. Google Scholar is another database for systematic reviews; hence, it is not advisable to use it as a primary database, as it has problems with the reproducibility of search results (Gusenbauer and Haddaway, 2020). Due to these reasons, we decided to opt for the SCOPUS database. Another important limitation is related to the exclusion criterion of including only English-only articles, also acknowledged in previous works (Hannah et al., 2024). However, it would not be possible to include different idioms due to a lack of proper language skills, which could lead to misinterpretations. We may have missed important information on applying the SEEA-EA in different national contexts. Our study focuses on core ecosystem accounts, excluding specific satellite accounts (e.g., biodiversity accounts) from the analysis. We decided to do so since countries are expected to focus primarily on the core accounts when implementing the SEEA-EA. Also, we did not include the term 'Natural Capital Accounting' as a keyword in our research. Although we recognise its significance within the context of SEEA-EA, we chose not to include it in our review because it serves as an umbrella term that can encompass ecosystem accounting as well as other concepts and results that may not be directly relevant to the focus of this study. Finally, the last limitation was the broad range of keywords, which resulted in a high number of exclusions. For example, we included environmental accounting and obtained several articles that employed the "emergy accounting" approach. However, we had test run the search query using only SEEA or SEEA-EA, which yielded very few results.

3.4. Implications for management

Implementing the SEEA-EA is considered essential to leverage the importance of natural capital, safeguard the sustainable supply of ES, and how we benefit from fully functioning ecosystems (Edens et al., 2022). Our results indicated that research on SEEA-EA has increased over time, and, as Comte et al. (2022) noted, it is currently in an initial phase. However, it is at this initial step that analysis like the one carried out in this study and previous studies (e.g., Comte et al., 2022; Lange et al., 2022; Rendon et al., 2019) provide essential information that can contribute further developing recommendations and guidelines on SEEA-EA. Providing a global overview of several aspects of SEEA-EA, such as the geographic imbalance or the focus on specific accounts or ET, is essential for understanding and directing future institutional and scientific efforts.

The implementation of SEEA-EA should be undertaken synergistically with ongoing efforts to implement other environmental directives and policies. The principles in SEEA-EA in integrating the value of ecosystems and their services are shared with other ongoing international efforts (Edens et al., 2022) like the UN 2030 Agenda for Sustainable Development (United Nations, 2015; UNSD, 2020), the Convention on Biological Diversity's previous Aichi Targets[21] and the new Kunming-Montreal Global Biodiversity Framework.[22] At the European level, SEEA-EA shares synergies with multiple policies (EEA, 2019) like the European Green Deal,[23] the previous Biodiversity Strategy

[19] https://biblioteca.ibge.gov.br/visualizacao/livros/liv102001_informativo.pdf.

[20] https://seea.un.org/sites/seea.un.org/files/documents/China_Inception_Mission/ncaves_-_china_-_country_report_-_final_web_ready.pdf.

[21] https://www.cbd.int/doc/strategic-plan/2011–2020/aichi-targets-en.

[22] https://www.cbd.int/gbf.

[23] https://commission.europa.eu/strategy-and-policy/priorities-2019–2024/european-green-deal.

2020[24] and the new Strategy for 2030,[25] the Common Agricultural Policy (Grondard et al., 2021), and the recently adopted EU Restoration Law.[26] Implementing SEEA-EA can deliver ready-to-use information that can be integrated into policies. Also, the work developed in implementing environmental policies (e.g., the EU Mapping and Assessment of Ecosystems and their Services (Maes, 2016) can directly contribute to SEEA-EA.

4. Conclusion

The present study explored the scientific efforts in developing ecosystem accounts within the SEEA-EA in urban, forest coastal and marine ecosystems. Most studies were conducted in Europe and Oceania. Few in America, Asia, and Africa. This is related to the implementation of SEEA-EA in the different continents. In Europe and Oceania, the SEEA-EA is fully implemented, whereas in other continents, it is not. For instance, in the continents or countries where more work is being developed, stakeholders will have better information about the value of their ecosystems and how they can contribute to the supply of ES essential for society. This is a great advantage for land use planning and management. Most studies have focused on one- and two-ecosystem accounts, primarily examining the extent of *ecosystems and the monetary value of* ES. The least studied account was *ecosystem assets,* with only two studies. As an important step in SEEA-EA, providing information on opening/ closing accounts, most studies overlook this for most ecosystem accounts. Although the study focused on urban, forests and coastal and marine ecosystems, the analysed works covered several other ET. European and National Land cover products were the most used, with remote sensing coming in second. Ecosystem condition was compiled mainly using indicators that do not fit into the ECT of SEEA-EA. Following the typology, the most assessed class was *Compositional state characteristics* related to species diversity and presence. Biophysical indicators and spatial proxies were the most used to assess ecosystem condition. Although an important step, most studies did not defined reference conditions and levels, as well as the translation of information into maps. More efforts should be put into defining guidelines to systematically define reference conditions (including spatial aspects and data availability). Regarding ES, the majority of the works compile physical and monetary accounts. Most studies focus on assessing one ES section, with regulating & maintaining ES being the most researched. Mixed methodological approaches were the most used to compile physical and monetary accounts, with biophysical methods focusing on statistical information and literature and economic methods focusing on market prices. Most studies were not validated or provided ES maps, which are two essential steps within the SEEA-EA. More efforts should be placed into developing guidelines for validating ES results. Despite some identified limitations, the study's results are essential for informing stakeholders and decision-makers on where to direct efforts for a global implementation of SEEA-EA. The synergy with multiple environmental policies supports the widespread application of SEEA-EA as a global ecosystem accounting standard.

CRediT authorship contribution statement

M. Inácio: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **E. Baltranaitė:** Writing – review & editing, Visualization, Formal analysis. **L.Valença Pinto:** Writing – review & editing, Visualization, Conceptualization. **M. Meisutovic-Akhtarieva:** Writing – review & editing, Visualization, Methodology, Conceptualization. **D. Barceló:** Writing – review & editing, Conceptualization. **P. Pereira:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2025.101752.

Data availability

Data will be made available on request.

References

Acharya, R.P., Maraseni, T., Cockfield, G., 2019. Global trend of Forest Ecosystem Services valuation – an analysis of publications. Ecosyst. Serv. 39, 100979. https://doi.org/10.1016/j.ecoser.2019.100979.

Adla, K., Dejan, K., Neira, D., Dragana, Š., 2022. Degradation of ecosystems and loss of ecosystem services. One Health 281–327. https://doi.org/10.1016/b978-0-12-822794-7.00008-3.

Alarcon Blazquez, M., van der Veeren, R., Gacutan, J., James, P., 2023. Compiling preliminary seea ecosystem accounts for the OSPAR Regional Sea: experimental Findings and lessons learned. One Ecosyst. 8. https://doi.org/10.3897/oneeco.8.e108030.

Almeida, B., Cabral, P., Fonseca, C., Gil, A., Scemama, P., 2024. Top 10+1 indicators for assessing forest ecosystem conditions: a five-decade fragmentation analysis. Sci. Total Environ. 957, 177527. https://doi.org/10.1016/j.scitotenv.2024.177527.

Almenar, J., Marando, F., Vallecillo, S., Zulian, G., Cortinovis, C., Zurbaran-Nucci, M., Chrysoulakis, N., Parastatidis, D., Heris, M., Grammatikopoulou, I., 2023. Urban Ecosystem accounts following the SEEA EA standard: A pilot application in Europe, Publications Office of the European Union, Luxembourg, JRC133240. https://doi.org/10.2760/741116.

Alpízar, F., Madrigal, R., Alvarado, I., Brenes Vega, E., Camhi, A., Maldonado, J.H., Marco, J., Martínez, A., Pacay, E., Watson, G., 2020. Mainstreaming of Natural Capital and Biodiversity into Planning and Decision-Making: Cases from Latin America and the Caribbean. https://doi.org/10.18235/0002667.

Álvarez-Ripado, A., Bruzón, A.G., Álvarez-García, D., Arrogante-Funes, P., 2024. Assessing urban ecosystem condition account with object-based methods. Ecol. Indic. 168, 112727. https://doi.org/10.1016/j.ecolind.2024.112727.

Araza, A., de Bruin, S., Hein, L., Herold, M., 2023. Spatial predictions and uncertainties of forest carbon fluxes for Carbon Accounting. Sci. Rep. 13 (1). https://doi.org/10.1038/s41598-023-38935-8.

Aznar-Sánchez, J.A., Belmonte-Ureña, L.J., López-Serrano, M.J., Velasco-Muñoz, J.F., 2018. Forest ecosystem services: an analysis of worldwide research. Forests 9 (8), 453. https://doi.org/10.3390/f9080453.

Baltranaite, E., Inacio, M., Pinto, L.V., Bogdziewicz, K., Rocha, J., Gomes, E., Pereira, P., 2025. Tourism impacts on marine and coastal ecosystem services: a systematic review. Geogr. Sustainability 6, 100277. https://doi.org/10.1016/j.geosus.2025.100277.

Bartelmus, P., 2015. Do we need ecosystem accounts? Ecol. Econ. 118, 292–298. https://doi.org/10.1016/j.ecolecon.2014.12.026.

Baltranaitė, E., Inácio, M., Valença Pinto, L., Bogdziewicz, K., Rocha, J., Gomes, E., Pereira, P., 2025. Tourism impacts on marine and Coastal Ecosystem Services: a systematic review. Geogr. Sustainability 6 (2), 100277. https://doi.org/10.1016/j.geosus.2025.100277.

Barton, D.N., Immerzeel, B., Brander, L., Grêt-Regamey, A., Kato Huerta, J., Kretsch, C., Le Clech, S., Rendón, P., Seguin, J., Arámbula Coyote, M., Babí Almenar, J., Balzan, M., Burkhard, B., Carvalho-Santos, C., Geneletti, D., Guisado Goñi, V., Giannakis, E., Liekens, I., Lupa, P., Villosalda, M., 2024. Increasing uptake of ecosystem service assessments: best practice check-lists for practitioners in Europe. One Ecosyst. 9. https://doi.org/10.3897/oneeco.9.e120449.

[24] https://eur-lex.europa.eu/EN/legal-content/summary/biodiversity-strategy-for-2020.html.

[25] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52020DC0380.

[26] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1991&qid=1722240349976.

Bekri, E.S., Kokkoris, I.P., Christodoulou, C.S., Sophocleous-Lemonari, A., Dimopoulos, P., 2023. Management implications at a protected, peri-urban, Salt Lake Ecosystem: the case of Larnaca's Salt Lakes (cyprus). Land 12 (9), 1781. https://doi.org/10.3390/land12091781.

Bielecka, E., Jenerowicz, A., 2019. Intellectual structure of Corine land cover research applications in web of science: a europe-wide review. Remote Sens. (Basel) 11 (17), 2017. https://doi.org/10.3390/rs11172017.

Bouwma, I., Schleyer, C., Primmer, E., Winkler, K.J., Berry, P., Young, J., Carmen, E., Špulerová, J., Bezák, P., Preda, E., Vadineanu, A., 2018. Adoption of the ecosystem services concept in EU policies. Ecosyst. Serv. 29, 213–222. https://doi.org/10.1016/j.ecoser.2017.02.014.

Brown, C.F., Brumby, S.P., Guzder-Williams, B., Birch, T., Hyde, S.B., Mazzariello, J., Czerwinski, W., Pasquarella, V.J., Haertel, R., Ilyushchenko, S., Schwehr, K., Weisse, M., Stolle, F., Hanson, C., Guinan, O., Moore, R., Tait, A.M., 2022. Dynamic World, near real-time Global 10 m land use land cover mapping. Sci. Data 9 (1). https://doi.org/10.1038/s41597-022-01307-4.

Bruzón, A.G., Arrogante-Funes, P., Santos-Martín, F., 2023. Modelling and testing forest ecosystems condition account. J. Environ. Manage. 345, 118676. https://doi.org/10.1016/j.jenvman.2023.118676.

Buonocore, E., Grande, U., Franzese, P.P., Russo, G.F., 2021. Trends and evolution in the concept of Marine Ecosystem Services: an overview. Water 13 (15), 2060. https://doi.org/10.3390/w13152060.

Burkhard, B., Maes, J. (Eds.), 2017. Mapping Ecosystem Services. Advanced Books. https://doi.org/10.3897/ab.e12837.

Burkhard, B., Kroll, F., Nedkov, S., Müller, F., 2012. Mapping Ecosystem Service Supply, demand and budgets. Ecol. Ind. 21, 17–29. https://doi.org/10.1016/j.ecolind.2011.06.019.

Busch, M., La Notte, A., Laporte, V., Erhard, M., 2012. Potentials of quantitative and qualitative approaches to assessing ecosystem services. Ecol. Ind. 21, 89–103. https://doi.org/10.1016/j.ecolind.2011.11.010.

Campagne, C.S., Roy, L.-A., Langridge, J., Claudet, J., Mongruel, R., Beillouin, D., Thiébaut, É., 2023. Existing evidence on the impact of changes in marine ecosystem structure and functioning on Ecosystem Service delivery: a systematic map. Environ. Eviden. 12 (1). https://doi.org/10.1186/s13750-023-00306-1.

Chalkiadakis, C., Drakou, E.G., Kraak, M.-J., 2022. Ecosystem service flows: a systematic literature review of marine systems. Ecosyst. Serv. 54, 101412. https://doi.org/10.1016/j.ecoser.2022.101412.

Cieślak, I., Szuniewicz, K., Pawlewicz, K., Czyża, S., 2017. Land use changes monitoring with Corine land cover data. IOP Conf. Ser.: Mater. Sci. Eng. 245, 052049. https://doi.org/10.1088/1757-899x/245/5/052049.

Comte, A., Sylvie Campagne, C., Lange, S., Bruzón, A.G., Hein, L., Santos-Martín, F., Levrel, H., 2022. Ecosystem Accounting: Past Scientific Developments and future challenges. Ecosyst. Serv. 58, 101486. https://doi.org/10.1016/j.ecoser.2022.101486.

Costa, M., Wartman, M., Macreadie, P.I., Ferns, L.W., Holden, R.L., Ierodiaconou, D., MacDonald, K.J., Mazor, T.K., Morris, R., Nicholson, E., Pomeroy, A., Zavadil, E.A., Young, M., Snartt, R., Carnell, P., 2024. Spatially explicit ecosystem accounts for Coastal Wetland Restoration. Ecosyst. Serv. 65, 101574. https://doi.org/10.1016/j.ecoser.2023.101574.

Costadone, L., Lai, T.-Y., Hurskainen, P., Kopperoinen, L., 2024. Co-creating Urban Ecosystem Accounting: Physical and monetary accounts of runoff retention service provided by Urban Green Spaces. Ecosyst. Serv. 65, 101576. https://doi.org/10.1016/j.ecoser.2023.101576.

Costanza, R., 2024. Misconceptions about the valuation of ecosystem services. Ecosyst. Serv. 70, 101667. https://doi.org/10.1016/j.ecoser.2024.101667.

Cummins, G.H., Navarro, M.L., Griffin, K., Partridge, J., Langlois, T.J., 2023. A global review of Ocean Ecosystem Accounts and their data: lessons learned and implications for marine policy. Mar. Policy 153, 105636. https://doi.org/10.1016/j.marpol.2023.105636.

Czúcz, B., Keith, H., Driver, A., Jackson, B., Nicholson, E., Maes, J., 2021. A common typology for ecosystem characteristics and ecosystem condition variables. One Ecosyst. 6. https://doi.org/10.3897/oneeco.6.e58218.

Danley, B., Widmark, C., 2016. Evaluating conceptual definitions of ecosystem services and their implications. Ecol. Econ. 126, 132–138. https://doi.org/10.1016/j.ecolecon.2016.04.003.

Dworczyk, C., Burkhard, B., 2021. Conceptualising the demand for Ecosystem Services – an adapted spatial-structural approach. One Ecosyst. 6. https://doi.org/10.3897/oneeco.6.e65966.

Edens, B., Maes, J., Hein, L., Obst, C., Siikamaki, J., Schenau, S., Javorsek, M., Chow, J., Chan, J.Y., Steurer, A., Alfieri, A., 2022. Establishing the SEEA ecosystem accounting as a global standard. Ecosyst. Serv. 54, 101413. https://doi.org/10.1016/j.ecoser.2022.101413.

EEA, 2019. Natural capital accounting in support of policymaking in Europe: a review based on EEA ecosystem accounting work. Publicat. Office Europ. Union. https://doi.org/10.2800/15480.

Ekinci, B., Grunewald, K., Meier, S., Schwarz, S., Schweppe-Kraft, B., Syrbe, R.-U., 2022. Supporting site planning through monetary values for biomass and nature conservation services from Ecosystem Accounts. One Ecosyst. 7. https://doi.org/10.3897/oneeco.7.e89706.

Erhard, M., Teller, A., Maes, J., Meiner, A., Berry, P., Smith, A., 2016. Mapping and assessment of ecosystems and their services. Mapping and assessing the condition of Europe's ecosystems: Progress and challenges. 3rd report, March 2016. Publications Office of the European Union, 192.

Esen, S.E., Hein, L., Suceloglu, G., 2023. Accounting for the water related ecosystem services of forests in the southern Aegean region of Turkey. Ecol. Ind. 154, 110553. https://doi.org/10.1016/j.ecolind.2023.110553.

ESRI, 2024. ArcGIS Pro (3.4.3). Environmental Systems Research Institute. Redlands, CA.

European Commission, 2024. Regulation (EU) 2024/3024 of the European Parliament and of the Council of 27 November 2024 amending Regulation (EU) No 691/2011 as regards introducing new environmental economic account modules. OJ L 2024/3024, 6.12.2024.

European Environment Agency, 2021. Copernicus Land Monitoring Service. CORINE Land Cover. User Manual. https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=metadata%0A.

Faccioli, M., Zonneveld, S., Tyler, C.R., Day, B., 2023. Does local natural capital accounting deliver useful policy and management information? a case study of Dartmoor and Exmoor National parks. J. Environ. Manage. 327, 116272. https://doi.org/10.1016/j.jenvman.2022.116272.

Failler, P., Liu, J., Lallemand, P., March, A., 2023. Blue accounting approaches in the emerging African blue economy context. J. Sustain. Res. 5, e230002. https://doi.org/10.20900/jsr20230002.

Farrell, C., Coleman, L., Norton, D., Kelly-Quinn, M., Obst, C., Eigenraam, M., O'Donoghue, C., Kinsella, S., Smith, F., Sheehy, I., Stout, J., 2021. Developing Peatland Ecosystem Accounts to guide targets for restoration. One Ecosyst. 6. https://doi.org/10.3897/oneeco.6.e76838.

Frazier, A.E., Kedron, P., 2017. Landscape metrics: past progress and Future Directions. Current Landscape Ecology Reports 2 (3), 63–72. https://doi.org/10.1007/s40823-017-0026-0.

Garcia Rodrigues, J., Conides, A., Rivero Rodriguez, S., Raicevich, S., Pita, P., Kleisner, K., Pita, C., Lopes, P., Alonso Roldán, V., Ramos, S., Klaoudatos, D., Outeiro, L., Armstrong, C., Teneva, L., Stefanski, S., Böhnke-Henrichs, A., Kruse, M., Lillebø, A., Bennett, E., Villasante, S., 2017. Marine and Coastal Cultural Ecosystem Services: Knowledge Gaps and Research priorities. One Ecosyst. 2. https://doi.org/10.3897/oneeco.2.e12290.

García-Álvarez, D., Nanu, S.F., 2022. Land use cover datasets: A Review. Land Use Cover Datasets and Validation Tools, 47–66. https://doi.org/10.1007/978-3-030-90998-7_4.

Geijzendorffer, I.R., Cohen-Shacham, E., Cord, A.F., Cramer, W., Guerra, C., Martín-López, B., 2017. Ecosystem Services in global sustainability policies. Environ Sci Policy 74, 40–48. https://doi.org/10.1016/j.envsci.2017.04.017.

Gomez Cardona, C., Moreno, J., Contreras, A., Sanchez-Nuñez, D., Arciniegas Moreno, N., Guerrero, D., Viloria Maestre, E., Lopez Navarro, J., 2023. Accounting of marine and coastal ecosystems at the ramsar site, Estuarine Delta System of the Magdalena River, Ciénaga Grande de Santa Marta, Colombia. One Ecosystem 8. https://doi.org/10.3897/oneeco.8.e98852.

Gómez-Baggethun, E., Gren, Å., Barton, D.N., Langemeyer, J., McPhearson, T., O'Farrell, P., Andersson, E., Hamstead, Z., Kremer, P., 2013. Urban Ecosystem Services. Urbanisation, Biodiversity and Ecosystem Services: Challenges and Opportunities, 175–251. https://doi.org/10.1007/978-94-007-7088-1_11.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., Moore, R., 2017. Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sens. Environ. 202, 18–27. https://doi.org/10.1016/j.rse.2017.06.031.

Grammatikopoulou, I., Vačkářová, D., 2021. The value of forest ecosystem services: a meta-analysis at the European scale and application to National Ecosystem Accounting. Ecosyst. Serv. 48, 101262. https://doi.org/10.1016/j.ecoser.2021.101262.

Grondard, N., Hein, L., Van Bussel, L.G.J., 2021. Ecosystem accounting to support the Common Agricultural Policy. Ecol. Ind. 131, 108157. https://doi.org/10.1016/j.ecolind.2021.108157.

Guerry, A.D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G.C., Griffin, R., Ruckelshaus, M., Bateman, I.J., Duraiappah, A., Elmqvist, T., Feldman, M.W., Folke, C., Hoekstra, J., Kareiva, P.M., Keeler, B.L., Li, S., McKenzie, E., Ouyang, Z., Reyers, B., Vira, B., 2015. Natural capital and ecosystem services informing decisions: from promise to practice. Proc. Natl. Acad. Sci. 112 (24), 7348–7355. https://doi.org/10.1073/pnas.1503751112.

Gusenbauer, M., Haddaway, N.R., 2020. Which academic search systems are suitable for systematic reviews or Meta-analyses? evaluating retrieval qualities of google scholar, pubmed, and 26 other resources. Res. Synth. Methods 11 (2), 181–217. https://doi.org/10.1002/jrsm.1378.

Haines-Young, R., Potschin, M., 2018. Common International Classification of Ecosystem Services (CICES) V5.1: Guidance on the Application of the Revised Structure. Fabis Consulting Ltd., Nottingham, UK (2018).

Hannah, K., Haddaway, N.R., Fuller, R.A., Amano, T., 2024. Language inclusion in ecological systematic reviews and maps: Barriers and perspectives. Res. Synth. Methods 15 (3), 466–482. https://doi.org/10.1002/jrsm.1699.

Hanssen, F., Barton, D.N., Venter, Z.S., Nowell, M.S., Cimburova, Z., 2021. Utilising lidar data to map tree canopy for urban ecosystem extent and condition accounts in Oslo. Ecol. Ind. 130, 108007. https://doi.org/10.1016/j.ecolind.2021.108007.

Hein, L., Bagstad, K., Edens, B., Obst, C., de Jong, R., Lesschen, J.P., 2016. Defining ecosystem assets for Natural Capital Accounting. PLoS One 11 (11). https://doi.org/10.1371/journal.pone.0164460.

Hein, L., Bagstad, K.J., Obst, C., Edens, B., Schenau, S., Castillo, G., Soulard, F., Brown, C., Driver, A., Bordt, M., Steurer, A., Harris, R., Caparrós, A., 2020. Progress in natural capital accounting for Ecosystems. Science 367 (6477), 514–515. https://doi.org/10.1126/science.aaz8901.

Heris, M., Bagstad, K.J., Rhodes, C., Troy, A., Middel, A., Hopkins, K.G., Matuszak, J., 2021. Piloting urban ecosystem accounting for the United States. Ecosyst. Serv. 48, 101226. https://doi.org/10.1016/j.ecoser.2020.101226.

Horváthová, E., 2022. Analysis of drinking water treatment costs – with an application to groundwater purification valuation. One Ecosyst. 7. https://doi.org/10.3897/oneeco.7.e82125.

IBGE, 2021. Ecosystem Accounts for Brazil. Results of the NCAVES Project.

Inácio, M., Karnauskaitė, D., Baltranaitė, E., Kalinauskas, M., Bogdzevič, K., Gomes, E., Pereira, P., 2020. Ecosystem Services of the Baltic Sea: an assessment and mapping perspective. Geogr. Sustainability 1 (4), 256–265. https://doi.org/10.1016/j.geosus.2020.11.001.

INEGI, 2021. Ecosystem accounts of Mexico: Results of the NCAVES project. INEGI 2021. Mexico.

IPBES, 2019. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. In: Brondizio, E.S., Settele, J., Díaz, S., Ngo, H.T. (Eds), IPBES secretariat, Bonn, Germany. 1148 pages. https://doi.org/10.5281/zenodo.3831673.

Jacobs, S., Burkhard, B., Van Daele, T., Staes, J., Schneiders, A., 2015. 'The matrix reloaded': a review of expert knowledge use for mapping ecosystem services. Ecol. Model. 295, 21–30. https://doi.org/10.1016/j.ecolmodel.2014.08.024.

JASP Team, 2024.
JASP (Version 0.17.3)
.

Ji, J., Zhu, T., Jia, C., Fan, Y., Song, Y., 2023. Testing ecosystem accounting in northern China – a case study of SEEA EA in Liaoning Province. J. Environ. Plan. Manag. 68, 751–772. https://doi.org/10.1080/09640568.2023.2269473.

Kalinauskas, M., Shuhani, Y., Pinto, L.V., Inácio, M., Pereira, P., 2024. Mapping Ecosystem Services in protected areas. a systematic review. Sci. Total Environ. 912, 169248. https://doi.org/10.1016/j.scitotenv.2023.169248.

Karra, K., Kontgis, C., Statman-Weil, Z., Mazzariello, J.C., Mathis, M., Brumby, S.P., 2021. Global land use / land cover with Sentinel 2 and Deep Learning. 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS. https://doi.org/10.1109/igarss47720.2021.9553499.

Keith, H., Czúcz, B., Jackson, B., Driver, A., Nicholson, E., Maes, J., 2020. A conceptual framework and practical structure for Implementing Ecosystem Condition Accounts. One Ecosyst. 5. https://doi.org/10.3897/oneeco.5.e58216.

Keith, H., Vardon, M., Stein, J.A., Stein, J.L., Lindenmayer, D., 2017. Ecosystem accounts define explicit and spatial trade-offs for managing natural resources. Nat. Ecol. Evol. 1 (11), 1683–1692. https://doi.org/10.1038/s41559-017-0309-1.

King, S., Agra, R., Zolyomi, A., Keith, H., Nicholson, E., de Lamo, X., Portela, R., Obst, C., Alam, M., Honzák, M., Valbuena, R., Nunes, P.A.L.D., Santos-Martin, F., Equihua, M., Pérez-Maqueo, O., Javorsek, M., Alfieri, A., Brown, C., 2024. Using the system of environmental-economic accounting ecosystem accounting for policy: a case study on forest ecosystems. Environ. Sci. Policy 152, 103653. https://doi.org/10.1016/j.envsci.2023.103653.

Klimanova, O.A., Bukvareva, E.N., Yu, K.E., Illarionova, O.A., 2023. Assessing Ecosystem Services in Russia: Case studies from four municipal districts. Land Use Policy 131, 106738. https://doi.org/10.1016/j.landusepol.2023.106738.

Kokkoris, I.P., Smets, B., Hein, L., Mallinis, G., Buchhorn, M., Balbi, S., Černecký, J., Paganini, M., Dimopoulos, P., 2024. The role of earth observation in ecosystem accounting: a review of advances, challenges and future directions. Ecosyst. Serv. 70, 101659. https://doi.org/10.1016/j.ecoser.2024.101659.

Koo, T.K., Li, M.Y., 2016. A guideline of selecting and reporting intraclass correlation coefficients for Reliability Research. J. Chiropr. Med. 15 (2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012.

Koutsos, T.M., Menexes, G.C., Dordas, C.A., 2019. An efficient framework for conducting systematic literature reviews in Agricultural Sciences. Sci. Total Environ. 682, 106–117. https://doi.org/10.1016/j.scitotenv.2019.04.354.

La Notte, A., Maes, J., Dalmazzone, S., Crossman, N.D., Grizzetti, B., Bidoglio, G., 2017. Physical and Monetary Ecosystem Service accounts for Europe: a case study for in-stream nitrogen retention. Ecosyst. Serv. 23, 18–29. https://doi.org/10.1016/j.ecoser.2016.11.002.

La Notte, A., Vallecillo, S., Grammatikopoulou, I., Polce, C., Rega, C., Zulian, G., Kakoulaki, G., Grizzetti, B., Ferrini, S., Zurbaran-Nucci, M., Garcia Bendito, E., Vysna, V., Paracchini, M.L., Maes, J., 2022. The Integrated System for Natural Capital Accounting (INCA) in Europe: Twelve lessons learned from Empirical Ecosystem Service Accounting. One Ecosystem 7. https://doi.org/10.3897/oneeco.7.e84925.

Lai, T.-Y., Salminen, J., Jäppinen, J.-P., Koljonen, S., Mononen, L., Nieminen, E., Vihervaara, P., Oinonen, S., 2018. Bridging the gap between Ecosystem Service Indicators and ecosystem accounting in Finland. Ecol. Model. 377, 51–65. https://doi.org/10.1016/j.ecolmodel.2018.03.006.

Lange, S., Campagne, C.S., Comte, A., Bank, E., Santos-Martín, F., Maes, J., Burkhard, B., 2022. Progress on ecosystem accounting in Europe. Ecosyst. Serv. 57, 101473. https://doi.org/10.1016/j.ecoser.2022.101473.

Li, X., Gong, S., Shi, Q., Fang, Y., 2023. A review of Ecosystem Services based on Bibliometric Analysis: Progress, challenges, and Future Directions. Sustainability 15 (23), 16277. https://doi.org/10.3390/su152316277.

Li, Y., Mei, B., Linhares-Juvenal, T., 2019. The economic contribution of the world's Forest Sector. Forest Policy Econ. 100, 236–253. https://doi.org/10.1016/j.forpol.2019.01.004.

Liao, Z., Zhou, B., Zhu, J., Jia, H., Fei, X., 2023. A critical review of methods, principles and progress for estimating the gross primary productivity of terrestrial ecosystems. Front. Environ. Sci. 11. https://doi.org/10.3389/fenvs.2023.1093095.

Ma, Y., Yang, J., 2025. A review of methods for quantifying Urban Ecosystem Services. Landsc. Urban Plan. 253, 105215. https://doi.org/10.1016/j.landurbplan.2024.105215.

Maes, J., 2016. Mapping and Assessment of Ecosystems and their Services. European Commission, JRC103530.

Maes, J., Bruzón, A.G., Barredo, J.I., Vallecillo, S., Vogt, P., Rivero, I.M., Santos-Martín, F., 2023. Accounting for forest condition in Europe based on an international statistical standard. Nat. Commun. 14 (1). https://doi.org/10.1038/s41467-023-39434-0.

Maes, J., Driver, A., Czúcz, B., Keith, H., Jackson, B., Nicholson, E., Dasoo, M., 2020. A review of Ecosystem Condition Accounts: Lessons learned and options for further development. One Ecosyst. 5. https://doi.org/10.3897/oneeco.5.e53485.

Martini, F., Conroy, K., King, E., Farrell, C.A., Kelly-Quinn, M., Obst, C., Buckley, Y.M., Stout, J.C., 2024. A capacity index to connect ecosystem consition to ecosystem accounts. Ecol. Ind. 167, 112731. https://doi.org/10.1016/j.ecolind.2024.112731.

McMahon, J.M., Hasan, S., Brooks, A., Curwen, G., Dyke, J., Ange, C.S., Smart, J.C.R., 2022. Challenges in modelling the sediment retention ecosystem service to inform an ecosystem account – examples from the Mitchell catchment in Northern Australia. J. Environ. Manage. 314, 115102. https://doi.org/10.1016/j.jenvman.2022.115102.

Mengist, W., Soromessa, T., Feyisa, G.L., 2020. A global view of regulatory ecosystem services: Existed knowledge, trends, and research gaps. Ecol. Process. 9 (1). https://doi.org/10.1186/s13717-020-00241-w.

Mengo, E., Grilli, G., Luisetti, T., Conejo Watt, H., Harper Jones, C., Posen, P., 2022. Marine and coastal accounts for Small Island developing States: a case study and application in Grenada. One Ecosyst. 7. https://doi.org/10.3897/oneeco.7.e84865.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Wellbeing: Synthesis. In: Ecosystems, vol. 5. Island Press. https://doi.org/10.1196/annals.1439.003.

Niedzwiedz, A., Montagné-Huck, C., 2014. Past, present, and future of Forest Accounting: an overview of the French experience. Ann. For. Sci. 72 (1), 1–7. https://doi.org/10.1007/s13595-014-0410-4.

Normyle, A., Doran, B., Vardon, M., Mathews, D., Melbourne, J., Althor, G., 2022. An indigenous perspective on ecosystem accounting: challenges and opportunities revealed by an Australian case study. Ambio 51 (11), 2227–2239. https://doi.org/10.1007/s13280-022-01746-8.

O'Grady, A.P., Smith, G.S., Ascui, F., Pinkard, E.A., 2020. The rise and rise of natural capital: what role for forestry? Aust. For. 83 (3), 103–106. https://doi.org/10.1080/00049158.2020.1820653.

Ochuodho, T.O., Alavalapati, J.R.R., 2016. Integrating natural capital into system of National Accounts for Policy Analysis: an application of a computable general equilibrium model. Forest Policy Econ. 72, 99–105. https://doi.org/10.1016/j.forpol.2016.06.020.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., Moher, D., 2021. The Prisma 2020 statement: an updated guideline for reporting systematic reviews. BMJ. https://doi.org/10.1136/bmj.n71.

Parkhurst, T., Standish, R.J., Prober, S.M., Kobryn, H., Vardon, M., 2024. Balancing the books of nature by accounting for ecosystem condition following ecological restoration. Sci. Rep. 14 (1). https://doi.org/10.1038/s41598-024-62137-5.

Paul, C., Hanley, N., Meyer, S.T., Fürst, C., Weisser, W.W., Knoke, T., 2020. On the functional relationship between biodiversity and economic value. Sci. Adv. 6 (5). https://doi.org/10.1126/sciadv.aax7712.

Peng, J., Xia, P., Liu, Y., Xu, Z., Zheng, H., Lan, T., Yu, S., 2023. Ecosystem Services Research: from Golden Era to next crossing. Trans. Earth, Environ., Sustainability 1 (1), 9–19. https://doi.org/10.1177/2754124x231165935.

Pereira, P., Inácio, M., Pinto, L., Kalinauskas, M., Bogdzevic, K., Zhao, W., 2024. Mapping Ecosystem Services in urban and Peri–urban areas. A Systematic Review. Geograp. Sustain. 5 (3), 491–509. https://doi.org/10.1016/j.geosus.2024.06.002.

Pereira, P., Inacio, M., Barcelo, D., Zhao, W., 2025. Ecosystem services mapping and modelling. where is the model's validation? Geogr. Sustainability 6, 100286. https://doi.org/10.1016/j.geosus.2025.100286.

Perevochtchikova, M., la Mora-De, D.e., la Mora, G., Hernández Flores, J.Á., Marín, W., Langle Flores, A., Ramos Bueno, A., Rojo Negrete, I.A., 2019. Systematic review of Integrated Studies on functional and thematic ecosystem services in Latin America, 1992–2017. Ecosyst. Serv. 36, 100900. https://doi.org/10.1016/j.ecoser.2019.100900.

Petersen, J.-E., Mancosu, E., King, S., 2022. Ecosystem extent accounts for Europe. Ecosyst. Serv. 57, 101457. https://doi.org/10.1016/j.ecoser.2022.101457.

Piikki, K., Wetterlind, J., Söderström, M., Stenberg, B., 2021. Perspectives on validation in digital soil mapping of continuous attributes—a review. Soil Use Manag. 37 (1), 7–21. https://doi.org/10.1111/sum.12694.

Pinto, L.V., Inácio, M., Ferreira, C.S., Ferreira, A.D., Pereira, P., 2022. Ecosystem Services and wellbeing dimensions related to urban green spaces – a systematic review. Sustain. Cities Soc. 85, 104072. https://doi.org/10.1016/j.scs.2022.104072.

Rau, A.-L., von Wehrden, H., Abson, D.J., 2018. Temporal Dynamics of Ecosystem Services. Ecol. Econ. 151, 122–130. https://doi.org/10.1016/j.ecolecon.2018.05.009.

Rendon, P., Erhard, M., Maes, J., Burkhard, B., 2019. Analysis of trends in mapping and assessment of ecosystem condition in Europe. Ecosyst. People 15 (1), 156–172. https://doi.org/10.1080/26395916.2019.1609581.

Saah, D., Tenneson, K., Matin, M., Uddin, K., Cutter, P., Poortinga, A., Nguyen, Q.H., Patterson, M., Johnson, G., Markert, K., Flores, A., Anderson, E., Weigel, A., Ellenberg, W.L., Bhargava, R., Aekakkararungroj, A., Bhandari, B., Khanal, N., Housman, I.W., Chishtie, F., 2019. Land cover mapping in data scarce environments: challenges and opportunities. Front. Environ. Sci. 7. https://doi.org/10.3389/fenvs.2019.00150.

Sangha, K.K., Gordon, I.J., Costanza, R., 2022. Ecosystem Services and human wellbeing-based approaches can help transform our economies. Front. Ecol. Evol. 10. https://doi.org/10.3389/fevo.2022.841215.

Schenau, S., van Berkel, J., Bogaart, P., Blom, C., Driessen, C., de Jongh, L., de Jong, R., Horlings, E., Mosterd, R., Hein, L., Lof, M., 2022. Valuing ecosystem services and ecosystem assets for the Netherlands. One Ecosyst. 7. https://doi.org/10.3897/oneeco.7.e84624.

Scheufele, G., Pascoe, S., 2023. Ecosystem Accounting: Reconciling Consumer surplus and exchange values for free-access recreation. Ecol. Econ. 212, 107905. https://doi.org/10.1016/j.ecolecon.2023.107905.
Schröter, M., Crouzat, E., Hölting, L., Massenberg, J., Rode, J., Hanisch, M., Kabisch, N., Palliwoda, J., Priess, J.A., Seppelt, R., Beckmann, M., 2020. Assumptions in ecosystem service assessments: increasing transparency for conservation. Ambio 50 (2), 289–300. https://doi.org/10.1007/s13280-020-01379-9.
Sink, K.J., Lombard, A.T., Attwood, C.G., Livingstone, T., Grantham, H., Holness, S.D., 2023. Integrated systematic planning and adaptive stakeholder process support a 10-fold increase in South Africa's Marine Protected Area Estate. Conserv. Lett. 16 (4). https://doi.org/10.1111/conl.12954.
Smit, K.P., Bernard, A.T.F., Lombard, A.T., Sink, K.J., 2021. Assessing Marine Ecosystem Condition: a review to support indicator choice and framework development. Ecol. Ind. 121, 107148. https://doi.org/10.1016/j.ecolind.2020.107148.
Smit, K.P., Van Niekerk, L., Harris, L.R., McQuatters-Gollop, A., Shannon, L.J., Sink, K.J., 2022. A roadmap to advance marine and Coastal monitoring, Biodiversity Assessment, and international reporting: a developing nation perspective. Front. Mar. Sci. 9. https://doi.org/10.3389/fmars.2022.886373.
Sousa, M.C., Martins, R., Simões, N.E., Feio, M.J., 2024. Ecosystem Services of Urban Rivers: a systematic review. Aquat. Sci. 87 (1). https://doi.org/10.1007/s00027-024-01138-y.
Stahmer, C., 1993. System for Integrated Environmental and Economic Accounting (SEEA) of the United Nations. In: Franz, A., Stahmer, C. (Eds.), Approaches to Environmental Accounting. Contributions to Economics. Physica, Heidelberg. https://doi.org/10.1007/978-3-642-49977-7_28.
Sutherland, I.J., Gergel, S.E., Bennett, E.M., 2016. Seeing the forest for its multiple ecosystem services: Indicators for cultural services in heterogeneous forests. Ecol. Ind. 71, 123–133. https://doi.org/10.1016/j.ecolind.2016.06.037.
Sylla, M., 2024. The application of ecosystem accounting principles at the local scale for a protected landscape: a case study of the sleza landscape park in Poland. Ecosyst. Serv. 66, 101604. https://doi.org/10.1016/j.ecoser.2024.101604.
Syrbe, R.-U., Grunewald, K., 2017. Ecosystem Service Supply and demand – the challenge to balance spatial mismatches. Int. J. Biodivers. Sci., Ecosyst. Serv. Manage. 13 (2), 148–161. https://doi.org/10.1080/21513732.2017.1407362.
Taljaard, S., Van Niekerk, L., Adams, J.B., Riddin, T., 2023. Advancing ecosystem accounting in Estuaries: Swartkops estuary case study. S. Afr. J. Sci. 119 (3/4). https://doi.org/10.17159/sajs.2023/14303.
Tanács, E., Bede-Fazekas, Á., Csecserits, A., Kisné Fodor, L., Pásztor, L., Somodi, I., Standovár, T., Zlinszky, A., Zsembery, Z., Vári, Á., 2022. Assessing ecosystem condition at the national level in Hungary - indicators, approaches, challenges. One Ecosyst. 7. https://doi.org/10.3897/oneeco.7.e81543.
Tandarić, N., Ives, C.D., Watkins, C., 2020. Can we plan for urban cultural ecosystem services? J. Urban Ecol. 6 (1). https://doi.org/10.1093/jue/juaa016.
Tao, W., Guang-shun, H., Li-jing, D., Rui, Z., Lu, Y., Yue, Y., 2021. The Framework Design and empirical study of China's Marine Ecological-Economic Accounting. Ecol. Ind. 132, 108325. https://doi.org/10.1016/j.ecolind.2021.108325.
Tinch, R., Beaumont, N., Sunderland, T., Ozdemiroglu, E., Barton, D., Bowe, C., Börger, T., Burgess, P., Cooper, C.N., Faccioli, M., Failler, P., Gkolemi, I., Kumar, R., Longo, A., McVittie, A., Morris, J., Park, J., Ravenscroft, N., Schaafsma, M., Ziv, G., 2019. Economic Valuation of Ecosystem Goods and services: a review for decision makers. J. Environ. Econ. Policy 8 (4), 359–378. https://doi.org/10.1080/21606544.2019.1623083.
Traganos, D., Lee, C.B., Blume, A., Poursanidis, D., Čižmek, H., Deter, J., Mačić, V., Montefalcone, M., Pergent, G., Pergent-Martini, C., Ricart, A.M., Reinartz, P., 2022. Spatially explicit seagrass extent mapping across the entire Mediterranean. Front. Mar. Sci. 9. https://doi.org/10.3389/fmars.2022.871799.
UNCEEA, 2022. Global Assessment of Environmental-Economic Accounting and Supporting Statistics 2022, available at: https://seea.un.org/sites/seea.un.org/files/global_assessment_2022_background_doc_v4_clean_1.pdf.
UNEP-WCMC, 2022. Urban Ecosystem Accounting: Concepts and implementation (https://resources.unep-wcmc.org/products/WCMC_PR023) (Handbook 1) UNEP-WCMC (2022) Urban Ecosystem Accounting: Applications (https://resources.unep-wcmc.org/products/WCMC_PR023) (Handbook 2).
United Nations, 2010. System of national accounts 2008. Studies in Methods (Ser. F). https://doi.org/10.18356/4fa11624-en.
United Nations, 2014a. System of Environmental-Economic Accounting 2012 - Central Framework. The United Nations, New York, USA, ISBN 978-92-1-055926-3, pp. 1–378.
United Nations, 2014b. System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting. The United Nations, New York, USA, ISBN 978-92-1-056285-0, pp. 1–198.
United Nations, 2015. Transforming our world: the 2030 Agenda for Sustainable Development. NY, USA, United Nations, New York.
United Nations, 2021. System of Environmental-Economic Accounting-Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. Available at: https://seea.un.org/ecosystem-accounting.
United Nations, 2022. Guidelines on Biophysical Modelling for Ecosystem Accounting. United Nations Department of Economic and Social Affairs, Statistics Division, New York.
UNSD, 2020. Using the SEEA EA for Calculating Selected SDG Indicators. United Nations Statistics Division, Department of Economic and Social Affairs, New York.
Urbina-Cardona, N., Cardona, V.O., Cuellar, S., 2023. Uncovering thematic biases in ecosystem services mapping: Knowledge shortfalls and challenges for use in conservation. Biol. Conserv. 283, 110086. https://doi.org/10.1016/j.biocon.2023.110086.
Vallecillo, S., Maes, J., Teller, A., Babí Almenar, J., Barredo, J.I., Trombetti, M., Abdul Malak, D., Paracchini, M.L., Carré, A., Addamo, A.M., Czúcz, B., Zulian, G., Marando, F., Erhard, M., Liquete, C., Romao, C., Polce, C., Pardo Valle, A., Jones, A., Zurbaran-Nucci, M., Nocita, M., Vysna, V., Cardoso, A.C., Gervasini, E., Magliozzi, C., Baritz, R., Barbero, M., Andre, V., Kokkoris, I.P., Dimopoulos, P., Kovacevic, V., Gumbert, A., 2022. EU-wide methodology to map and assess ecosystem condition: Towards a common approach consistent with a global statistical standard. Publications Office of the European Union, Luxembourg, JRC130782. https://doi.org/10.2760/13048.
Vardon, M., May, S., Keith, H., Burnett, P., Lindenmayer, D., 2019. Accounting for ecosystem services – lessons from Australia for its application and use in Oceania to achieve sustainable development. Ecosyst. Serv. 39, 100986. https://doi.org/10.1016/j.ecoser.2019.100986.
Vargas, L., Hein, L., Remme, R.P., 2017. Accounting for ecosystem assets using remote sensing in the colombian orinoco river basin lowlands. J. Appl. Remote Sens. 11 (2), 026008. https://doi.org/10.1117/1.jrs.11.026008.
Venter, Z.S., Czúcz, B., Stange, E., Nowell, M.S., Simensen, T., Immerzeel, B., Barton, D. N., 2024. 'Uncertainty audit' for ecosystem accounting: Satellite-based ecosystem extent is biased without design-based area estimation and accuracy assessment. Ecosyst. Serv. 66, 101599. https://doi.org/10.1016/j.ecoser.2024.101599.
Villamagna, A.M., Angermeier, P.L., Bennett, E.M., 2013. Capacity, pressure, demand, and flow: a conceptual framework for analysing ecosystem service provision and delivery. Ecol. Complex. 15, 114–121. https://doi.org/10.1016/j.ecocom.2013.07.004.
Villasante, S., Lopes, P.F.M., Coll, M., 2016. The role of Marine Ecosystem Services for Human Wellbeing: Disentangling Synergies and trade-offs at multiple scales. Ecosyst. Serv. 17, 1–4. https://doi.org/10.1016/j.ecoser.2015.10.022.
Visintin, F., Tomasinsig, E., Spoto, M., Marangon, F., D'Ambrosio, P., Muscogiuri, L., Fai, S., Troiano, S., 2022. Assessing the Benefit Produced by Marine Protected areas: the Case of Porto Cesareo Marine Protected Area (Italy). Sustainability 14 (17), 10698. https://doi.org/10.3390/su141710698.
Vysna, V., Maes, J., Petersen, J.E., La Notte, A., Vallecillo, S., Aizpurua, N., Ivits, E., Teller, A., 2021. Accounting for ecosystems and their services in the European Union (INCA). Final report from phase II of the INCA project aiming to develop a pilot for an integrated system of ecosystem accounts for the EU. Statistical report. Publications office of the European Union, Luxembourg.
Wang, L., Jia, M., Yin, D., Tian, J., 2019. A review of remote sensing for mangrove forests: 1956–2018. Remote Sens. Environ. 231, 111223. https://doi.org/10.1016/j.rse.2019.111223.
Willcock, S., Hooftman, D.A., Balbi, S., Blanchard, R., Dawson, T.P., O'Farrell, P.J., Hickler, T., Hudson, M.D., Lindeskog, M., Martinez-Lopez, J., Mulligan, M., Reyers, B., Shackleton, C., Sitas, N., Villa, F., Watts, S.M., Eigenbrod, F., Bullock, J. M., 2019. A continental-scale validation of Ecosystem Service models. Ecosystems 22 (8), 1902–1917. https://doi.org/10.1007/s10021-019-00380-y.
Winkler, K., Fuchs, R., Rounsevell, M., Herold, M., 2021. Global land use changes are four times greater than previously estimated. Nat. Commun. 12 (1). https://doi.org/10.1038/s41467-021-22702-2.
Wyborn, C., Louder, E., Harrison, J., Montambault, J., Montana, J., Ryan, M., Bednarek, A., Nesshöver, C., Pullin, A., Reed, M., Dellecker, E., Kramer, J., Boyd, J., Dellecker, A., Hutton, J., 2018. Understanding the impacts of research synthesis. Environ. Sci. Policy 86, 72–84. https://doi.org/10.1016/j.envsci.2018.04.013.
Zhang, C., Li, X., 2022. Land use and land cover mapping in the era of big Data. Land 11 (10), 1692. https://doi.org/10.3390/land11101692.