D4.1 Systematic review of ecosystem assessment model uptake for decision-support

29/12/23

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Funded by the European Union

SELINA receives funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060415. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the EU nor the EC can be held responsible for them.

Prepared under contract from the European Commission
Grant agreement No. 101060415
EU Horizon 2020 Research and Innovation Actions

Project acronym:	**SELINA**
Project full title:	**Science for Evidence-based and sustainabLe decIsions about NAtural capital**
Project duration:	01.07.2022 – 30.06.2027 (60 months)
Project coordinator:	Prof Dr Benjamin Burkhard, Gottfried Wilhelm Leibniz University Hannover
Call:	HORIZON-CL6-2021-BIODIV-01
Deliverable title:	Systematic review of ecosystem assessment model uptake for decision-support
Deliverable n°:	D4.1
WP responsible:	WP4
Nature of the deliverable:	Report
Dissemination level:	Public
Lead beneficiary:	NINA
Citation:	Barton, D.N., Immerzeel, B. & et al. (2023). SELINA D4.1. Systematic review of ecosystem assessment model uptake for decision-support.
Due date of deliverable:	Month 18
Actual submission date:	Month 18

Deliverable status:

Version	Status	Date	Author(s)	Reviewer
1.0	Draft	01 October 2023	David N. Barton, Bart Immerzeel (NINA)	WS2 break-out session participants
1.1	Draft for Review	05 December 2023	David N. Barton, Bart Immerzeel (NINA), all co-authors	Inge Liekens (VITO), Fernando Santos-Martín (URJC)
1.2	Final	29 December 2023	David N. Barton (NINA)	

1 Preface

The importance of biodiversity, natural capital and healthy ecosystems and the services they supply has increasingly been acknowledged in diverse policy initiatives (e.g., EU Biodiversity Strategies 2020 and 2030, Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), Natural Capital and Ecosystem Services Accounting, Intergovernmental Panel on Climate Change (IPCC) and Convention on Biological Diversity (CBD)).

The EU Horizon Research and Innovation Action "Science for Evidence-based and sustainabLe decIsions about NAtural capital" (SELINA) aims to provide robust information and guidance that can be harnessed by different stakeholder groups to support transformative change in the EU, to halt biodiversity decline, to support ecosystem restoration and to secure the sustainable supply and use of essential Ecosystem Services (ES) in the EU by 2030.

SELINA builds upon the Mapping and Assessment of Ecosystems and their Services (MAES) initiative that has provided the conceptual, methodological, data and knowledge base for comprehensive assessments on different spatial scales, including the EU-wide assessment (Maes, 2020)[1] and assessments in EU member states. Knowledge and data for different ecosystem types are increasingly available.

The overall objective of Work Package (WP) 4 "Ecosystem services mapping and assessment" is to refine the ES knowledge base that is available from prior EU Actions by diagnosing, developing and testing the capabilities of ES assessment approaches, models and indicators that increase the likelihood of uptake in decision-making.

The Deliverable D4.1 "Systematic review of ecosystem assessment model uptake for decision-support" is a manuscript entitled "Increasing uptake of ecosystem service assessments: best practice check-lists for practitioners in Europe" that is submitted to the scientific journal One Ecosystem. It builds upon the review of 111 guidance documents on ES assessments presented in Milestone report M08. The paper summarises factors that have been identified to limit the uptake of ES assessment in the decision-making context. Furthermore, it gives guidance for practitioners on how to improve ES assessments in the future aiming at increasing their robustness and hence likelihood of uptake at different governance levels.

[1] Maes, J., et al. (2020). Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment. Publications Office of the European Union, Luxembourg. DOI:10.2760/757183, JRC120383.

Version: Submission One Ecosystem (Pensoft)

Title: ***Increasing uptake of ecosystem service assessments: best practice check-lists for practitioners in Europe***

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Abstract

Aiming at understanding the role of plural values in decision-making the IPBES Values Assessment defined nature valuation broadly as including biophysical, economic and socio-cultural assessments, including ecosystem service assessment. IPBES reviews of scientific literature revealed a lack of documentation of uptake by stakeholders across method types. At the same time, ES assessments are increasingly used in EU policy, such as an EU regulation on ecosystem accounting. National level ES assessments have been carried out and the number of guidelines for implementation has been growing during the past decade. The EU project SELINA aims to contribute to increasing uptake of ES assessments at different governance levels. The project is undertaking a series of steps to increase the use of guidance in national and local applications by compiling study design recommendations for ES assessments across Europe and then testing them in demonstration projects around Europe. As a first step the project conducted a review of 111 guidance documents on ES assessments covering 12 European languages. Guidance documents were evaluated based on 7 diagnostic topics suggested to increase relevance and robustness of ES assessments: ecosystem condition variables; capacity-potential, supply-demand; spatial scaling and resolution capability; social and health benefit compatibility; economic valuation compatibility and uncertainty assessment. We developed the guidance recommendations across these features into a set of checklists for practitioners and contractors of ES assessments. We discuss possible synergies between these study design features, and gaps in guidance in relation to the policy cycle. Checklists are aimed at projects self-assessing and improving their assessment practice to increase robustness of their ES assessment. From a knowledge supply perspective this is expected to increase the likelihood of uptake of results by stakeholders. However, we end the paper with some cautions on limitations to uptake from different perspectives and the demand of and political uses of ES assessment knowledge.

Keywords

ecosystem condition, social benefits, health benefits, economic valuation, ecosystem accounting, spatial scale, spatial resolution, ecosystem capacity, ecosystem potential, uncertainty

1. Introduction

Mapping and assessment of ecosystem services includes biophysical, socio-cultural and economic techniques (Santos-Martin et al. 2018). With the aim of understanding the role of plural values in decision-making, the IPBES Values Assessment (VA) identified biophysical, monetary and socio-cultural value indicators all as types of valuations of nature (Termansen et al. 2022). The IPBES VA argued that understanding how methods to assess nature, including biophysical assessments, represent different kinds of broad and specific values and value indicators can help explain stakeholders use of different types of knowledge (Pascual et al. 2023).

Two IPBES VA reviews of the scientific literature independently revealed a lack of documentation of uptake across method types, including ES assessments (Barton et al. 2022; Termansen et al. 2022). Several recent reviews of scientific literature on the assessment of ecosystems and their services in the last decade have had similar findings (Chan and Satterfield 2020; Laurans et al. 2013; Mandle et al. 2020; Saarikoski et al. 2018). 'Documented uptake' refers here to scientific publications reporting on use of assessment outputs by stakeholders (Barton et al. 2022). Findings by Laurans et al. (2013) of as little as 2% of economic ecosystem service valuation documenting uptake showed little signs of improvement in the reviews by the IPBES VA a decade later (Barton et al. 2022; Termansen et al. 2023). The IPBES VA identified potential blindspots with regard to legitimacy, credibility, salience, timeliness, process documentation, and study cost to explain lacking uptake of assessments (Barton et al. 2022). In their synthesis of the IPBES VA findings, Pascual et al. (2023) recommend increasing relevance by clearly defining purpose and targeting assessment in relation to stages in the policy cycle.

The findings on uptake from the scientific literature reviews contrasts with recent developments at the EU policy. The EU Biodiversity Strategy for 2030 (EC 2020) calls for developing an EU-wide methodology to map, assess, and achieve good condition of ecosystems, so they can deliver benefits to society through the provision of ecosystem services. (Vallecillo et al. 2022) propose an EU-wide methodology for ecosystem condition building on the Mapping and Assessment of Ecosystems and their Services (MAES) and related integrated framework (B Burkhard and Maes 2017). The MAES framework includes different methods of ES quantification using, biophysical, monetary and social-cultural approaches. The first EU mapping and assessment of ecosystems and their services was conducted in 2020 (EC 2020). Planning is underway for the second EU ecosystem assessment in 2026. MAES were initially carried out for the purpose of generally informing, awareness raising and agenda-setting among the public, in business and government (e.g. Schröter et al., 2016). The policy cycle has evolved during the last decade to MAES increasingly being recognised as supporting EU policy frameworks such as the Biodiversity Strategy and in specific regulation, such as environmental economic accounting and the Nature Restoration Law.

The European Parliament reached an agreement on the EU Nature Restoration Law for a target of restoring 20% of the EUs land and sea by 2030. Some of the law's specific targets refer to indicators of ES (e.g., enhance stock of organic carbon), and others to ecosystem condition variables (e.g., amount of deadwood in forests, no net loss of green space in urban ecosystems by 2030, total increase by 2040). Member states will have to adopt targets in national restoration plans. The implementation of this law will require practitioners guiding EU Member States to do ES assessments that address no net loss and positive gain targets.

Ecosystem services assessment lies at the core of standardisation of ecosystem accounting (UN 2021) in the EU and member states. Recent signs of increased uptake at EU policy level include EUROSTATs collaboration with national statistical offices on a proposal for the amendment of the EU regulation 691/2011 on environmental economic accounts. The amendment covers ecosystem type extent for all

ecosystem types, a selection of condition variables and biophysical ecosystem service accounts to be estimated in selected ecosystem types. User friendly tools and guides for national level implementation of ES models are being developed, such as the INCA Tool (Buchhorn et al. 2022). Key bottlenecks in method implementation have been identified in the SEEA EA research agenda(UN 2021). Legitimacy of national level ecosystem accounts will in part depend on methods being not only robust and resource efficient from the 'knowledge supply side', but also relevant for the 'knowledge demand side' by sub-national and local governance actors.

Burkhard et al. (2018) called for integrated ecosystem assessment linking biophysical assessment to human well-being within complex interlinked Social-Ecological Systems. Their integrated MAES framework proposed nine steps focused on spatially explicit ecosystem types, condition and services mapping that could be used 'to set-up related research and development initiatives and to guide involved scientists, decision-makers and practitioners' (op.cit). The integrated MAES framework recognises that the demand for ES assessment is determined by a complex system, but Burkhard et al. (2018) do not address the detail of what linking to SES entails. Socio-ecological systems (SES) include 'governance systems' and 'actors' acting withing 'social, economic and political settings' (McGinnis and Ostrom 2014). Assessment of ecosystem services in social ecological systems, faces challenges to uptake as does valuation of nature more broadly (Barton et al. 2022). The plural valuation approach of the IPBES VA can complement biophysical ES assessment in the MAES framework, by recognising biophysical metrics as one set of values and designing an assessment process that also recognises stakeholders other plural values (Pascual et al. 2023; Termansen et al. 2023).

This paper aims to strengthen the recent trend in increased uptake at EU level by collating guidance for sub-national applications. It aims to identify common ecosystem service assessment design recommendations intended to increase uptake. The IPBES VA reviews of uptake of nature valuation (Barton et al. 2022; Termansen et al. 2023) did not address "grey" literature, such as guidance documents. This paper addresses this gap by reviewing best practice recommendations in guidance documents in different European languages, which were evaluated based on selected diagnostic topics, as described in Section 2. Based on the review we formulate a sets of checklist questions to support practitioners in carrying out a diagnostic of ES assessments. In order to identify blindspots in these recommendations we also evaluate the checklist questions in relation to their relevance for different steps of a policy cycle, and compare them to the IPBES VA 5-step framework for plural valuation (Termansen et al. 2023). The paper is part of ongoing work in the EU project SELINA (https://project-selina.eu/) to develop guidance for the project's ES assessment demonstration projects in partner countries.

2. Identifying diagnostic topics to improve uptake of ES assessments

In this section we describe how we develop the MAES framework and its integration with social-ecological systems through 7 diagnostic topics. The diagnostic topics are also aim at increase likelihood of uptake by improving robustness and relevance from the 'knowledge supply side'. The diagnostic topics aim to strengthen both the biophysical assessment 'core' of the MAES approach, as well as deepen its plural valuation characteristics to better link to different dimensions of welfare in SES:

Strengthening biophysical ecosystem service assessment:

1. **Spatial resolution and scaling capability of assessments**. At the core of the MAES framework is mapping of extent, condition and ecosystem service at compatible scales and resolutions with available data (e.g. Andrew et al., 2015; Frank and Burkhard, 2017; Martínez-López et al., 2019).

It involves determining the appropriate spatial scale and resolution at which ecosystem services should be assessed to ensure accuracy and relevance. In practical terms, high spatial resolution allows for more detailed and precise mapping of ecosystem services, which is essential for localized planning and management. Conversely, broader scaling capabilities enable the integration of local data into larger frameworks, aiding in regional or national policy development and decision-making. The challenge lies in balancing the need for detailed local data with the broader perspective required for large-scale environmental management

2. **Ecosystem condition in ecosystem service assessment**. Ecosystem service assessments have the potential to be more relevant and robust by being sensitive to changes in both ecosystem extent and condition (e.g. Broszeit et al., 2017; Bruins et al., 2017; Kim et al., 2023). This aspect of ecosystem service assessment emphasizes the importance of evaluating the condition or health of ecosystems as a critical factor in understanding and quantifying the services they provide. Ecosystem condition refers to the quality and functionality of an ecosystem, which directly impacts its ability to deliver ES. Considering ecosystem condition in ecosystem service assessments provides a more holistic and accurate understanding of the capacity of ecosystems to deliver services.
3. **Identifying ecosystem service capacity, potential, supply-use and demand** is recommended to understand mismatches between supply and demand, assess sustainability of use and determine the lifetime of ecosystems as assets in accounting (e.g. Dworczyk and Burkhard, 2021; Hein et al., 2016). This aspect of ES assessment focuses on quantifying and understanding the actual usage and demand by human societies. Each component plays a vital role in sustainable ecosystem management and policy-making. Balancing these aspects is essential for understanding and managing the mismatches between what ecosystems can sustainably offer (capacity and potential) and what is required or desired by human populations (demand). By identifying these disparities, decision-makers can implement strategies to ensure sustainable usage, protect ecosystem condition, and maintain the long-term viability of ecosystem services**.**
4. **Uncertainty documentation** in all steps of assessment of ecosystem services aims at communicating robustness, increasing stakeholder trust, an uptake of results in policy (e.g. Bryant et al., 2018; Hamel and Bryant, 2017; Hou et al., 2013; Lautenbach et al., 2019; Schulp and Landuyt, 2017). Uncertainty in ecosystem service assessments can arise from various sources, including data limitations (e.g., gaps in data, variability in data quality), model uncertainties (e.g., assumptions, simplifications), and inherent variability in ecological systems. It can also stem from socio-economic factors, such as changing land-use patterns or economic fluctuations. Methods to document and address uncertainty include statistical analysis, scenario planning, sensitivity analysis, and using a range of models or approaches to cross-verify results. Moreover, clearly communicating these uncertainties, both in scientific publications and in more accessible formats for policymakers and the public, is key to ensuring that the findings of ecosystem service assessments are understood and used appropriately.

<u>Strengthening plural valuation:</u>

5. **Compatibility of ES assessment with economic valuation** has been a persistent challenge (Boyd et al. 2015) and is in focus in operationalising ecosystem accounting (NCAVES and MAIA 2022). Economic valuation methods that are sensitive to both ecosystem service and condition metrics are expected to be more valid and reliable in value transfer for multiple decision support applications (Grammatikopoulou et al. 2023; Johnston et al. 2021)
6. **Compatibility with social benefits and justice assessment** will make ES assessments more relevant for local communities and by addressing justice issues such as unequal access to services

can facilitate more inclusive and legitimate assessment processes (e.g. Calderón-Argelich et al., 2021; Gould et al., 2020; Loos et al., 2023; Schaafsma et al., 2023)

7. **Compatibility with health benefit assessment** further extends ES assessments relevance for human welfare (e.g. Oosterbroek et al., 2016; Remme et al., 2021). Demonstrating human health impacts of ecosystem degradation is also a strategy for mobilizing wider sector policy support for values of nature (Pascual et al. 2023)

3. Methods and materials

In this section we first describe the materials of the guidance document review, and then describe the IPBES Values Assessment policy cycle and 5 steps of plural valuation used to further classify the diagnostic topic checklists.

3.1 Materials

The assessed guidance documents were chosen because they describe current best practices and advised methods for ES assessment in Europe. Guidance documents can be reports resulting from research projects, official policy documents for national assessments, instruction manuals written for specific management programs or for a range of other applications. However, one common factor is that there is no common repository for these. Therefore, the review team collected documents by using expert knowledge on the latest state-of-the-art in using ES assessment for supporting European policy and decision making. Experts were from 50 project partners in the EU SELINA project in 27 member state and Norway, Switzerland, the UK and Israel. During the document collection period, SELINA members could submit any document they considered a relevant guidance document and, based on scanning the document, marked them for relevance for each of the diagnostic topics. The following requirements were placed on whether a document was relevant for the review:

- The document ideally should not be published before 2018.
- The document could be in any of the languages of SELINA partners.
- The document must address at least one of the diagnostic topics as described in Table 1 in the context of ES assessment.

122 documents were collected for review. These were written in either English, Bulgarian, Croatian, Danish, Dutch, Estonian, French, German, Hungarian, Norwegian, Polish or Swedish. Five of the documents were unavailable for download and six were not guidance documents but peer-reviewed scientific publications, leaving 111 guidance documents to be distributed among the diagnostic topic groups for review. Each document could be marked as relevant for multiple topics, leading to a final number of reviewed documents per topic as shown in Table 1. For a full overview of all 111 documents included in the review, see Supplement S8.

Table 1 Distribution of guidance documents for review across diagnostic topics

Diagnostic topic	Number of documents reviewed
Spatial scaling and resolution capabilities	74
Ecosystem condition variables in ES models	59
Capacity, potential & actual supply, use, demand	80
Economic valuation compatibility	56
Social benefit compatibility and dimensions of justice	48
Health benefit compatibility	44

Each diagnostic topic was assessed independently by groups of 5-7 co-authors. Each diagnostic topic group developed a survey in Google Forms for reviewing the documents. For each diagnostic topic these surveys aimed to cover to what extent it was addressed in the guidance document, how it defined the topic, and to what extent the guidance was specific to certain stages of the policy cycle (section 3.2).

All groups summarised their findings into a working paper (Immerzeel et al., 2023). Each review team for diagnostic topics reworked the recommendations in the working paper into one checklist of questions per diagnostic topic. The checklist questions were classified into one of the 5 plural valuation steps by each review team (section 3.3). Each recommendation checklist was collated to provide an overview of thematic coverage across the assessment steps and the relative knowledge gaps across steps. The review teams discussed potential knowledge gaps in the guidance documents from their perspectives as ES assessment practioners. These knowledge gaps were then formulated as additional batteries of checklist questions. Each group formulated hypotheses about linkages and synergies between the 7 diagnostic topics in ES assessment – linkages are visualised in a network diagram. Finally, limitations and potential for testing in real world use cases was discussed by each group. Narratives of each review team's approach can be found in Supplements S1-S7.

3.2 Methods – policy cycle framework

We also assess the extent to which EU guidance documents cover different 'political settings' defined here by stages in a *policy cycle* (IPBES 2022; Pascual et al. 2023). Step of the policy cycle are defined as (1) aiding agenda setting and support to agreed goals; (2) providing technical assistance for policy formulation by, for example, agreeing on the alternatives under consideration, or the design of economic incentives, such as payments for ecosystem services (PES); (3) supporting decisions for policy adoption and assessing cost-effectiveness of alternatives for policy action; (4) facilitating adjustments to implementation measures or budget allocations; and (5) helping undertake retrospective policy evaluation (Pascual et al. 2023). Did ES assessment guidance favour any particular stage of the cycle? We classified recommendations in the guidance documents in relation to the above stages of the policy cycle (**Figure 1**).

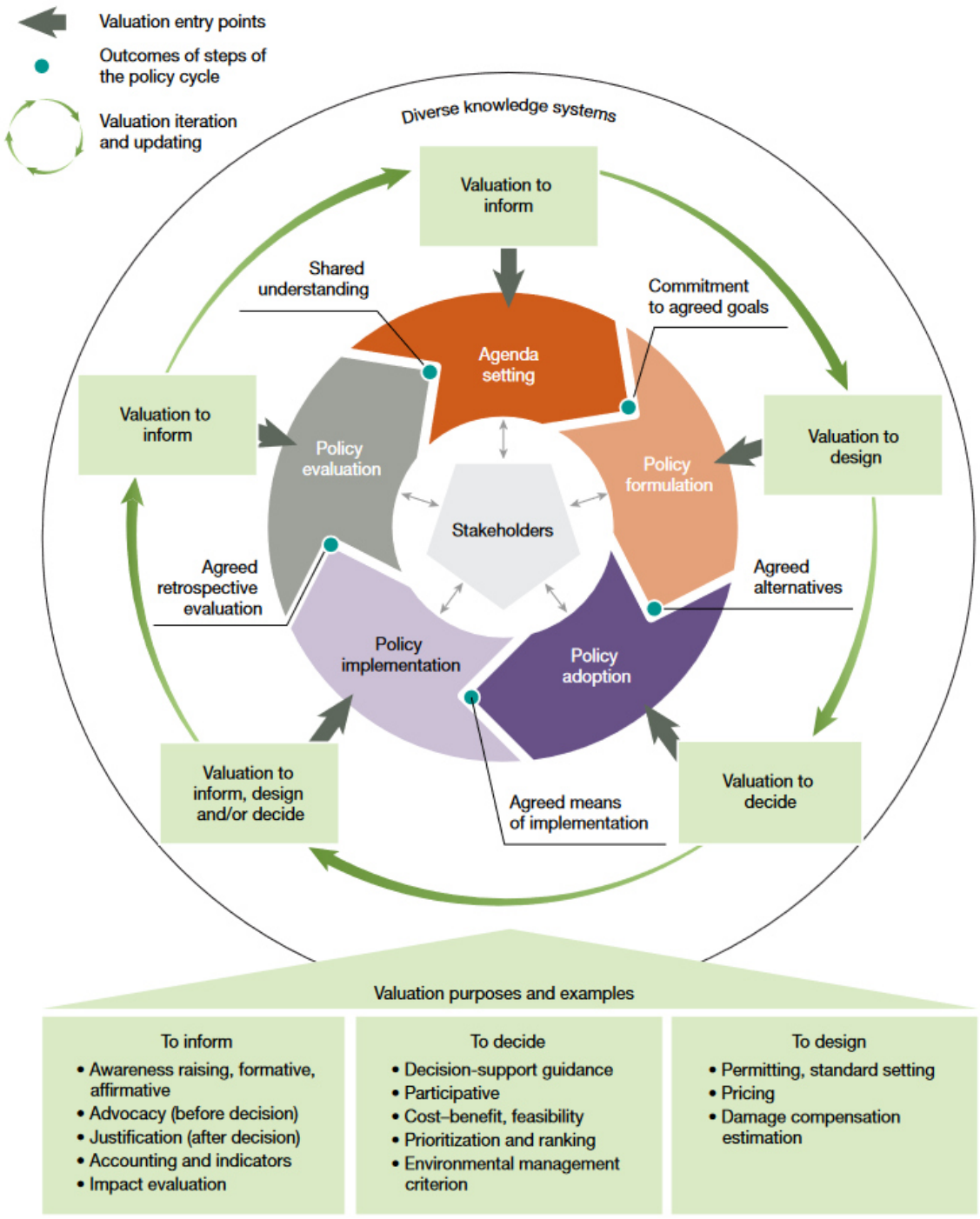

Figure 1 Policy cycle and potential entry points for uptake of ES assessments. Source: Pascual et al. 2023 .

In principle the recommendations and checklist questions could be applied at any time during a policy cycle, but certain study design features are more important than others depending on when and the kind of policy support needed at that time. Review teams screened all the diagnostic topics according to the frequency by which recommendations could be associated with a particular policy cycle stage. In the results section we report the 1st and 2nd most frequently cited policy stages by the guidance documents. This coarse scanning of guidance documents provides a sketch of where the strength of guidance for ES assessment currently lies.

3.3 Methods - plural valuation framework

The review of guidance documents sorted recommendations into the 7 'diagnostic' topics. These were reformulated to a series of checklists for ES assessment practitioners and commissioners. The aim of checklists is to support a practitioner who has a preselection of methods under consideration and/or is designing their implementation. Before the final study design and data collection, the practitioner wants to do a check of whether the valuation process has the characteristics likely to increase uptake. During a study, practitioners may also wish to conduct an internal audit of their study process to check progress against planned study design. The use of checklists can also make it easier for external parties to question and if necessary, contest the study, thereby increasing legitimacy and potential for uptake. In the case of a commissioner of an ecosystem service assessment, the checklist can serve as a guide to doing a "due diligence" evaluation of terms of reference for a study, before putting it out for tender.

Do our checklist questions for each diagnostic topic address plural valuation recommendations? Drawing from the IPBES Values Assessment, Termansen et al. (2023) recommend a 5-step valuation framework to embed plural values in decision-making (**Figure 2**).

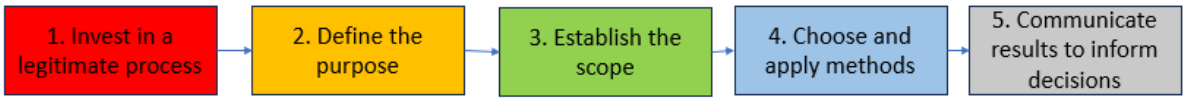

Figure 2. General IPBES 5-step valuation framework to be applied to ES assessment. *Source: based on Termansen et al. (2023)*

The 7 diagnostic topics can potentially contribute to strengthening ES assessment in any of the five steps. We used the following definitions of the plural valuation steps to further classify the checklist questions:

(1) **Invest in a legitimate process**, to ensure that the providers of assessment information are explicitly defined, and that there is transparency in the robustness of the assessment, particularly regarding representativeness and participation.

(2) **Define the purpose with stakeholders**, with certain societal goals and decision-making purposes.

(3) **Establish the scope**, identifying which metrics will be explored or addressed by the assessment. IPBES VA emphasises that different ecosystem service assessment metrics represent different value types.

(4) **Choose and apply methods**, that realise, recognise and represent the full extent of value diversity entailed by the purpose.

(5) **Communicate results to inform decisions**, with effective and transparent communication, that is also an honest reflection of the limitations and omissions of the assessment process.

4. Results of the guidance document review

In this section we first present an overview of the coverage of ES assessment guidance documents of the policy cycle. Second we present the checklist questions for each diagnostic topic derived from the guidance documents, and classify them according to plural valuation steps.

4.1 Guidance coverage of the policy cycle.

The policy cycle stages best covered by guidance are agenda setting, policy formulation and policy implementation. The least covered are policy evaluation and policy adoption. Supporting choice between options and evaluating those choices are forms of decision-support. Broadly speaking, ES assessment guidance literature is the least rich in terms of ex ante supporting choice between policy options and ex post evaluating the outcomes of those options. This relative knowledge gap was also reflected by the IPBES VA review finding that a majority of nature valuation studies made only cursory reference to their relevance for decision-support (Barton et al. 2022).

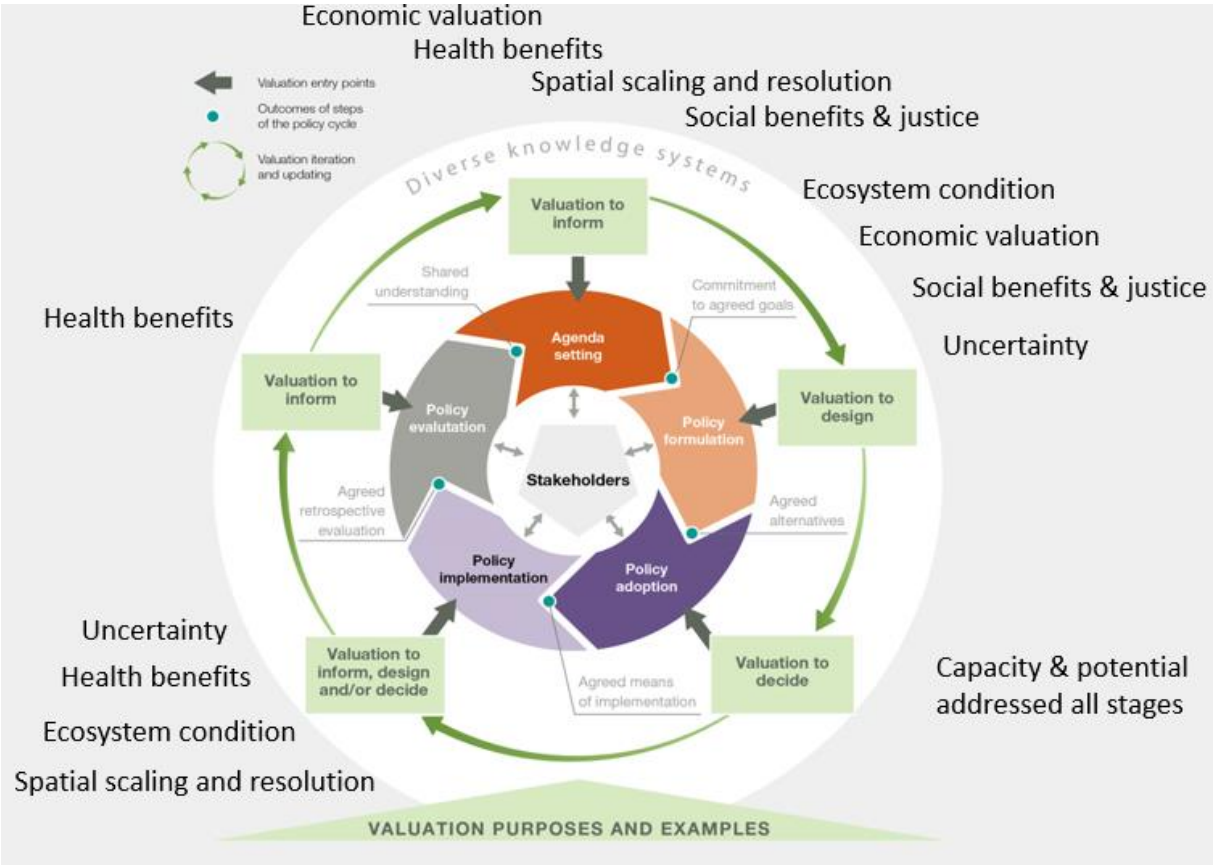

Figure 3. Policy cycle stages with best coverage in ES guidance. *Note: diagnostic topics are assigned to the policy cycle stage at which they were referred to 1st and 2nd most frequently in the guidance review by Immerzeel et al. 2023. Source: adapted from Pascual et al. 2023 .*

4.2 Diagnostic check lists

The results of the grey literature review are presented as a series of checklists for practitioners covering the 7 ES assessment diagnostic topics. The full-length checklists can be found in Supplementary Material S1-S7. In next steps the checklists will be tested and validated in real world ES applications within the EU SELINA project. Validation will entail researchers and stakeholders in each application

case determining testing whether the checklist questions identify assessment design features that are likely to increase uptake. The validation of these checklists is beyond the scope of this paper.

Figure 4 visualises this two-dimensional classification – there is a variable number of questions per diagnostic topic, as derived from the guidance document review. The number of checklist questions per diagnostic topic presents the relative richness of recommendations in the guidance documents reviewed. Note that the relative number of checklist questions *is not* proportional to the number of guidance documents that were reviewed per topic (**Table 1**). For example, the smallest number of guidance questions was derived from the topic with the largest number of documents reviewed (capacity-potential[..]), whereas the topic with smallest number of reviewed documents resulted in a comprehensive checklist (uncertainty documentation).

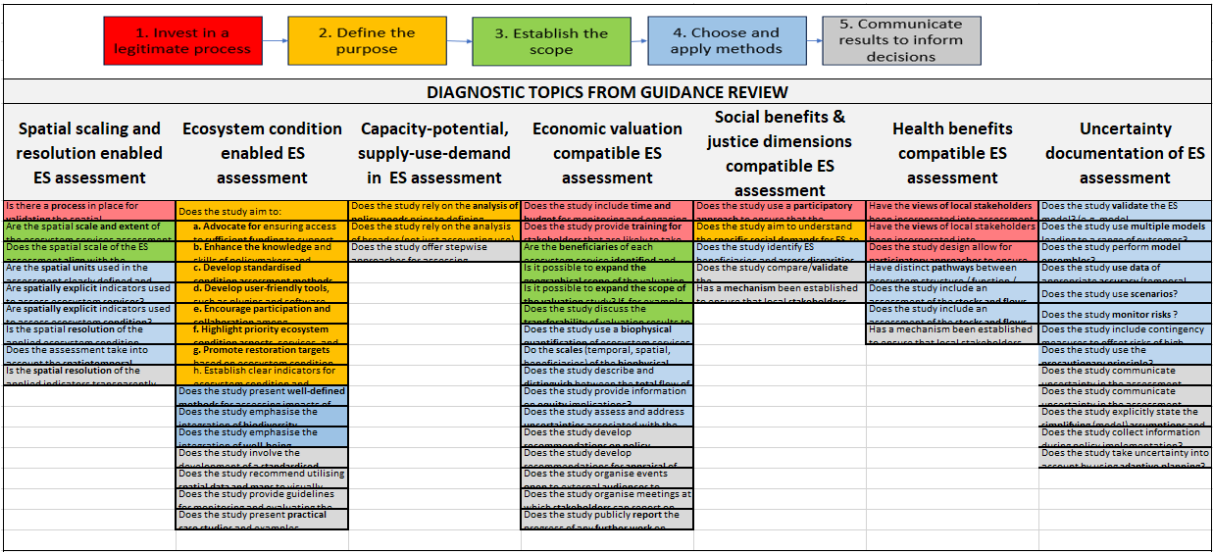

***Figure 4* Checklist questions per diagnostic topic (columns) from the guidance document review, classified by plural valuation steps (colour coding).** *For illustrative purposes the small print in the table represents individual checklist questions – to read checklist questions in normal font please refer to supplements S1-S7.*

Some broad thematic patterns can be discerned from the classification. Spatial scaling and resolution guidance does not provide recommendations on the 'purpose' of assessments. This can perhaps be explained by spatial scale and resolution being general features that must be adapted to any ES assessment purpose. Guidance on the topics of 'ecosystem condition' and ES 'capacity-potential-supply-use-demand' did not cover recommendations for 'investing in a legitimate assessment process'. This supports the hypothesis that assessment guidance on biophysical methods of condition and ecosystem services is largely focused on scientific-technical study design issues, not addressing stakeholder benefits. This may indicate a relative knowledge gap with respect to making biophysical assessment directly relevant for stakeholders' decision-support needs. On the other hand, all of the ES assessment outcomes related to benefits (economic, social, health) have checklist recommendations on engaging stakeholders in the assessment process.

In the following we provide a narrative summary of the checklist questions through the lens of the plural valuation steps. We comment on elements that are specific to ecosystem service assessment and contrast them with the recommendations on plural valuation from the IPBES VA, as summarised by Termansen et al. (2023).

Invest in a legitimate process. The review of ES guidance documents recommends a participatory approach that validates and grounds the classification and spatial representation of ecosystem services in the needs, perspectives, knowledge and values of people who rely on the ecosystem services. The process should make it possible for stakeholders to also contribute to the design of the assessment as it proceeds, and to evaluate the predicted outcomes of ES assessment in the policy cycle after the study is completed. This is resource demanding and requires adequate time and budgets. Despite these broadly useful points in line with plural valuation, our review showed that guidance specific to designing an ES assessment process is limited, especially for biophysical assessments. Comparing to IPBES VA recommendations we can note that adapting ES classification and representation to local stakeholder perceptions is a recommendation that may be at odds with the standardised ES classifications such as CICES or ecosystem accounting at national level (IPBES 2022). Furthermore, ecosystem services assessment guidance focuses on relevance to humans, whereas legitimacy in a plural valuation process also considers non-human individuals, groups and communities (Termansen et al. 2023).

Define the purpose. With the exception of checklists for ecological condition, the review of guidance documents provided limited advice in defining different purposes of ES assessment. Understanding context specific policy and social needs is required to identify the data needed for assessing capacity, supply and demand. Specifying purpose can increase the cost-effectiveness of the ES assessment by calibrating data use to the minimum requirements for robustness for a specific purpose, while considering available resources. Through the policy cycle, the method and data infrastructure development, advocacy & awareness raising, policy design, decision-support, implementation & management, and ex post policy impact evaluation all have different requirements for robustness that need to be understood before starting ES assessment. In the IPBES VA understanding the purpose of the assessment goes beyond simple identification of where in the policy cycle the assessment finds itself. It should also include an understanding of which stakeholders are being addressed and their decision-making roles. Also, understanding is needed of the policy windows for ES assessment outcomes to be able to influence decisions, and the constraints on decision-making procedures impacting nature (Termansen et al. 2023).

Establish the scope. Existing guidance on ES assessment is limited in its interpretation of 'scope' to the considerations of spatial scaling and resolution. The spatial scale and extent of the ecosystem services assessment should align with the management or policy decision to be assessed and be defined explicitly before methods are chosen. Identification of the beneficiaries of each ecosystem service is key to identifying economic valuation methods. The initial geographical scope or range of ecosystem services that can be assessed with available data and resources may be incomplete relative to expected impacts of policy. To address such limitations, economic valuation also considers the scope for value transfer from existing study sites. In the IPBES VA the interpretation of scoping to also critically consider the different values held by the stakeholders affected is not predominant in assessment guidance on ecosystem condition and biophysical ecosystem service assessment. In plural valuation the scoping stage also includes inventorying stakeholders, including rightsholders, that are affected by changes in nature, and their instrumental, relational or intrinsic value types affected (Termansen et al. 2023). This promotes a more representative choice of assessment methods.

Choose and apply methods. ES assessment guidance is diverse in providing recommendations on methods. Method recommendations cutting across diagnostic topics include appropriate choice of spatial resolution of assessments to match both the spatial scale and the required spatial and temporal accuracy demanded by stakeholders for their decision-support purposes. This includes considering potential future changes and the spatiotemporal dynamics that need to be described by the

assessment methods. With the notable exception of ecosystem accounting, common knowledge gaps include the lacking treatment of temporal variation in the ES assessments (e.g. Burkhard et al. 2014), and the impacts of temporal mismatches between supply and demand, and ultimately on sustainable use. Guidance documents emphasise the challenge of identifying causal pathways and integrated biophysical model compatibility between ecosystem structure, condition and services. The biophysical metrics used must match the methods for assessing benefits. Doing this is recognised as challenging because interactions across economic, social and health benefits must be acknowledged and controlled for. The risks of integrating assessments across long causal chains, leading to decreasing accuracy, should be acknowledged and reported. Shortening causal chains to look at well-being outcomes directly associated with ecosystem condition is among recommendations in the checklists.

The IPBES VA plural valuation recommendations emphasise making and documenting informed method choices, considering trade-offs between relevance, robustness and resource availability; taking into account the previous steps of legitimacy of the assessment process, its purpose and scope. Recent guidances on MAES (e.g. Burkhard et al., 2018; Grêt-Regamey et al., 2017) and Ecosystem Accounting (United Nations, 2022a, 2022b) acknowledge such trade-offs through a tiered approach to method selection. Even with such 'tiered' guidance there are risks that those in power to commission the studies, as well as practitioners' disciplinary and professional biases, may determine method selection. By doing 'due diligence' documentation of method selection practitioners can mitigate the risks that the study will not necessarily realise, recognise or represent the full extent of value diversity entailed by the purpose' as determined by a legitimate valuation process (Termansen et al. 2023).

Communicate results to inform decision-makers. Our review of ES assessment guidance also shows ample recommendations on both direct communication of results, as well as mechanisms for increasing uptake once the assessment is completed. Common recommendations refer to communicating outcomes in maps which clearly show the spatial resolution of ES indicators and resolution and variation of the input data. Standardising the communication of model assumptions and levels of uncertainty is also a general recommendation. Recommendations also include iterative assessment of ecosystem-based adaptative management, as opposed to simple before-after assessment. Meetings with stakeholders and options to make assessment corrections during the study should be considered. Input data can be validated with local communities. Assessments should plan for what happens after the science is completed, including open consultation of results with external audiences. Mechanisms should be in place to hear and record local stakeholders' feedback. Iterative improvement in ES assessment and adaptive planning should be considered. An iterative, stepwise approach to integrating study results into decision making implies that integrated ES assessment runs through all the stages of a policy cycle. The IPBES VA recommends explicitly evaluating the factors limiting uptake in this process, honest reflection of the limitations and of any omissions in the assessment process. It also recommends that practitioners explicitly provide opportunities for contestation by stakeholder of the conclusions reached (Termansen et al. 2023).

5. Discussion

In this section we address the relative blindspots uncovered in current ES guidance recommendations by using extended checklist questions. We discuss the potential interlinkages between assessment design features that can increase uptake. Finally we discuss the policy demand side - how ES knowledge may be taken up in different ways by a political process, independently of how practitioners may supply that knowledge.

5.1 An extended check-list for ES assessment

Each diagnostic topic review group also proposed a number of additional checklist questions to address relative gaps in checklist questions shown in **Figure 4**. The additional checklist questions were defined based on the review groups own experience as ES assessment practitioners. The extended checklists area visualised in **Figure 5** – the full text checklist questions can be found in Supplements S1-S7.

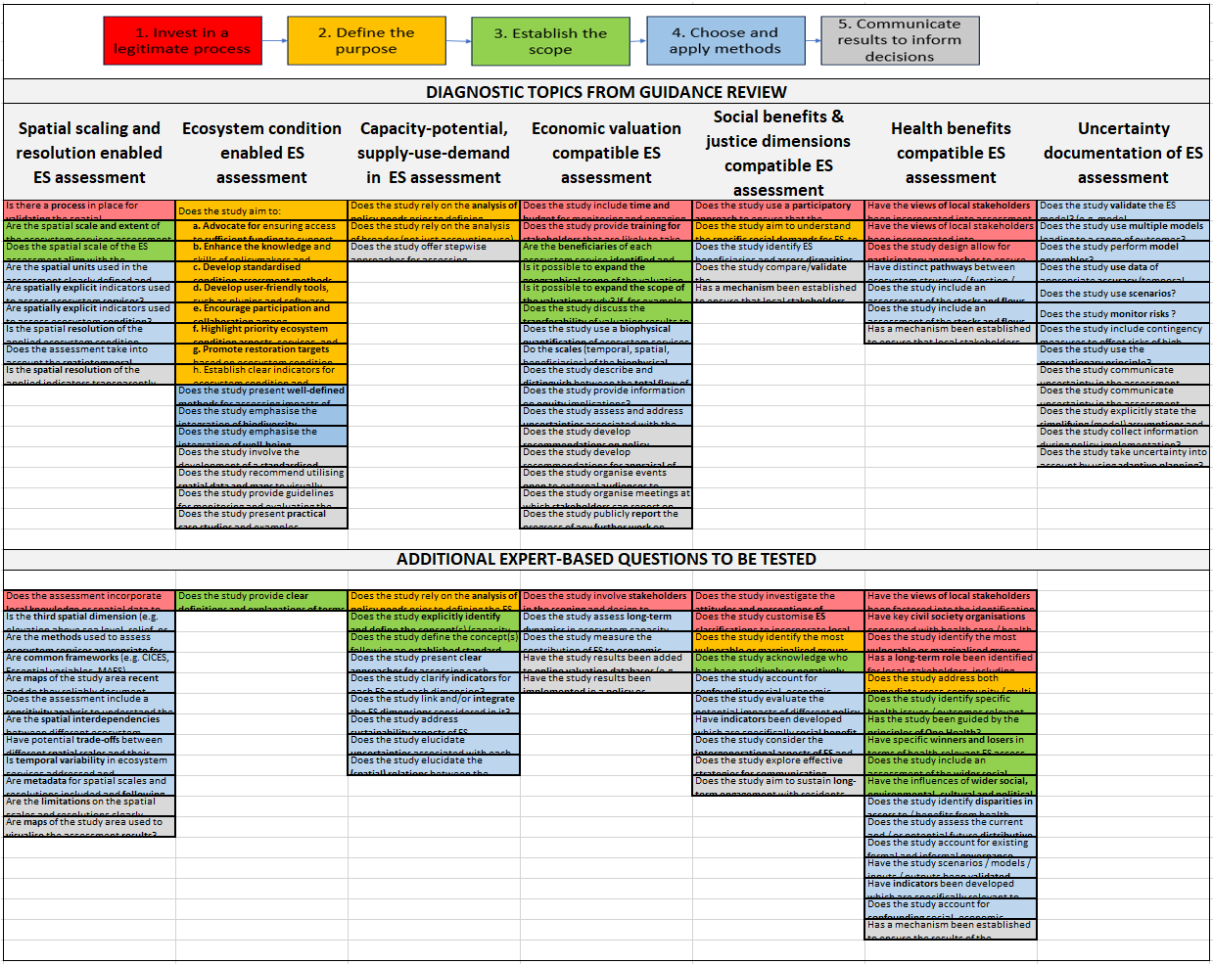

Figure 5 Visualisation of additional checklists to cover knowledge gaps in the ES assessment guidance literature. Note: *For illustrative purposes the small print in the table represents individual checklist questions – to read checklist questions in normal font please refer to supplements S1-S7.*

Notable characteristics of these extended checklists is the large number of questions added to evaluate social and health benefits, relative to the recommendations found in the ES guidance literature. The rationale for this is the relative lack of guidance in particularly for the health sector on how to employ ecosystem service assessments. A lot of emphasis is placed on additional questions to achieve legitimate involvement of local communities, and identifying purpose and defining scope that is compatible with justice dimensions and health outcomes. Notable also are the many additional checklist questions to address methods gaps in spatial scaling and resolution, and understanding ecosystem service capacity-potential, supply-use-demand relationships. Guidance on ecological condition was considered mostly sufficient. Notably, no additional questions were added to

uncertainty checklists – at the time of writing this topic was the subject of a separate dedicated review of the scientific literature which had not concluded[1].

Given the vast variation in assessment contexts it is not likely that all checklist questions are relevant for each application site. The extended checklists are designed as menus of potentially relevant features for practitioners to use in a 'self-audit', aimed at increasing likelihood of uptake. Practitioner and stakeholders collaborating in real world ES assessments can revise and consolidate them to fit their purposes.

5.2 Potential interlinkages between study design features and increased likelihood of uptake

Diagnostic topic review teams also identified potential synergies between assessment design features (**Figure 6**). Common to all diagnostic topic groups was the recommendation that spatial and temporal scale and resolution should be explicitly chosen to integrate across ecosystem condition, ecosystem services and economic, social and health benefit outcomes. A second common feature was that adequate definition of ecosystem condition is expected in conjunction to improve the robustness and relevance of ecosystem service and economic, social and health metrics. Specifying ecosystem condition is also expected to improve economic valuation, social justice and health outcome evaluation independently of whether ecosystem service modelling is conducted or not. Thirdly, economic, social and health benefits are mutually determined and should, resources permitting, be assessed together. Fourth, all the above study design features require documentation of uncertainty individually, and also in terms of joint probabilities across integrated ecosystem service assessment.

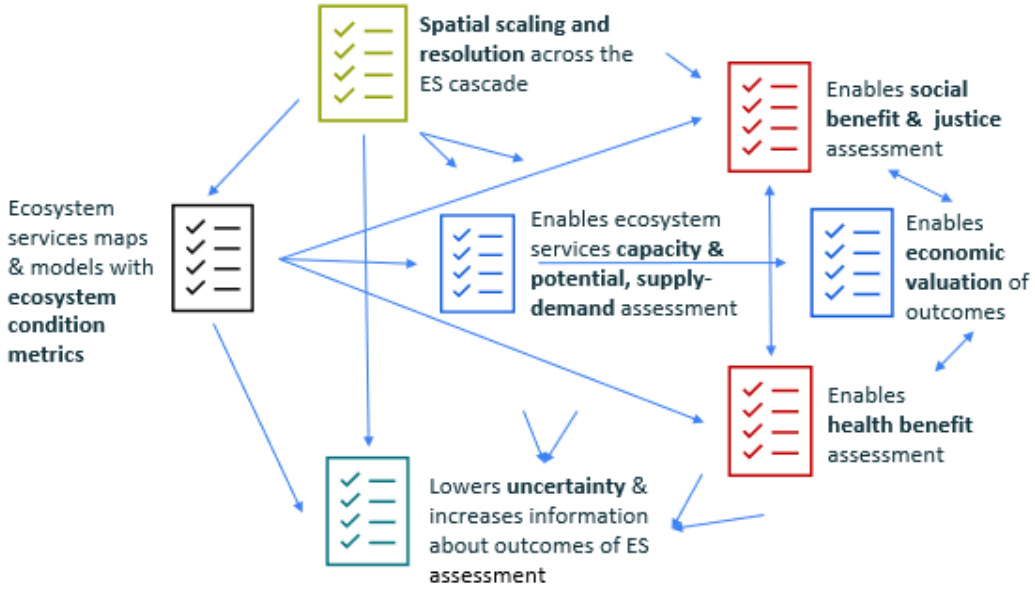

Figure 6 Potential synergies between ES assessment features to be tested in real world case studies. *Arrows in the diagram represent potential synergies identified by review teams.*

[1] As part of the EU SELINA project: https://project-selina.eu/ project

5.3. The limitation of checklists - intended purposes of ES assessment versus actual use for political interests. Defining the purpose of ecosystem services assessment can help the practitioner to choose robust methods with the available resources. However, this definition of purposes is from the 'supply' perspective of a knowledge provider. Checklists for assessment design only go as far as the knowledge supplied by the practitioner. Political actors use of the knowledge may mean that actual uptake is determined by power and political expediency. To this end Jacobs et al. (2023) outlines political valuation typologies which can provide an understanding of why ES assessment is not taken up, or even misused, relative to the purpose intended by the practitioner. We briefly paraphrase the Jacobs et al. (op.cit) typology in terms of ecosystem service assessment and comment on its relevance for the diagnostic topics.

Affirmative ES assessment legitimately represents all stakeholders and recognises their plural values 'actively counterbalancing injustices built into history, place, and social arrangements'. This use of ES assessment puts particular emphasis on assessment of social justice dimensions. The checklists in this paper assumes this 'best possible' use case with mutually reinforcement of all the 7 topics of ES assessment design.

Confirmative ES assessment still brings a diverse set of value to the table, but 'is often applied to justify decisions already taken, and builds credibility and acceptance within broader actor groups'. While practitioners aim to identify biophysical services, economic values, health and social impacts, stakeholders wishing to confirm a status quo may not be favourable to documentation of uncertainty, since it can shed light on knowledge gaps which serve to justify inaction and the status quo power of some actors.

Moving away from the ideal contexts of ES assessment in academia, a*ppropriative ES assessment* sets up an assessment processes to be 'participatory, representative, and/or inclusive, but in the end, a powerful minority uses these qualities to push for an outcome that advances their private benefits'. In such a setting those commissioning an assessment may not want uncertainty documentation because it could cast the foregone conclusions of the study's sponsors into doubt.

Moving yet further from an academic ideal, a *repressive assessment* may covertly design an assessment process with potentially opposing actors to 'thereby utilizing their time, energy, and buy-in otherwise available for opposition'. Overtly repressive assessment would even aim to 'discredit or dismiss legitimate claims of opposing actors, as Jacobs et al. put it 'with arguments such as 'actor subjective perceptions' versus 'expert facts'.

In *discriminative ES assessment* powerful actors carry out or commission an assessment 'directly in their own interest and use this as a power lever to trump other actors' interests and values'. Such an assessment would not use methods reflecting economic, social or health impacts of societal stakeholders that were not allied with actors in power.

The latter political uses could be expected to go undocumented in scientific literature and may seem unusual for practitioners in some European countries. However, Jacobs et al. (2023) typology offers a perspective on the risks of not investing in, or not being allowed to invest in, 'legitimate assessment process' in the first step of an ES assessment.

5. Conclusions

Mapping and assessment of ecosystem services (MAES) is increasingly used in European and member state policy, such as EU Biodiversity strategy to 2020 and 2030 and the proposed EU regulation on ecosystem accounting. Policy targets for nature positive restoration will also come into force through the EU Nature Restoration Law, requiring assessment of ecosystem services. Recent scientific literature reviews on valuation of nature, including mapping and assessment of ecosystem services (MAES), have at them same time concluded that during the last 20 years there has been a lack of uptake of valuation results by stakeholders for use in decision-support. However, those reviews have not included 'grey literature' such as methodological guidance documents, nor has this been done especially for ecosystem services assessment where future policy demand is expected. We therefore reviewed 111 guidance documents on ES assessment from across Europe. Based on the review we collated guidance recommendations across 7 diagnostic topics aimed at strengthening integrated MAES. We formulated recommendations into checklists questions for each diagnostic topic – the questions are available in method supplements S1-S7. Checklists are aimed at increasing the relevance, robustness and efficiency of knowledge supplied on ecosystem services from practitioners to policy makers.

We classified checklist questions according to the policy cycle and the IPBES Values Assessment 5-step recommendations for plural valuation, aiming to strengthen the integration of ES assessment with welfare assessment in social-ecological systems perspective. In relation to the policy cycle, we found that there is relatively little guidance available on supporting policy adoption and policy evaluation, pointing to possibilities for strengthening future methodological guidance work. We examined potential synergies between diagnostic topics. We concluded that identifying ecosystem condition is key to increasing robustness of not only ecosystem service models, but also economic valuation of ES benefits, social and health benefits. Our plural valuation screening also uncovered some knowledge gaps in current guidance, especially in relation to linking ecosystem services to health and social benefits and justice dimensions. We therefore extended checklist questions to cover these and other gaps. Checklists questions available in method supplements will next be tested in collaboration with stakeholders in real world ES applications by the SELINA project. Finally, we recognise that our recommendations are limited to the ES knowledge 'supply side' – likelihood of uptake make be limited by political agendas beyond the awareness and influence of ES assessment practitioners.

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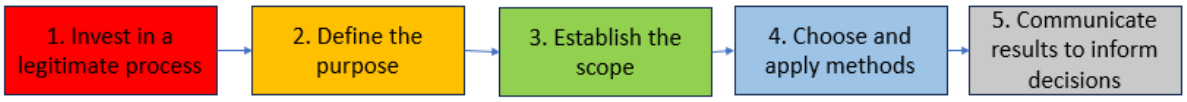
Supplementary Materials

Table of Contents

731 # S1. Ecosystem condition variables in ES assessments



732

	Checklist	Y	N	N R	Comments
1	Does the study aim to:				
	a. **Advocate for** ensuring access to **sufficient funding** to support the implementation of new condition assessment approaches/standards, including training and incorporating new professionals?	☐	☐	☐	Sourced from reviewed guidance documents
	b. **Enhance the knowledge** and skills of policymakers and supporting scientists/technicians on agreed condition assessment approaches?	☐	☐	☐	Sourced from reviewed guidance documents
	c. **Develop standardised condition assessment methods** and accessible, interoperable databases to overcome fragmented data inventory reality faced by policymakers?	☐	☐	☐	Sourced from reviewed guidance documents
	d. **Develop user-friendly tools**, such as plugins and software, enabling policymakers and practitioners to analyse, visualise, and interpret data on ecosystem condition and services?	☐	☐	☐	Sourced from reviewed guidance documents
	e. **Encourage participation and collaboration** among stakeholders in the design and implementation of strategies like conservation, ecotourism, and monitoring of ecosystems?	☐	☐	☐	Sourced from reviewed guidance documents
	f. **Highlight priority ecosystem condition aspects**, services, and their benefits, helping policymakers focus on impactful aspects of their decisions?	☐	☐	☐	Sourced from reviewed guidance documents
	g. **Promote restoration targets** based on ecosystem condition needs and emphasise the importance of improving degraded ecosystems?	☐	☐	☐	Sourced from reviewed guidance documents
	h. Establish clear indicators for ecosystem condition and services at national, regional, or local levels for monitoring and evaluation in policy development?	☐	☐	☐	Sourced from reviewed guidance documents
2	Does the study present **well-defined methods** for assessing impacts of ecosystem condition on services?	☐	☐	☐	Sourced from reviewed guidance documents
3	Does the study emphasise the integration of **biodiversity conservation** within the evaluation of ecosystem conditions and services?	☐	☐	☐	Sourced from reviewed guidance documents

4	Does the study emphasise the integration of **well-being** assessment within the evaluation of ecosystem conditions and services?	☐	☐	☐	Sourced from reviewed guidance documents
5	Does the study involve the development of a **standardised framework** for integrated assessment of ecosystem condition and services to **aid policymakers** in understanding and utilising information?	☐	☐	☐	Sourced from reviewed guidance documents
6	Does the study recommend utilising **spatial data and maps** to visually present ecosystem condition and services data for policymakers?	☐	☐	☐	Sourced from reviewed guidance documents
7	Does the study provide guidelines for monitoring and evaluating the impacts of **ecosystem-based adaptation interventions**, such as nature-based solutions or green-blue networks?	☐	☐	☐	Sourced from reviewed guidance documents
8	Does the study present **practical case studies** and examples illustrating successful integration of ecosystem condition and services into decision-making processes?	☐	☐	☐	Sourced from reviewed guidance documents
	ADDITIONAL EXPERT-BASED TOPICS				
9	Does the study provide **clear definitions and explanations of terms** related to ecosystem condition and services, ensuring consistency and better understanding?	☐	☐	☐	Based on reviewer expertise

Approach for checklist compilation

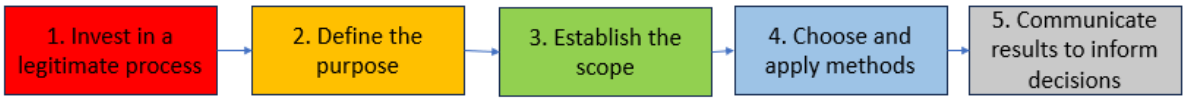
The checklist for evaluating studies incorporating ecosystem condition variables into ecosystem services models was developed through the examination of guidance documents and leveraged the expertise and experience of the reviewers in this field. The process involved synthesising insights from established methodologies and practical applications found in the guidance document. Assumptions were made based on the belief that **a robust assessment tool should encompass key dimensions important for policymakers and practitioners.** These dimensions include clarity of definitions, standardised frameworks, prioritisation of ecosystem aspects, establishment of indicators, promotion of restoration, transparent presentation of methods, integration of biodiversity and well-being, use of spatial data, stakeholder participation, enhancement of policymakers' knowledge, practical case studies, and a call for standardised methods and accessible databases. These assumptions aimed to ensure a comprehensive, practical, and widely applicable checklist, facilitating meaningful integration of ecosystem condition considerations into ecosystem services modelling and ultimately into decision-making processes.

Expected limitations and possible steps for improvement

While the checklist provides some criteria for evaluating studies incorporating ecosystem condition variables into ecosystem services models, there are some potential limitations when applied to real world cases. Firstly, the checklist assumes a certain level of **data availability** and accessibility, which may vary across ES assessment applications with differing resource constraints. Additionally, the checklist's emphasis on **standardisation** and clear indicators may face challenges in the context of **diverse ecosystems and regional variations**. To enhance its applicability to cases, steps for improvement could involve creating a **tiered system** that accommodates variations in data availability

and resource capacities. The checklist could also benefit from **iterative feedback** from case studies to refine and tailor its criteria based on real-world experiences. Furthermore, incorporating flexibility into the checklist to allow for **project-specific adaptations** would enhance its usability across a range of ecological, socio-economic, and political contexts. Regular **updates** based on emerging best practices and technological advancements would ensure the checklist remains a dynamic and relevant tool for guiding ecosystem condition and services assessments in case studies and other applications.

761 ## S2. Dimensions of capacity-potential, supply-demand in ES assessment



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	Checklist	Y	N	N R	Comments
1	Does the study rely on the **analysis of policy needs** prior to defining **indicators** for each of the ES dimension (capacity, supply, demand)? (document #4)	☐	☐	☐	Sourced from reviewed guidance documents
2	Does the study rely on the analysis of broader (not just accounting use) **policy needs** prior to defining what **input data** to and/or outputs to generate? (document #4)	☐	☐	☐	Sourced from reviewed guidance documents
3	Does the study offer stepwise approaches for assessing ecosystem service capacity, potential supply, actual supply and/or, demand and **integrating them into decision-making**?	☐	☐	☐	Sourced from reviewed guidance documents
	ADDITIONAL EXPERT-BASED TOPICS				
4	Does the study rely on the **analysis of policy needs** prior to defining the ES **dimension** (capacity, supply, demand)?	☐	☐	☐	Based on reviewer expertise
5	Does the study **explicitly identify and define the concept**(s) (capacity, potential supply, actual supply and/or, demand)?	☐	☐	☐	Based on reviewer expertise
6	Does the study define the concept(s) following an **established standard terminology** (e.g., Burkhard et al. 2012; Millennium Ecosystem Assessment; CICES; IPBES)?	☐	☐	☐	Based on reviewer expertise
7	Does the study present **clear approaches** for assessing each dimension?	☐	☐	☐	Based on reviewer expertise
8	Does the study clarify **indicators** for each ES and each dimension?	☐	☐	☐	Based on reviewer expertise
9	Does the study link and/or **integrate** the ES **dimensions** considered in it?	☐	☐	☐	Based on reviewer expertise
10	Does the study address **sustainability aspects** of ES dimensions?	☐	☐	☐	Based on reviewer expertise
11	Does the study elucidate **uncertainties** associated with each of the assessed dimension(s) (and indicator(s))?	☐	☐	☐	Based on reviewer expertise
12	Does the study elucidate the **(spatial) relations** between the assessed dimensions?	☐	☐	☐	Based on reviewer expertise

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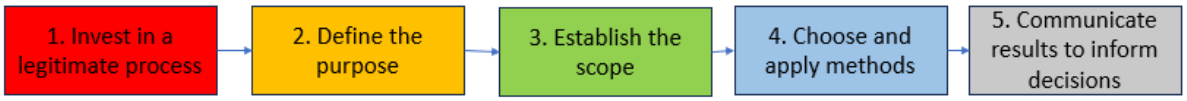
Approach for checklist compilation

The checklist has mainly been compiled by relying on the reviewers' own experience in the design, application and communication of ecosystem services assessment, with a specific focus drawn on the concept from the **SEEA-EA framework** (concepts of capacity, potential supply, actual supply (flow), use, and/or demand). Reviewers' own experience was combined as much as possible with guidance extracted from the reviewed literature, although it remained rather incomplete with respect to the link to policy. This diagnostic topic was addressed through twelve questions related to four topics: 1) the identification and **distinction of the concepts** of capacity, potential supply, actual supply (flow), use, and/or demand, 2) the **indicators** used to characterise those concepts in the assessments, 3) the link between the concepts and their i**ntegration in assessments**, 4) the implications of distinguishing and/or using this set of concepts in **policy making**. For each of these four topics, specific points of guidance were extracted by reviewers. These points of guidance were subsequently synthesised and reformulated into checklist questions. The review of the guidance documents and personal knowledge and experience of the experts enable them to identify further checklist questions based on their experience of how research and application of concepts of capacity, potential supply, actual supply (flow), use, and/or demand can feed into decision making.

Expected limitations and possible improvements

There is still some **confusion around the definition of the concepts** in the existing literature, as well as a lack of common understanding. Consequently, there is a risk that (most) concepts are still largely unclear in real world cases. Clear definitions and **examples** of the concepts should be then provided to case studies, to ensure that they are defined and applied in an appropriate and homogenous way by case studies. In addition to providing the proper documentation defining these concepts, further explanation may be needed, e.g., on how to assess them and on the **choice of indicators**, as examples of studies using modelling approaches (wrt tools, indicators) for several of these concepts are still limited. **Testing** on the ground should be conducted with case study practitioners to validate and, when needed, complement and reformulate the check-list questions.

S3. Social benefit compatibility of and dimensions of justice in ES assessments



	Checklist	Y	N	NR	Comments
1	Does the study use a **participatory approach** to ensure that the assessment of ES is rooted in the needs, knowledge and values of the communities or residents relying on these services?	☐	☐	☐	Sourced from reviewed guidance documents
2	Does the study aim to understand the **specific social demands** for ES to inform the assessment more effectively?	☐	☐	☐	Sourced from reviewed guidance documents
3	Does the study identify ES beneficiaries and **assess disparities** in access and distribution of benefits?	☐	☐	☐	Sourced from reviewed guidance documents
4	Does the study compare/**validate** the scenarios/models/inputs/outputs with local inputs and community perspectives to enhance their credibility?	☐	☐	☐	Sourced from reviewed guidance documents and expanded based on reviewer expertise
5	Has a **mechanism** been established to ensure that local **stakeholders** can **respond** to the results and recommendations from the study?	☐	☐	☐	Sourced from reviewed guidance documents
	ADDITIONAL EXPERT-BASED TOPICS				
6	Does the study investigate the **attitudes and perceptions of communities** towards specific ES and their importance for well-being?	☐	☐	☐	Based on reviewer expertise
7	Does the study customise **ES classification**s to incorporate **local perspectives**?	☐	☐	☐	Based on reviewer expertise
8	Does the study identify the most **vulnerable or marginalised groups** within the study area, and have their needs, perspectives and values been explicitly identified and accounted for?	☐	☐	☐	Based on reviewer expertise
9	Does the study acknowledge who has been **positively or negatively affected** by changes in ES supply or access due to specific interventions?	☐	☐	☐	Based on reviewer expertise
10	Does the study account for **confounding** social, economic, cultural and environmental **factors** which mediate the relationships between ES and social benefit and justice outcomes?	☐	☐	☐	Based on reviewer expertise
11	Does the study evaluate the potential impacts of different **policy actions** on the distribution of ES benefits among various societal groups?	☐	☐	☐	Based on reviewer expertise
12	Have **indicators** been developed which are specifically **social benefit-relevant** as determined by the engagement with stakeholders?	☐	☐	☐	Based on reviewer expertise

13	Does the study consider the **intergenerational aspects of ES** and their implications for future well-being (e.g., impacts of policies or activities)?	☐	☐	☐	Based on reviewer expertise
14	Does the study explore effective **strategies for communicating** complex ES-related information to diverse audiences?	☐	☐	☐	Based on reviewer expertise
15	Does the study aim to sustain **long-term engagemen**t with residents and communities beyond initial policy development (e.g., monitoring and management)?	☐	☐	☐	Based on reviewer expertise

798 **Approach to checklist compilation**

799 The checklist aims to address critical gaps identified in existing guidance documents. These gaps likely
800 arise from limitations in understanding the intricate connections between ES and their social
801 implications, including those related to social and environmental justice. For instance, exploring the
802 relationships between biodiversity, ES, and social and environmental justice requires insights from
803 disciplines such as political ecology and diverse social sciences. Moreover, existing guidelines lack
804 information for addressing social and economic inequalities as confounding factors, which are
805 essential when monitoring the effectiveness of models and indicators to demonstrate the connection
806 between ES and human well-being. As a result, the presented checklist, simplified into yes/no
807 questions, has been improved by using experts' perspectives on this topic.

808 **Expected limitations and possible improvement**

809 Despite the above information, the existing checklist has limitations. It assumes that real world cases
810 as end users possess the necessary knowledge and resources to address the complex pathways
811 between ES and social benefits and justice. This assumption includes conducting comprehensive
812 stakeholder mapping and implementing transdisciplinary, cross-sectoral approaches. However, it
813 overlooks the critical need for additional guidance in navigating the complexities of social benefits and
814 justice linked to ES. Moreover, addressing these complexities requires a more comprehensive and
815 inclusive approach, potentially necessitating collaboration across various disciplines and sectors that
816 could be a challenge for some of the projects.

817 Finally, while the checklist is a step towards understanding and assessing the social implications of ES,
818 it is limited in its ability to comprehensively capture the multidimensional aspects of social benefit and
819 justice evaluation that tend to be highly context-specific, highlighting the need for a more collaborative
820 and holistic approach in its development and implementation.

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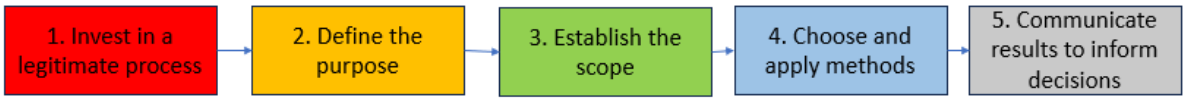
822 # S4. Health benefit compatibility of ES assessments



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	Checklist	Y	N	N R	Comments
1	Have the **views of local stakeholders** been incorporated into assessment design?	☐	☐	☐	Sourced from reviewed guidance documents
2	Have the **views** of local stakeholders been incorporated into **classifications of health-relevant ES**?	☐	☐	☐	Sourced from reviewed guidance documents
3	Does the study design allow for **participatory approaches** to ensure that the assessment is appropriately informed and guided by local community knowledge, perspectives, needs and values?	☐	☐	☐	Sourced from reviewed guidance documents
4	Have distinct **pathways** between ecosystem structure / function / ecosystem services been explored or identified for those health aspects?	☐	☐	☐	Sourced from reviewed guidance documents
5	Does the study include an assessment of the **stocks and flows** of health relevant ES?	☐	☐	☐	Sourced from reviewed guidance documents
6	Does the study include an assessment of the **stocks and flows** of health relevant ES?	☐	☐	☐	Sourced from reviewed guidance documents
7	Has a mechanism been established to ensure that local stakeholders can **respond to the results** and recommendations from the study?	☐	☐	☐	Sourced from reviewed guidance documents
	ADDITIONAL EXPERT-BASED TOPICS				
8	Have the **views of local stakeholders** been factored into the identification of health benefits?	☐	☐	☐	Based on reviewer expertise
9	Have key **civil society organisations** concerned with health care / health inequality / community care / specific health challenges been **engaged** in the study?	☐	☐	☐	Based on reviewer expertise
10	Does the study identify the most **vulnerable or marginalised groups** within the study area, and have their specific health needs, perspectives and values been explicitly identified and accounted for?	☐	☐	☐	Based on reviewer expertise
11	Has a **long-term role** been identified for local stakeholders, including vulnerable and marginalised groups, in **monitoring and managing** the results of policy implementation?	☐	☐	☐	Based on reviewer expertise
12	Does the study address both **immediate** cross-community / multi-stakeholder rights, **needs** and	☐	☐	☐	Based on reviewer expertise

	values (equity) as well as **longer term solutions** to securing equitable access (justice)?				
13	Does the study identify specific health issues / outcomes relevant to the **geographic area / population / community** being studied?	☐	☐	☐	Based on reviewer expertise
14	Has the study been guided by the **principles of One Health**?	☐	☐	☐	Based on reviewer expertise
15	Have specific **winners and losers** in terms of health-relevant ES access and benefit sharing been identified?	☐	☐	☐	Based on reviewer expertise
16	Does the study include an assessment of the **wider social, economic, environmental and cultural context** within which health-relevant ES supply and demand are determined? (consider climate change, water and air quality, demography, social cohesion, social partnerships, etc.)	☐	☐	☐	Based on reviewer expertise
17	Have the influences of **wider social, environmental, cultural and political issues on health** and health inequalities been accounted for?	☐	☐	☐	Based on reviewer expertise
18	Does the study identify **disparities in access** to / benefits from health-benefit ES and attempt to understand the **drivers** and consequences of such disparities?	☐	☐	☐	Based on reviewer expertise
19	Does the study assess the current and / or potential future **distributive impacts** of policies or activities on ecosystem management?	☐	☐	☐	Based on reviewer expertise
20	Does the study account for existing formal and informal **governance mechanisms** relevant to ES in the study area?	☐	☐	☐	Based on reviewer expertise
21	Have the study scenarios / models / inputs / outputs been **validated against local knowledge** or perspectives?	☐	☐	☐	Based on reviewer expertise
22	Have **indicators** been developed which are specifically relevant to **health benefits**, as determined by engagement with stakeholders?	☐	☐	☐	Based on reviewer expertise
23	Does the study account for **confounding** social, economic, cultural and environmental **factors** which mediate the relationships between ES and health outcomes?	☐	☐	☐	Based on reviewer expertise
24	Has a mechanism been established to ensure the results of the assessment and related decision-making are **effectively communicated** to all stakeholders?	☐	☐	☐	Based on reviewer expertise

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Approach to checklist compilation

The checklist aims to help to address some of the major gaps identified in the guidance documents during the review; however, it is likely that those gaps reflect gaps in knowledge and expertise (on linkages between ecosystem services and health, and / or on how to assess those connections) in development of those guidance documents, and the **difficulty in synthesising fairly complex cross-cutting issues** for which much more research may be required. For example, assessing relationships between biodiversity, ES and infectious disease risk frequently **requires inputs from** eco-epidemiology and various social sciences, and often hinges on perspectives from a **diversity of disciplines or sectors** which may include agriculture, forestry, urban planning, tourism, hydrology, etc. In some cases (particularly relating to mental and physical well-being benefits from recreation) various methodologies have been tried and tested, however where these were incorporated into guidance there was (with only one exception) a lack of guidance on dealing with **confounding factors** and establishing appropriate cross-cutting and benefit-relevant indicators. There was also no guidance on understanding how **social, economic and environmental determinants of health interact,** or how these relate to issues of health inequality and justice.

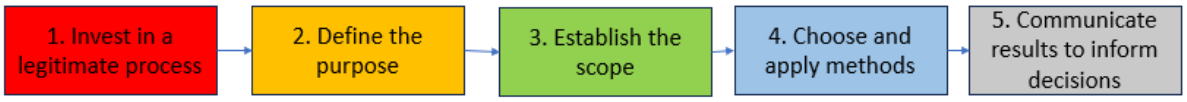
Expected limitations and possible improvement

In order to limit the checklist to simple yes / no questions, we necessarily assume that the end users will already have the supporting knowledge and resources to identify and unpack the pathways between ES and health, carry out **appropriate stakeholder mapping**, and use that information to build the appropriate trans-disciplinary and cross-sector approaches.

Following from the above, we would expect that real world cases may **struggle to identify** the full complement of **health issues** relevant to their projects or project areas, and to explore ES and health linkages in great detail, except perhaps where there is a focus on health promotion through recreation. Improvements would come from a more detailed unpacking of ES-health pathways and paradigms and more detailed guidance on identifying appropriate stakeholders and experts for specific health issues, and further guidance on identifying and addressing related dimensions of justice.

See further narrative on compilation approach here: https://docs.google.com/document/d/15dQQIbSi2GMK0sj_np2bdnrYbr3IzvOb/edit

853 # S5. Economic valuation compatibility of ES assessments



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	Checklist for economic valuation compatibility	Y	N	N R	Comments
1	Does the study include **time and budget** for monitoring and engaging in the **policy** development **process**?	☐	☐	☐	Sourced from reviewed guidance documents
2	Does the study provide **training for stakeholders** that are likely to take the results forward?	☐	☐	☐	Sourced from reviewed guidance documents
3	Are the **beneficiaries** of each ecosystem service **identified** and quantified (number of beneficiaries, population density, proximity to urban areas etc.) to reflect demand?	☐	☐	☐	Sourced from reviewed guidance documents
4	Is it possible to **expand the geographical scope** of the valuation study? If, for example, the original study was for a specific ecosystem, and there is stakeholder demand and funding for **scaling up** the analysis to the regional or national level.	☐	☐	☐	Sourced from reviewed guidance documents
5	Is it possible to **expand the scope of the valuation** study? If, for example, the original study was for a limited set of ES, there might be interest and funding for extending the analysis to other relevant ES.	☐	☐	☐	Sourced from reviewed guidance documents
6	Does the study discuss the **transferability** of valuation results to other contexts and regions?	☐	☐	☐	Sourced from reviewed guidance documents
7	Does the study use a **biophysical quantification** of ecosystem services as the basis for the economic valuation?	☐	☐	☐	Sourced from reviewed guidance documents
8	Do the **scales** (temporal, spatial, beneficiaries) of the **biophysical** quantification of ecosystem services **match** the economic valuation ?	☐	☐	☐	Sourced from reviewed guidance documents
9	Does the study describe and **distinguish** between the **total** flow of the ecosystem service and **changes** in the flow (as result of a change in management, extent, condition etc)?	☐	☐	☐	Sourced from reviewed guidance documents
10	Does the study provide information on **equity** implications?	☐	☐	☐	Sourced from reviewed guidance documents
11	Does the study assess and address **uncertainties** associated with the valuation, providing a clear indication of the confidence level in the results?	☐	☐	☐	Sourced from reviewed guidance documents
12	Does the study develop **recommendations on policy** responses in light of its findings?	☐	☐	☐	Sourced from reviewed guidance documents
13	Does the study develop recommendations for **appraisal** of alternative **policy options**?	☐	☐	☐	Sourced from reviewed guidance documents
14	Does the study organise events **open** to external **audiences** to present the results or present at events organised by others (locally, nationally and internationally)?	☐	☐	☐	Sourced from reviewed guidance documents

15	Does the study organise meetings at which **stakeholders** can report on progress towards improved ecosystem management?	☐	☐	☐	Sourced from reviewed guidance documents
16	Does the study publicly **report** the progress of any **further work** on ecosystem valuation and, if relevant, keep the study website up to date?	☐	☐	☐	Sourced from reviewed guidance documents
	ADDITIONAL EXPERT-BASED TOPICS				
17	Does the study involve **stakeholders in the scoping** and design to enhance relevance?	☐	☐	☐	Based on reviewer expertise
18	Does the study assess **long-term dynamics** in ecosystem capacity, supply and demand in order to measure the **sustainability** of ES use and values.	☐	☐	☐	Based on reviewer expertise
19	Does the study measure the contribution of ES to **economic development indicators** (e.g. employment, growth)?	☐	☐	☐	Based on reviewer expertise
20	Have the study results been added to **online valuation databases** (e.g. ESVD, EVRI)?	☐	☐	☐	Based on reviewer expertise
21	Have the study results been **implemented** in a **policy** or **management** tool?	☐	☐	☐	Based on reviewer expertise

Approach to checklist compilation

The checklist has been compiled by combining guidance drawn from the review process described in Section 3. For each diagnostic question addressed in the review, specific points of guidance were recorded by reviewers as free text in the review form. These points of guidance were subsequently synthesised and reformulated into checklist questions. In addition, other points of guidance from the reviewed studies that do not directly relate to the diagnostic questions were also reformulated into checklist questions. Alongside this process, and with reflection on the points identified through the review, reviewers were invited to include additional checklist questions **based on their experience** of how economic valuation research can feed into decision making.

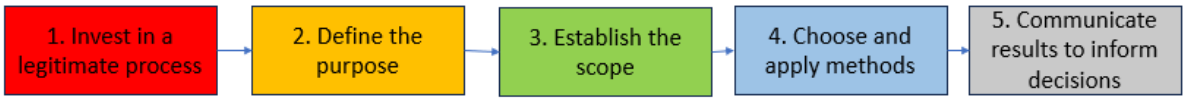
Expected limitations and possible improvement

Some checklist items delve into **technical aspects of economic valuation**, which might be challenging for practitioners in real world cases without specialised knowledge. This complexity necessitates additional explanations or expert guidance for effective comprehension and application. The checklist could also benefit from **practical testing within case studies**; real-world applications can reveal areas for refinement and enhancement. Suggested improvement steps could include: (i) further elaboration and refinement of the checklist questions, informed by practical **testing** and feedback from cases, can enhance clarity and usability; this process should aim to demystify technical aspects and make the valuation more accessible and applicable (ii) establishing a structured **feedback mechanism** to collect and analyse responses, questions, and suggestions from cases can also provide valuable insights for continuous improvement of the checklist, and (iii) providing additional resources, such as **explanatory guides** or access to expert consultation, can assist cases in navigating the more technical aspects of the checklist.

For instance, one important limitation is the potential mismatch between the generalised recommendations in the checklist and the **specific, localised needs of individual case studies**. This could lead to a lack of precision in addressing the unique economic aspects of ecosystem services in

varied geographical and socio-economic settings. To improve the checklist's applicability, it would be beneficial to incorporate a mechanism for **contextual adaptation.** This could involve providing guidelines on how to modify or augment the checklist based on local economic conditions, stakeholder priorities, and specific ecosystem characteristics. Additionally, the checklist could be enhanced by integrating feedback mechanisms, where practitioners can provide insights based on their on-ground experiences. This process would allow for continuous **refinement of the checklist**, ensuring its relevance and effectiveness in diverse case applications dealing with ecosystem service economic valuation.

892 ## S6. Spatial scaling and resolution capabilities of ES assessments



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	Checklist	Y	N	NR	Comments
1	Is there a **process** in place for **validating** the spatial representation of ecosystem services with **stakeholders**?	☐	☐	☐	Sourced from reviewed guidance documents
2	Are the spatial **scale and extent** of the ecosystem services assessment **explicit**ly stated?	☐	☐	☐	Sourced from reviewed guidance documents
3	Does the spatial scale of the ES assessment **align** with the objectives of the **management or policy** decision it aims to inform?	☐	☐	☐	Sourced from reviewed guidance documents
4	Are the **spatial units** used in the assessment clearly defined and justified?	☐	☐	☐	Sourced from reviewed guidance documents
5	Are **spatially explicit** indicators used to assess ecosystem **services**?	☐	☐	☐	Sourced from reviewed guidance documents
6	Are **spatially explicit** indicators used to assess ecosystem **condition**?	☐	☐	☐	Sourced from reviewed guidance documents
7	Is the spatial **resolution** of the applied ecosystem condition indicators **appropriate** for the **scale** of the assessment?	☐	☐	☐	Sourced from reviewed guidance documents
8	Does the assessment take into account the **spatiotemporal dynamics** and potential future changes of ES?	☐	☐	☐	Sourced from reviewed guidance documents
9	Is the **spatial resolution** of the applied indicators transparently stated?	☐	☐	☐	Sourced from reviewed guidance documents
	ADDITIONAL EXPERT-BASED TOPICS				
10	Does the assessment incorporate **local knowledge** or spatial data to enhance the relevance and accuracy of the analysis?	☐	☐	☐	Based on reviewer expertise
11	Is the **third spatial dimension** (e.g. elevation above sea level, relief, or slope) considered in the ES assessment?	☐	☐	☐	Based on reviewer expertise
12	Are the **methods** used to assess **ecosystem services appropriate** for the **complexity** of the ecosystem services evaluated?	☐	☐	☐	Based on reviewer expertise
13	Are **common frameworks** (e.g. CICES, Essential variables, MAES) considered in order to homogenise comparisons?	☐	☐	☐	Based on reviewer expertise
14	Are **maps** of the study area **recent** and do they reliably document recent land use and land cover changes at a relevant spatial scale?	☐	☐	☐	Based on reviewer expertise
15	Does the assessment include a **sensitivity analysis** to understand the effects of varying spatial resolutions?	☐	☐	☐	Based on reviewer expertise
16	Are the **spatial interdependencies** between different ecosystem services within the study area assessed and reported?	☐	☐	☐	Based on reviewer expertise

	Checklist	Y	N	NR	Comments
17	Have potential **trade-offs** between different **spatial scales** and their implications on ecosystem services been considered?	☐	☐	☐	Based on reviewer expertise
18	Is **temporal variability** in ecosystem services addressed and documented in the assessment?	☐	☐	☐	Based on reviewer expertise
19	Are **metadata** for spatial scales and resolutions included and **following** the **INSPIRE** directive?	☐	☐	☐	Based on reviewer expertise
20	Are the **limitations** on the spatial scales and resolutions clearly identified and justified?	☐	☐	☐	Based on reviewer expertise
21	Are **maps** of the study area used to **visualise** the assessment **results**?	☐	☐	☐	Based on reviewer expertise

Approach to checklist compilation

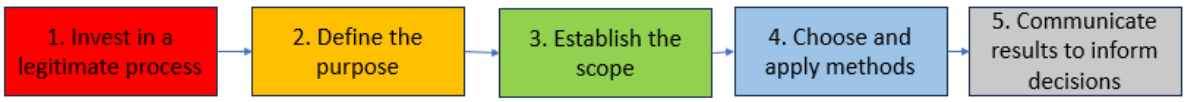
The checklist for sensibly addressing spatial scaling and resolution capabilities in a robust ecosystem services assessment has been compiled based on information that has been collected during the review process on guidance documents described in the SELINA M08 report. Insights from established proceedings and practical applications found in the guidance document were queried through closed and free text questions. Furthermore, the reviewers complemented this list based on their own expertise. All assumptions were synthesised and rephrased into 21 questions aiming to ensure a comprehensive, practical, and widely applicable checklist that increases the uptake of findings from ecosystem services assessments in decision-making processes.
One key outcome is to **be very transparent and explicit** about the spatial scale, spatial dimensions, spatial resolution, spatial dynamics, applied indicators and frameworks, uncertainties etc. in order to improve the comprehensibility of the assessment.

Expected limitations and possible improvement

While the checklist provides some aspects to strengthen the spatial scaling and resolution capabilities of ecosystem services assessments, it also contains some potential limitations when applied by practitioners in real world cases. In practice, it is often not the most suitable ES assessment that will be carried out, but a lack of time and resources makes it necessary to evaluate the feasibility in the respective scope. Even if practitioners have decided on the most suitable spatial scale and spatially explicit indicators with a meaningful resolution, the lack of data availability or accessibility may cause an impassable barrier. For now, no guidance on the most suitable, best-use indicators for different spatial scales and different purposes or suggestions for openly available datasets. Additionally, the background and expertise of the practitioners in case studies will most likely be very heterogeneous. Combined with the often inconsistent use and understanding of certain terms and concepts in the ecosystem services domain, we see a high risk of misunderstanding or misinterpretation of certain pieces of advice. Hence, we strongly recommend case studies to use the established Glossaries alongside as a common basis. The creation of meaningful, visually appealing maps (related i.a. to questions 12-13) requires specialised GIS knowledge. Moreover, the map users, notably decision makers, should be cautious when using ecosystem services maps for decision making and ensure they fully understand what is shown and what limitations and uncertainties come with the respective assessment. It is advisable to not only rely on a single map.

Some of the questions in this checklist should be mandatory, while some of the more specialised questions may be optional and depend for example on the purpose of the assessment or the chosen spatial scale. This could be tested by concrete use cases within case studies and adjusted in the future. Moreover, the checklists would profit from an iterative feedback mechanism to constantly refine and update them as well as from good-practice examples potentially linking the identified questions specifically to the realisation in the assessment to provide clarification.

S7. Uncertainty assessment



	Checklist	Y	N	NR	Comments
1	Does the study **validate** the ES model? (e.g. model intercomparison, external observations, sensitivity analysis)	☐	☐	☐	Sourced from reviewed guidance documents
2	Does the study use **multiple models** leading to a range of outcomes?	☐	☐	☐	Sourced from reviewed guidance documents
3	Does the study perform **model ensembles**?	☐	☐	☐	Sourced from reviewed guidance documents
4	Does the study **use data** of appropriate **accuracy** (temporal, spatial resolution)?	☐	☐	☐	Sourced from reviewed guidance documents
5	Does the study use **scenarios**?	☐	☐	☐	Sourced from reviewed guidance documents
6	Does the study **monitor risks**?	☐	☐	☐	Sourced from reviewed guidance documents
7	Does the study include contingency measures to offset risks of high uncertainty in model outcomes, e.g. risk multipliers.	☐	☐	☐	Sourced from reviewed guidance documents
8	Does the study use the **precautionary principle**?	☐	☐	☐	Sourced from reviewed guidance documents
9	Does the study communicate uncertainty in the assessment results through **levels of uncertainty**? *(e.g. Action A is 80% likely to have a certain impact.)*	☐	☐	☐	Sourced from reviewed guidance documents
10	Does the study communicate uncertainty in the assessment results by **expressing variation** in the results?	☐	☐	☐	Sourced from reviewed guidance documents
11	Does the study explicitly state the **simplifying** (model) **assumptions** and underlying uncertainties?	☐	☐	☐	Sourced from reviewed guidance documents
12	Does the study collect information during policy implementation? (allowing for **iterative** improvements of the model)	☐	☐	☐	Sourced from reviewed guidance documents
13	Does the study take uncertainty into account by using **adaptive planning**?	☐	☐	☐	Sourced from reviewed guidance documents

S8 Full list of publications reviewed on ES assessment guidance

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