D4.2 Diagnostic of ES model decision-support capabilities

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1 Preface

The importance of biodiversity, natural capital and healthy ecosystems and the services they provide 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 (e.g. SEEA EA), 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 et al. 2020) 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 D4.2 "Diagnostic of ES model decision-support capabilities" presents the results of a diagnostic exercise of ES model applications in SELINA Demonstration Projects and Test Sites. This includes an application and refinement of diagnostic checklists for ES model applications with the goal of assessing their fitness for uptake in decision-support, a presentation of best practice cases of ES model applications for distinct types of ecosystem services, and a presentation of draft Terms of Reference for ES model applications optimised for decision-support.

2 Summary

The growing number of ecosystem services model applications is justified by models' ability to provide information on the interrelations between human activity, ecosystem functioning and societal wellbeing. This information can potentially aid stakeholders in improved public and private decision-making on the management and restoration of ecosystems. However, literature reviews show that documented uptake of ecosystem services model applications in decision-making processes is limited. To improve the likelihood of uptake of ES model applications in decision-making, SELINA Work Package 4 has adopted a diagnostic approach to assessing ES model applications' suitability for decision-support. This SELINA Deliverable 4.2 technical report presents the results of work done to diagnose a range of ES model applications for their suitability for uptake in decision-support.

The work presented in this report builds on Deliverable 4.1, in which a set of diagnostic checklists was presented across a range of topics judged to increase the likelihood of uptake. These checklists were developed by a combination of literature review of guidance documents on ES assessments and expert judgement of SELINA consortium members. They cover the following topics:

- Inclusion of ecosystem condition variables in ecosystem services models
- Ability to assess ecosystem services capacity, potential, supply and demand
- Spatial and temporal scaling and resolution capabilities
- Inclusion of uncertainty analysis and information costs
- Social benefit compatibility
- Health benefit compatibility
- Economic valuation compatibility

Following the development of these diagnostic checklists, ecosystem services groups were formed, consisting of SELINA consortium members involved in ecosystem services modelling applications in Demonstration Projects and Test Sites. Each group was focused on a specific group of ecosystem services. The aim of these groups was to test the diagnostic approach on real-world modelling applications, to define best practice examples within their group that show high likelihood of uptake using the diagnostic approach, and to develop draft Terms of Reference for uptake-enabled ecosystem services modelling. This report presents the results of this work, including best-practice examples and draft Terms of Reference for improved decision-support capabilities, produced by each of the following groups:

- Hydrological and water quality related ecosystem services
- Climate and air quality related ecosystem services
- Amenity and recreation related ecosystem services
- Agriculture and forestry related ecosystem services
- Fisheries, aquaculture and marine harvest ecosystem services

The report further describes the learning points taken from the diagnostic process, the planned steps forward towards developing common Terms of Reference in collaboration with SELINA stakeholders, and the contributions of the findings from the work to knowledge building across SELINA.

3 List of abbreviations

CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
CoP	Communities of Practice
CO_2	Carbon dioxide
DP	Demonstration Project
DALY	Disability Adjusted Life Years
EC	Ecosystem Condition
ES	Ecosystem Services
EU	European Union
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
LULC	Land-use / Land-cover
MAES	Mapping and Assessment of Ecosystem Services
NRL	Nature Restoration Law
SEEA EA	System of Environmental Economic Accounting - Ecosystem Accounting
TS	Test Site
ToR	Terms of Reference

4 Introduction

4.1 Ecosystem services models and uptake

Models for assessment and mapping of ecosystem services (ES) are increasingly used (Chan & Satterfield, 2020) and integrated into institutional frameworks as useful information sources for decision-making (United Nations, 2021). ES models typically estimate a quantified flow of ecosystem services from a study area, either in biophysical units alone, in monetary terms, in other measures of societal benefit, or in a combination of these. They can come in a variety of forms, depending on the purpose and scope of the model design. For example, some are based in ecological modelling, such as phenomenological models or trait-based models, some are based on hydrological modelling of flood risk, and others are based on modelling socio-economic interactions, such as travel cost analysis. The MAES Methods Explorer gives an overview of the breadth of models used for ES mapping and assessment.

The main argument for the usefulness of ES models is that increased knowledge of the role that nature plays in our economic system and in broader societal wellbeing helps to steer decisions in a direction that maximises economic and social welfare, taking into account the values that ES provide society. This trend has led to increasing numbers of ES modelling applications being performed in a variety of decision-making contexts (Brander, de Groot et al. 2024). However, recent literature reviews have shown that the vast majority of ES assessments do not clearly communicate how they are relevant for policy: literature reviews in the IPBES Values Assessment found that less than 5% of ES studies have reported documented uptake of their findings in decision-making (Barton et al.2023, Termansen et al. 2023). If ES modelling applications are to play a useful part in decision-support, the enabling factors for this need to be clearly defined and feed into guidance on best practices for ES assessment for increased likelihood of uptake in decision-making.

The SELINA project builds on previous frameworks for mapping and assessment of ecosystem services (MAES), ecosystem accounting and the IPBES plural valuation to advance the use of ecosystem services models to inform instrument design and decision-support in policy and planning. SELINA is organized into 3 “strands” of research: A: Engaging stakeholders; B: Understanding ecosystems and their services and C: Informing decisions on the ground in demonstration projects. This report provides examples of how clarification of ES assessment purpose (strand C) is needed for ‘best practice’ design of ES assessment (Strand B). The report is written from the perspective of SELINA researchers as ES assessment practitioners or suppliers of knowledge.

SELINA D4.1 presented the results of a literature review of 111 guidance documents on ES assessment, which together with expert assessment from the SELINA consortium led to the development of draft checklists for diagnosing ES model applications’ fitness for use in decision-support. This literature and expert judgement-based approach clarified the importance of the role of condition-enabling ES models for improving decision-support capabilities. In addition, a manuscript for a scientific publication currently under development in this Work Package indicates how improving model performance across these diagnostic topics can reduce uncertainty of the model outputs and their relevance for decision-support.

This report presents the results of a diagnostic exercise, in which SELINA Demonstration Projects (DP) and Test Sites (TS) applied diagnostic questions across 7 study design topics to a range of ES model applications. The aim was to revise, consolidate questions into draft template Terms of Reference (ToR) that can be used to commission and design 'best practice' ES modelling for improved decision-support. These ToR define how to apply ES models most effectively for decision-support by supplying guidance in the form of checklists on the choice of methods, input data, and links of the output to decision-making information needs. This diagnostic approach takes as a starting point the draft checklists for ES model diagnosis as developed in D4.1. These were then tested on specific ES model applications within five ES groups. Each of these groups focused on a specific type of ecosystem services.

By diagnosing real world ES model applications using the diagnostic approach, each of the ES groups produced revised and improved diagnostic checklists and was then able to present best-practice examples of ES modelling applications for decision-support. The final output of this exercise was the creation of draft Terms of Reference for ES assessment design, based on the refinement and revision of the checklists by applying them to real world ES model applications.

A more detailed description of the methods used is presented in the following chapter.

4.2 Objectives

The work presented in this report has the overarching objective of creating a knowledge base for guidance on enabling ES models for decision-support, by starting from the latest state-of-the-art on the links between ES model design and likelihood of uptake in decision-making, diagnosing ES models in collaboration with DP and TS representatives and drafting a template for best practice applications of ES models for decision-support. The results of this diagnostic exercise will allow for creating guidance that gives government and businesses the capabilities to commission appropriate ES model applications to meet the reliability requirements of different generic decision-settings within the policy cycle.

This objective can be broken down into the following operationalised sub-objectives:

- To refine the diagnostic approach for ES model decision-support capabilities by testing and revising diagnostic checklists in model applications across five ES groups.
- To provide one or more best practice examples of ES model applications for each ES group.
- To develop draft Terms of Reference for improved decision-support of ES models, based on the revision of the diagnostic approach and the findings from best practice ES model applications in the ES groups.

4.3 Place in SELINA

This Deliverable is a building block in SELINA's **Strand B** (Understanding ecosystems and their services) that further develops our knowledge on how to choose and apply ES models for best decision-support capabilities. Building on the knowledge building work in **Task 4.1**, draft Terms of Reference were developed in a collaboration with representatives of SELINA's Demonstration Projects. These draft ToR will be further developed into general guidance on enabling ES models for decision-support in **Task 4.3** by synthesising the work presented in this deliverable with stakeholder decision-support needs identified in the Communities of Practice (CoP) in **WP2,** leading to co-created ToR for different stages in policy and project management cycles. The contributions of stakeholder decision-support needs from the CoP also serve as documented uptake for the best practice ES model applications. These ToR will feed into the Framework for Integrated Ecosystem Assessment under development in **Task 6.4** as methods for designing an integrated ecosystem assessment. The ToR will also be included in the SELINA Database, developed in **Task 6.6.** More information on how this deliverable contributes to knowledge building in SELINA can be found in Chapter 7. The next steps of WP4 and the SELINA project will validate study design recommendations discussed in this report with stakeholders in Communities of Practice, emphasizing strand A.

4.4 Relevance for decision-support

The results of the diagnostic exercise presented in this report serve to provide the basis for guidance on how to apply ES modelling for decision-support. By testing the diagnostic method in practice in applications that have active decision-maker participation, the results show how decisions in nature restoration and ecosystem management can effectively include knowledge on ecosystem services. By linking ES model applications to different stages in policy and decision-making, knowledge generated by modelling ecosystem services can be effectively applied to inform agenda setting, policy formulation, policy adoption, policy implementation and policy evaluation. Providing information on ecosystem services across this policy cycle can help steer society to reaching the goals set out by the Kunming-Montreal Global Biodiversity Framework and the implementation of the EU's Nature Restoration Law.

5 Methods

5.1 Method for Diagnosing ecosystem services model applications

5.1.1 Diagnostic checklists

The starting point for defining best-practice ES model applications was a series of checklists presented in SELINA D4.1. These checklists were developed using a literature review of 111 guidance documents on ES assessment and expert assessment by SELINA consortium members. Their aim was to define the requirements for ES model applications for enabling effective decision-support according to the current state-of-the-art. The checklists were grouped in seven diagnostic topics, each of which represented a theme that was judged to increase the legitimacy, salience, credibility, and timeliness of an ES model application **(Fig. 1)**. **Table 1** gives a description of the seven diagnostic topics and their links to decision-support. **Fig. 2** gives an overview of their interrelations. This figure highlights the inclusion of ecosystem condition metrics in ES models as a key enabling factor in optimising model applications for decision-support, as well as the overall goal of reducing uncertainty about outcomes of ES assessment.

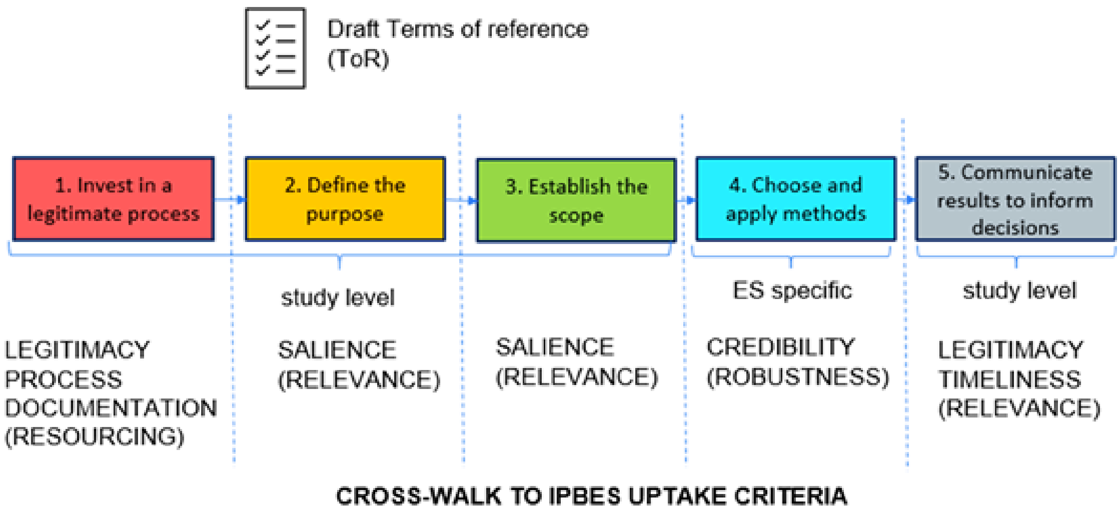


Figure 1: Diagnostic topic checklists were classified according to the plural valuation steps recommended by the IPBES Values Assessment (Termansen et al. 2023).

Table 1: An overview of the diagnostic topics and their hypothesised links to increased likelihood of ES assessment uptake in decision-making.

Diagnostic topic name	Links to decision-support
Inclusion of ecosystem condition variables in ecosystem services models	Using indicators that describe the condition of the ecosystem in models as explanatory variables for generating ES can support setting policy targets on restoring or maintaining EC by assessing effects on ES, as well as for evaluation of nature restoration projects to include effects on ES.

Ability to assess ecosystem services capacity, potential, supply and demand	Ecosystem services capacity and potential are defined by ecosystem extent and condition. Supply and demand include socio-economic factors by considering human-nature interactions that generate societal benefits. Using knowledge on all these factors separately, decision-makers can identify bottlenecks and gaps and create targeted measures for each of them more effectively.
Spatial and temporal scaling and resolution capabilities	The potential supply of ES from an area is influenced by its surroundings. Additionally, the location and timing of ES supply and ES demand can differ. Knowledge on the spatial and temporal dynamics not only reduces ES model outcome uncertainty but can help decision-makers set effective targets by considering effects over space and time.
Inclusion of uncertainty analysis and information costs	Uncertainty in the model assumptions and accuracy of data inputs and outputs informs the risks of implementing or evaluating policy. In combination with knowledge on the cost of generating ES information it can be used to assess whether the benefits of more effective decision-making outweigh the costs of improving ES methods.
Social benefit compatibility	Social benefits of ES include access to the basic materials of a good life required to sustain livelihoods, sufficient food, shelter and access to goods, as well as health, good social relations and freedom of choice and action. If an ES model can inform on the wider social benefits of ES to society and how they are distributed over different groups, the societal effects of ES-related policy and any social justice-related effects can be better integrated into decision-making processes.
Health benefit compatibility	Interactions with nature provide people with a variety of health benefits. If an ES model makes explicit the links between access to nature and improved physical and mental health, it allows decision-making to better assess the effects of improving the condition of and access to ecosystems on human health.
Economic valuation compatibility	ES can be valued in economic terms using a variety of methods, to reflect either the market value of a good or service provided by an ecosystem, or an estimation of the value of the increase in welfare that an ES provides. If an ES model includes estimates of the economic value of the ES, it allows decision-makers to justify the cost of ecosystem restoration by providing quantitative estimates of the gained benefits, to analyse economic effects of policy alternatives, and to include economic distributional effects into decision-making.

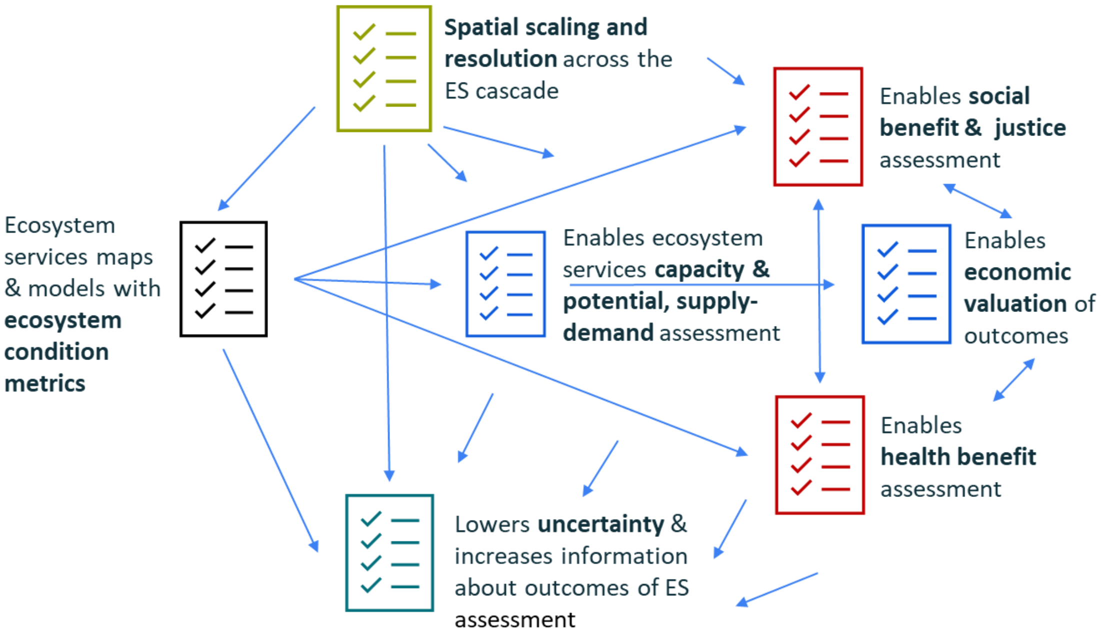


Figure 2: A schematic overview of the seven diagnostic topics for which checklists were developed in D4.1. This figure also shows the interrelations among the topics, with arrows pointing from topics to those topics they enable or strengthen when applied correctly.

5.1.2 Best practices for ES model applications and draft Terms of Reference

Following the development of the diagnostic checklists in D4.1, groups were formed according to types of ES. Each of these groups consisted of representatives of DPs and SELINA consortium members working in Test Sites that had access to model applications for ES relevant to that ES group. The table below gives an overview of the ES groups, the SELINA partner leading each and the DPs and Test Sites involved in each of them.

Table 2: Overview of ES groups, the SELINA consortium member leading the groups, the DPs involved in the groups for testing models and defining best practices, and the geographic range covered by the groups' DPs and Test Sites (note that not all DPs and Test Sites present best-practice cases in this report).

ES group	Lead SELINA partner	DPs represented	Geographic range in testing ES models (DPs and Test Sites)
Hydrological and water quality related ES	NIGGG-BAS	DP03, DP04, DP14	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Israel, Italy

Climate and air quality related ES	WU	DP03, DP04, DP08, DP13, DP14	Belgium, Bulgaria, Italy, Poland, Austria, Greece, Denmark, Portugal (including Azores).
Amenity and recreation related ES	NINA	DP03, DP04, DP07, DP10	Belgium, Croatia, Denmark, Italy, Latvia, Malta, Norway, Poland, Slovenia
Agriculture and forestry related ES	NINA	DP02, DP04, DP12, DP13	Cyprus, Denmark, Estonia, Germany, Lithuania, Poland, Portugal, Spain, Sweden
Fisheries, aquaculture and marine harvest ES	BEF	DP07	Latvia

The process of testing models and defining best practices in these groups was designed to be iterative and inclusive, to allow for a broad variety of knowledge holders to give input into the diagnostic process. Each ES group self-organised their method for refining the diagnostic checklists and defining best-practice example model applications.

Each group had the goal to present at minimum one best practice model application. What is considered best practice can be study and context specific, which meant that for some ES groups it was more useful to present multiple best practice examples, each of which represents a specific decision-support context.

Fig. 3 provides a general workflow overview of the diagnostic task that each ES group followed. The diagnostic checklists developed in D4.1 were first applied to ES model applications in the DPs and TSs. During this process, the checklists were revised and consolidated based on applicability, user-friendliness, and relevance to the tested model applications from the perspective of their study. A common template for consolidation of the checklists into draft ToR was used by all ES groups (Annex 2).

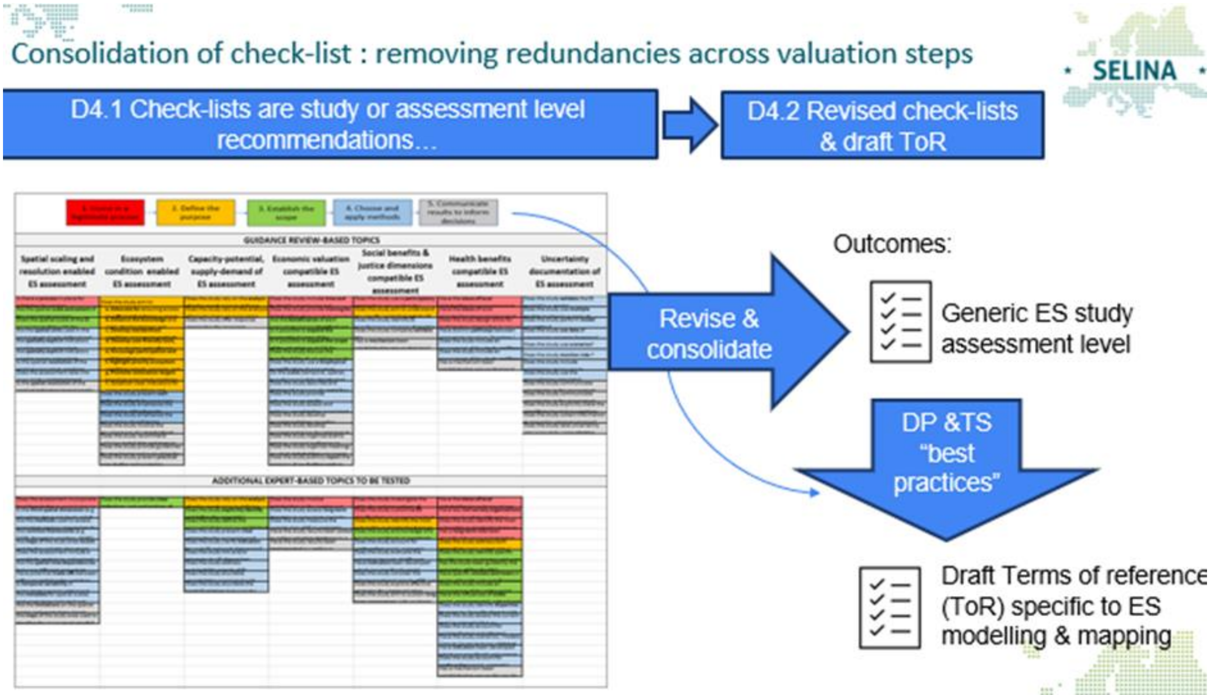


Figure 3: Each ES group uses [a template](#) to consolidate check-lists into a draft ToR focusing on ES modelling & mapping relevant from the perspective of their study.
An overarching objective of developing Terms of Reference templates for ecosystem service assessment is to increase likelihood of uptake by stakeholders.

The definition of best practice for an ES model application includes selecting the right methods depending on the scale and resolution of the available data, as well as the purpose of the stakeholder commissioning the ES assessment. Previously the ESMERALDA project provided guidance on selecting methods based on Tiers (1-3) of increasing data demands (Gret-Regamey et al. 2015). ES method tiers were determined principally by the site specificity of data required for mapping (**Fig. 4**).

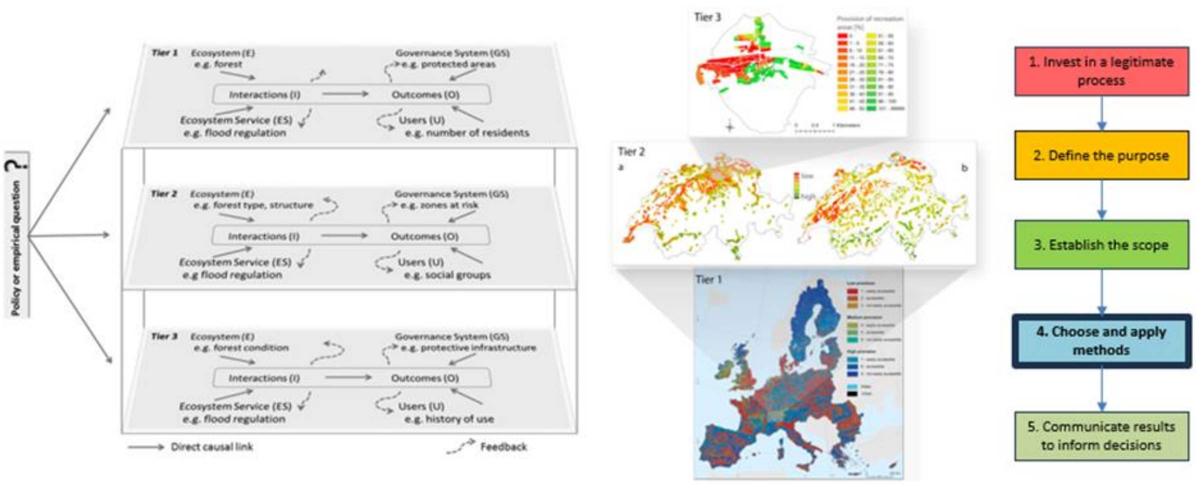


Figure 4: ES method tiers have previously been determined principally by the scale and resolution (site specificity) of data required for ES mapping (Fig. 6) Source: adapted from Grêt-Regamey et al. 2015.

ES groups were requested to revise and consolidate the diagnostic checklist questions from D4.1 to arrive at a shorter and improved list of questions. The purpose of the questions is to guide the commissioning and/or design of ES model application - what we define as a template for “terms of reference” (ToR). This exercise in D4.2 is a step on the way to developing templates for “terms of reference” for different ES model types in D4.3.

Building on ESMERALDAs method tiers approach, SELINAs D4.2-D4.3 work aims to develop ToR templates that take into consideration the knowledge demands of different purposes of ES assessment. Stakeholder expectations for reliability (credibility) of assessments are expected to vary across a policy project cycle (**Fig. 5**), depending on whether the assessment is *to inform*, *to design* interventions/instruments or *to decide* on actions/implementation. This method also aligns with the methods applied in SELINA WP8, in which public Demonstration Projects also assess their decision context within the frame of the policy cycle.

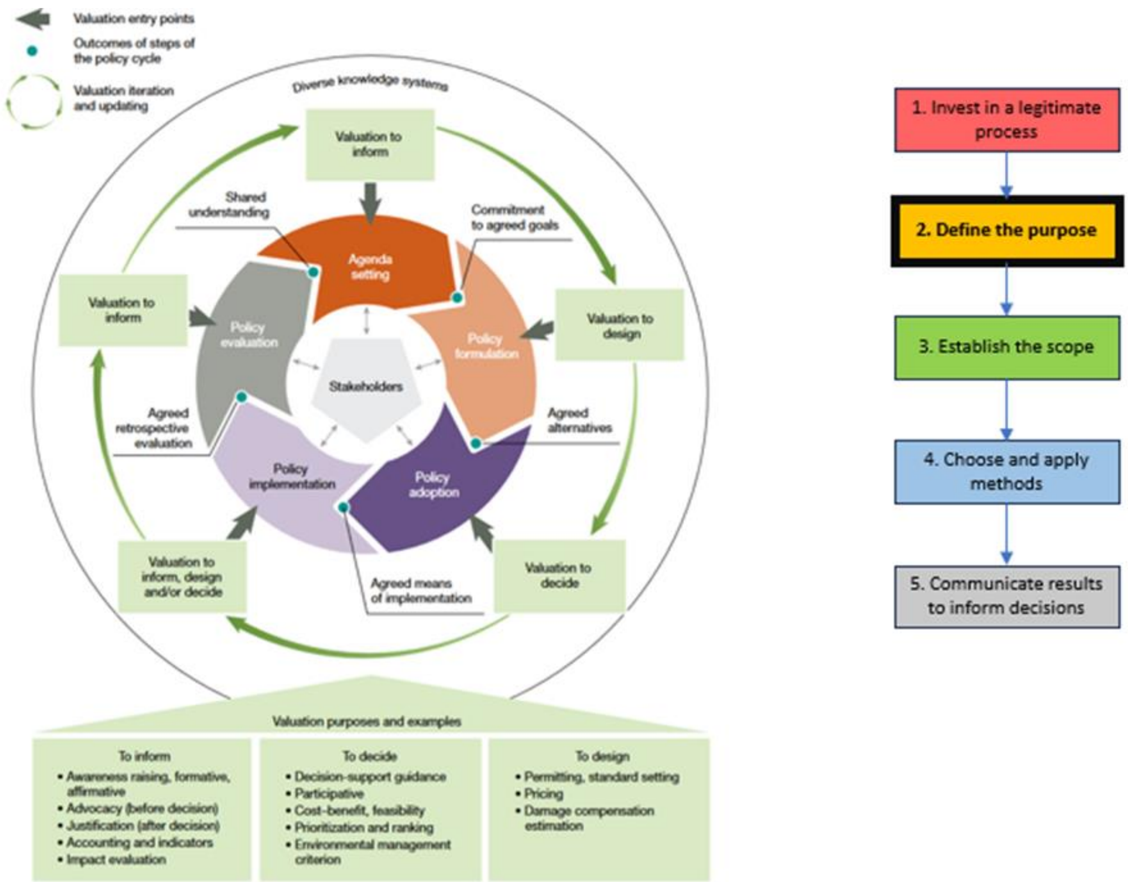


Figure 5: Policy cycle and different purposes and requirements to inform, to design or to decide in the scoping of the ES assessment. Source: adapted from Pascual et al. (2023).

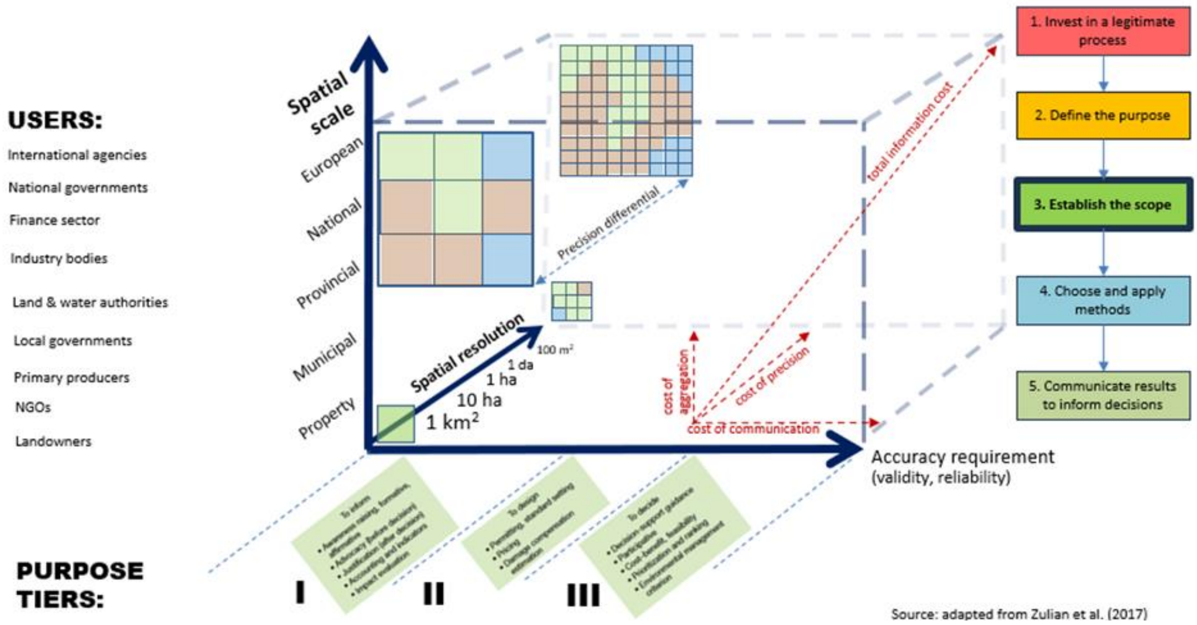


Figure 6: the information requirements of ES assessments and their resource needs/costs are broadly assumed to increase with scale, resolution and purposes from (I) to inform, (II) to design, to decide (III) between interventions/actions.

The assessment by DPs/TS of "best practice" is therefore assumed to be conditional on the purpose of the stakeholder who is commissioning the ES assessment.

SELINAs ES groups contain a diversity of DPs and TSs. Each study specifies the governance level, stakeholder use case and purpose of their assessment when applying the template for consolidating checklists. Case study recommendations for draft ToR are expected to cluster in their recommendations based on study purpose and governance level/stakeholder type (**Fig. 7**).

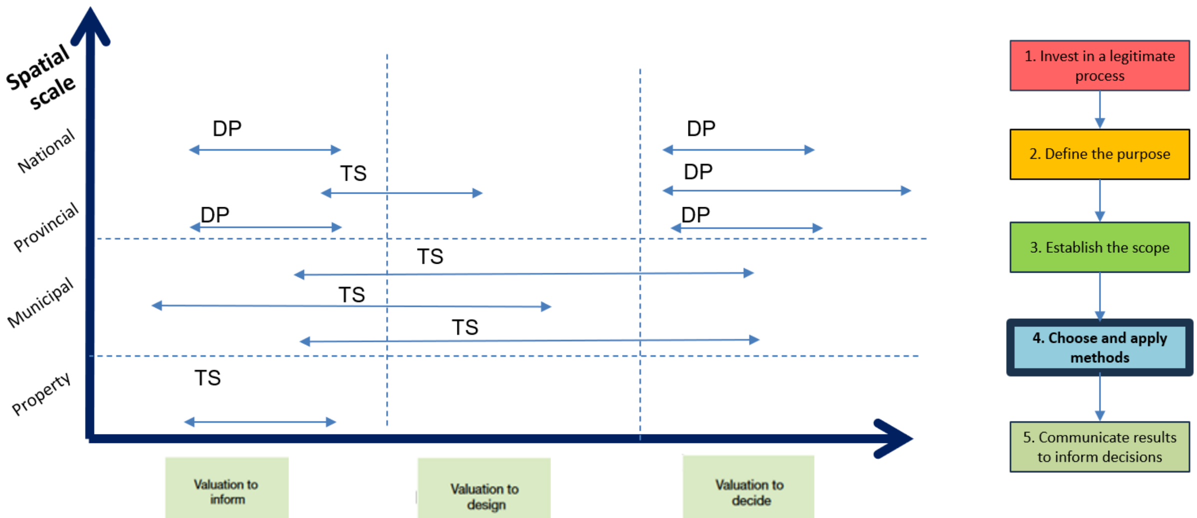


Figure 7: Example. Ecosystem service groups included a mix of demonstration projects (DP) and test sites (TS) which were expected to cluster in their recommendations based on study purpose and governance level/stakeholder type.

The number of different studies tested and their clustering also varied across ES groups. One of the aims of D4.2 is therefore to create an overview of this diversity of ToR recommendations from volunteering DPs/TS. The aim of D4.3 will be to look for systematic patterns within and across ES method groups to develop standardised templates for ToR that can be adapted by stakeholders to specific cases. This work aims to strike a balance between ES and purposes specific recommendations (not too many, but not too few ToR templates either)

Steps for testing 'best practice' diagnostic questions on ES model applications

Each ES group in SELINA Task 4.2 was provided with a common method for testing 'best practice' questions for ES model application in volunteering demonstration projects and Test Sites. Each ES group adapted some version of the following steps to meet the interests and needs of the partners in their group.

The "testing" of the check-list questions from D4.1 against ES applications in demonstration projects and test sites was carried by DP and TS leads in each ES group. In the template each case was asked to use their specific ES models in evaluating each check-list question based on expert judgement. They were also requested to state the end-user of the ES assessment findings, to make the context even more specific. Each DP/TS lead could propose revisions and consolidations of the questions to make the language less scientific / more appropriate for the format of a Terms of Reference template that might be used by a stakeholder commissioning an assessment. Nevertheless, the detailed steps below only result in a consolidated proposal from the perspective of the ES practitioner in SELINA. This is why the output of D4.2 is still titled "draft" ToR. In the next stage of WP4 the language will be further validated with stakeholders in DP and TS sites.

Steps:

1. Develop a graphical illustration of DP/TS ecosystem service model applications using an ES logic chain or cascade. The model illustration facilitates visualisation of the application context in which the questions are tested and refined.

2. Validate and consolidate the selection of checklist questions in each diagnostic topic from D4.1 Supplementary material, focusing on step 4. "Choose and apply methods".

   a. Identify irrelevant method questions in the checklists ("false positives")

   b. Identify missing key method questions from checklists

   c. Feedback from DPs/TS on wording of checklists from yes/no responses to open / method descriptive questions

   d. Feedback from DPs/TS on logical order of questions

The following two steps are planned for the deliverable D4.3 as continuation of this process towards developing Terms of Reference for ES model applications:

3. Standardise the description of the DP and TS method selection descriptions using the SELINA Database descriptors (22 descriptors). Systematic DP&TS feedback on method descriptors.

4. Check consistency of draft ToRs with IPBES VA plural valuation steps (reported in Termansen et al. 2023).

5. Integrate the ToRs templates into the SELINA Integrated Assessment Tool

The "ES logic chains «are used in ecosystem accounting to visualise information flow between accounts and is similar to the ES cascade. To facilitate visualisation of similarities and differences between "best practice" studies, each volunteering DP/TS developed a logic chain of the main data on ecosystem extent, condition (ecosystem types - assets), ecosystem services and benefits (beneficiaries) relevant for the assessment purpose (**Fig. 8**).

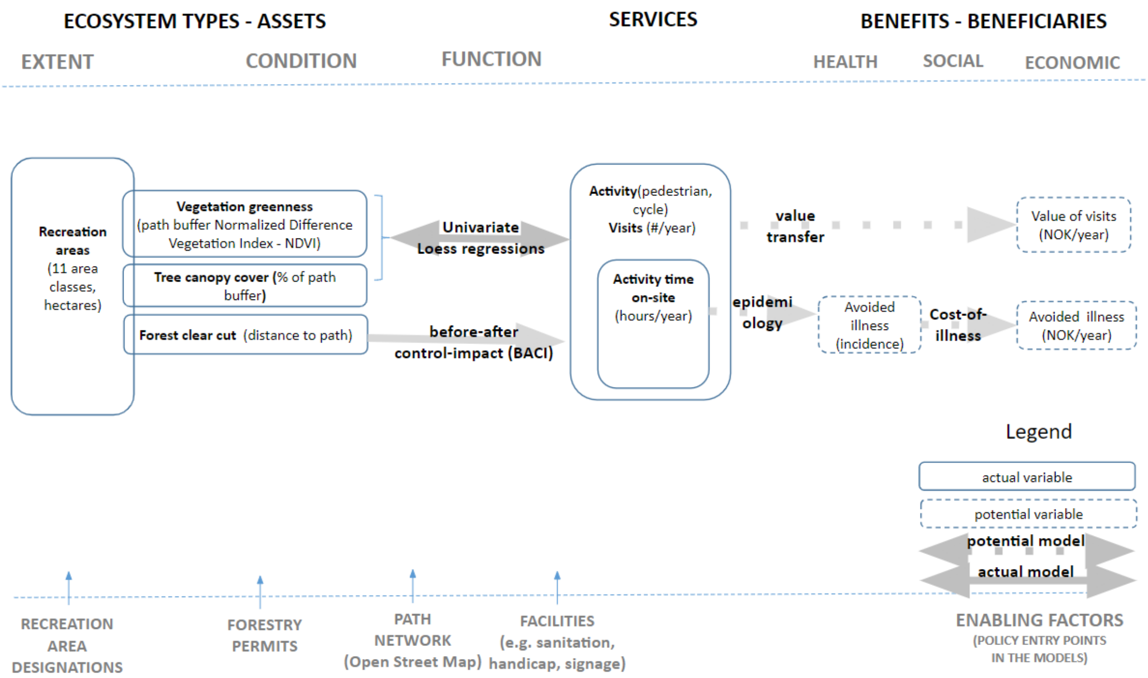


Figure 8: ES logic chain / cascade diagram example of recreation services model application.

Cases in SELINA vary widely in the maturity of ES model applications. Some partners have published a number of applications in previous projects that are being shared with SELINA - this is one of the criteria of "Test Sites" in SELINA. The Demonstration Projects are in some cases still in the process of defining stakeholders needs, decision-support relevant ES indicators and selecting ES models. Volunteering cases were encouraged to illustrate their ES logic chain distinguishing between "actual" and "potential" variables/models. Potential models are under development. This aimed to cover the variation across cases using the same diagrams.

To increase policy relevance of logic chains additional information on enabling factors and economic inputs needed in "co-provision" of the service can also be identified. This provides a basis for thinking about possible interventions/policy to enhance service delivery and benefits.

DPs/TSs were encouraged to develop the visualisation further than a conceptual ES cascade diagram to represent actual or planned ES model applications, identifying key input-output variables, and the ES model type used for operations on the variables. Volunteering DP and TS cases used a template to test and consolidate D4.1 checklist questions on 'methods' (see a template in appendix). The ES groups and volunteering cases were recommended to evaluate the template on an individual case basis, followed by a collation and synthesis of the ES group lead. ES group leads documented the specific approaches used by their group, as some adjustments were needed due to differences in the ES type and the partner composition of the ES groups.

SELINA partners volunteering cases were encouraged to illustrate potential applications that could make their case "best practice" for uptake. "Best practice" is context and purpose specific, understood as being specific to the region or country. To link the definition of best practice to stakeholder needs, each DP/TS was requested to specify the decision-support purpose and the use case/stakeholder they considered when testing the diagnostic topic checklist on their study context. **Table 3** shows an excerpt of the template for this specification exercise.

Table 3: Excerpt from template on specifying the use case for the ToR.

For the purpose of evaluating the **decision-support use case** of your recommendations please specify the type of decision-maker /stakeholder hypothetically commissioning your study and their knowledge need / purpose that you will have in mind when answering the questions below:	<insert user type description> governance level; public/private etc. <main assessment purpose / knowledge need> to inform <specify> to design <specify> to decide <specify>

Some groups assessed the checklist questions according to a 'traffic light' classification (**Table 4)**. After providing responses to each check-list question in the template, the case provided a colour coded evaluation of their perception of the usefulness of this question for a decision-maker hypothetically commissioning their ES model application.

Table 4: Checklist question feedback template.

Checklist question /ToR item	**DP& TS response**
S1-7. Diagnostic topic (from D4.1 supplement)	
Potential ToR question always useful	<insert response>
Potential ToR question useful in some cases	<insert response>
Potential ToR question never useful	<insert response>

Questions that consistently are evaluated as not useful(orange) could be dropped from the list of "best practice" features; questions that are sometimes useful (yellow) could be considered for reformulation to try to increase their relevance.

This approach was intended to help further consolidate the check-list questions into items that could be used in a Terms of reference template

5.2 Overview of tested model applications

Table 5: Each ES group considered a number of ES model applications for testing the diagnostic approach and defining best practices for ES model applications. This table gives an overview of the models considered for testing by the groups, including a brief description and links to additional information sources. For more detailed information on the models, see Annex 1.

Model name	DP/TS location	Model description	Links
Hydrological and water quality related ES			
EPA Stormwater Management Model (SWMM)	DP03 Italy Trento	SWMM is a runoff simulation model used for single event or long-term simulations of water runoff quantity and quality in primarily urban areas, which can explicitly model eight different generic green infrastructure practices.	Information page
ArcSWAT	TS Ogosta river basin, Bulgaria	ArcSWAT is a river basin/watershed scale model developed to predict the impact of land management practices on water, sediment, or agricultural yields in large complex watersheds with varying soils, land, and management conditions over a long period.	Information page
Blue-Green Model	TS Cyprus	The Blue-Green Model simulates long-term, daily soil water balances of crop fields, using the FAO56 dual crop coefficient approach. It computes green water (rain) use, blue water (irrigation) demand and yield reductions of rainfed crops. The model has been applied on a national level in Cyprus, using crop plot data from the applications for the Common Agricultural Policy Single Area Payment	Scientific publication

		scheme, and high resolution gridded soil and climate data.	
HEC-HMS	TS Israel Planted forest ES	HEC-HMS is a Hydrologic Modelling System developed by the U.S. Army Corps of Engineers and is designed to simulate the complete hydrologic processes of dendritic watershed systems following rainfall events.	Information page
Climate and air quality related ES			
Lavbundsområder 3.1.1 (indicators)	TS Denmark Gudenå river catchment	Tool for assessing CO_2 emissions from wetlands based on groundwater level and soil C content.	Scientific publication
Urban Multi-Scale Environmental Predictor	DP03 Italy Trento (Not applied, only considered)	City-based climate service tool that combines models and tools essential for climate simulations. UMEP has broad utility for applications related to outdoor thermal comfort, wind, urban energy consumption and climate change mitigation.	Manual Scientific publication
ENVI-met	DP03 Italy Trento (Not applied, only considered)	ENVI-met is a three-dimensional microclimate model designed to simulate the surface-plant-air interactions in urban environments, used to assess microclimate regulation and air pollution reduction.	Manual Scientific publication
IPCC Guidelines for National Greenhouse Gas Inventories – Tier 1 stock balance method	DP14 International Coca-Cola	A model that assesses change in carbon stock in different pools (biomass, dead organic matter, soil) due to land use change versus a baseline, using C sequestration as an indicator.	Information page
InVEST Carbon Storage and Sequestration	TS Portugal (Azores) & Greece (Peloponnesus)	A model that estimates the current amount of carbon stored in a landscape and values the amount of sequestered carbon over time. It aggregates the biophysical amount of carbon stored in four carbon	Manual

		pools (aboveground living biomass, belowground living biomass, soil, and dead organic matter) based on land use/land cover (LULC) maps provided by users.	
SarCarbon	TS Portugal (Azores) & Greece (Peloponnesus)	A multistep approach based on fusion of remote sensing data to generate carbon stock change maps.	Information page
UrbClim	Not applied, only considered	UrbClim is designed to simulate and study urban heat stress for agglomeration-scale model domains at a high spatial resolution (up to 1m), using the following indicators: UHI, Heat Wave Days, heat-related mortality, lost working days.	Scientific publication
Amenity and recreation related ES			
Condition-service univariate regression	Oslo peri-urban recreation TS	Loess regression with confidence interval of relationship between forest vegetation cover condition-recreation visits	Scientific publication
Before-after-control-impact (BACI)	Oslo peri-urban recreation TS	Impact evaluation of forestry clear-cut on recreation activity	Information page
Condition-service Multivariate regression	Oslo peri-urban recreation TS; Malta nature-based tourism DP	GLM/GMM of qualitative subjective condition variables of designated recreation areas on recreation activity	Report
GIS mapping; survey in preschools, statistical analysis	Poznan schools gardens TS	Statistical modelling of condition variables as predictors of duration, frequency of outdoor activities in contact with nature during stay in preschools.	

Participatory GIS	Malta nature-based tourism DP; Latvia Baltic coast DP	Online and face-to-face PGIS survey of users to identify favourite activities, their geographical distribution, as well as perceived well-being benefits and other aspects important for visits	Information page
Hotspot analysis	Malta nature-based tourism DP	Spatial modeling of social media and citizen science observation densities and labelling	Scientific publication
Recreation supply-demand model	Bosland DP	Bespoke web-based recreation supply-demand model integrating condition variables	
GIS based mapping	Gudenaa River TS	GIS based mapping of preferred land cover types	
Landscape character assessment	Latvia Baltic coast DP	comprehensive indicator-based landscape quality assessment allows pinpointing areas with distinct natural, cultural, and aesthetic significance	Report
Travel cost	Malta nature-based tourism DP	Economic valuation of recreation site demand	Information page
Restoration cost	Malta nature-based tourism DP	Restoration costs distributed by site visitation frequency (cost-based)	
Value transfer	Oslo peri-urban recreation TS	Value of peri-urban recreation visit transferred to from other sites using different types of methods	Scientific publication
Cost-of-illness	Oslo peri-urban recreation TS		Information page
Agriculture and forestry related ES			
ESTIMAP pollination model	TS Germany	The model application focuses on assessing the potential for the regulating ecosystem service 'crop	Scientific publication

	Lower Saxony	pollination', by modelling the potential habitat suitability for wild bees (Hinsch et al. 2024). The modelling approach combines ESTIMAP modules (Vallecillo et al. 2018) with ecosystem condition indicators to increase the sensitivity of model outcomes against changing habitat conditions for pollinators.	
Soil erosion control by forest	TS Northern Portugal	Forest. Based on Morgan-Morgan-Finney soil erosion model, which has been widely used in Portugal. The novelty of this application was to spatially incorporate actual observed fire severity calculated by the satellite Sentinel-A and adapt the parameters from Parente et al. (2022).	Scientific publication
Fodder provision coastal meadows	TS Estonia	Ecosystem types extent and qualities mapping. High resolution plant community types delineation and characterization by field observations of plant species composition combined with UAV multispectral data and Sentinel 2.	Scientific publication Scientific publication
Provision of habitats for native biodiversity (birds), coastal meadows	TS Estonia	Coastal meadows. Mapping of breeding habitats of waders. High resolution plant community types delineation and characterization by field observations of plant species composition combined with UAV multispectral data and Sentinel 2.	Scientific publication Scientific publication
Global climate regulation. Carbon uptake.	TS Estonia	Coastal meadows. Remote sensing enabled proxies of top-soil carbon dynamics.	Scientific publication

Monetary value of cropland food provision	TS Denmark Gudenå basin	Cropland. Based on statistical data. Contribution of 302 crops, 12 years. Soil characteristics (texture and OMC). Correction for human inputs, fertiliser type, irrigation, field size, husbandry density. 100 m grid.	Report Report
Soil erosion regulation, food production, flood regulation.	DP Lithuania	In progress. Soil, topographic, climatic, geographical and human use variables based on GIS-based national level statistics, remote sensing and field observations to develop ecosystem condition indicators. Integrate EC variables into ES models (i.e. soil erosion regulation, food production and flood regulation). GIS statistics and RS enabled condition proxies validated with field observations/sampling.	Scientific publication Scientific publication
Timber and other biomass products from urban-peri-urban forests	TS Sweden Stockholm	Assessment under development.	
Drinking water provision. INVEST/SWAT model	DP 01 Spain	Surface water for drinking. Model development in process. Identifying the interrelationships between ecosystem condition and ES provision using a tiered and tailored approach based on specific context and data availability (considering national vs autonomous communities' datasets).	
Regulation of chemical composition of atmosphere and oceans. INVEST model	DP 01 Spain	Total carbon content and net carbon balance. Model development in process.	
Hydrological cycle and water flow regulation (Including flood control	DP 01 Spain	Identifying the interrelationships between ecosystem condition and ES provision using a tiered and tailored	

and coastal protection). SWAT mode		approach based on specific context and data availability (considering national vs autonomous communities' datasets).	
Soil erosion control. INVEST model.	DP 01 Spain	Identifying the interrelationships between ecosystem condition and ES provision using a tiered and tailored approach based on specific context and data availability (considering national vs autonomous communities' datasets).	
Food production urban agriculture	TS Poland Gorzów Wielkopolski	Model development in progress. Urban Agriculture type - allotment gardens.	
Fisheries, aquaculture and marine harvest ES			
Fish provisioning ES integration in Maritime Spatial Planning	DP 07	Total and per species fish landing are presented at two scales for different spatial units: 1) open sea data – (tons/km^2/year); 2) coastal sea data – per relevant administrative unit, up to 20 m depth. The fish landing maps represent annual and longer time periods, spanning at least 10 years, as the spatial fish abundance between years might change due to climatic parameters. Fishermen's logbooks are the data source used to produce spatial maps on fish landing. The data were processed with R Statistical Software to estimate the total value of fish landings in a grid cell per species. Economic valuation could be implemented using market prices (in process). The spatial model was used for the Latvian MSP development in 2015 (see the link to the publication) and for interim evaluation in 2023 (Deliverable 8.1).	Publication Scientific publication

6 Diagnosis of ecosystem service model applications

6.1 Hydrology & water quality related ecosystem services

6.1.1 Summary of ES group approach

The group started by making an overview of the selected models or approaches from DPs and TSs. It was made by filling a template that contains the main characteristics of the models that were expected to be included in the selection of the “best practice examples”. The template contains five main parts: 1) General information (name; DP/TS; partner); 2) Model information (model name; model type; tier); 3) Case study (case study type; spatial scale; temporal scale); 4. Ecosystem services (water supply; water purification; water flow regulation; flood control; ES supply; ES demand); 5. Methods (social; biophysical; economic). At the next stage the diagnostic questions from D4.1 were assessed for reduction and consolidation according to the specifics of the hydrology and water related ES. The diagnostic questions were arranged into an assessment matrix (**Annex 3**) that contained two parts: 1) assessment of the diagnostic questions; 2) possibility for consolidation. In the first part the members of the group were asked to evaluate the relevance of each question in a three-level assessment scale:

1 - low relevance;
2 - moderate relevance;
3 - high relevance.

The second part contained two columns. In the first one, the possibility for consolidation was evaluated by using a binary scoring 0 for no option to be consolidated with other question/s and 1 for question that could be merged with other question/s. The second column was for the particular suggestions for consolidation where the members of the group were asked to insert the number of the diagnostic topic and the number of the question from the column that they considered for consolidation.

The assessment had been done by seven partners (NIGGG, UniTrento, PLUS, DS, CZEG, CYI, and UoH) (**Annex 3**). The assessment tables were integrated and analysed by calculating average scores and standard deviation of the scores per each diagnostic question. The results were analysed according to the distribution into diagnostic topics and assessment steps. The results per diagnostic topic (**Fig. 9**) show slightly higher scores for S6 but relatively similar scores for all the other topics. There was almost no difference in the scores between the main and additional question.

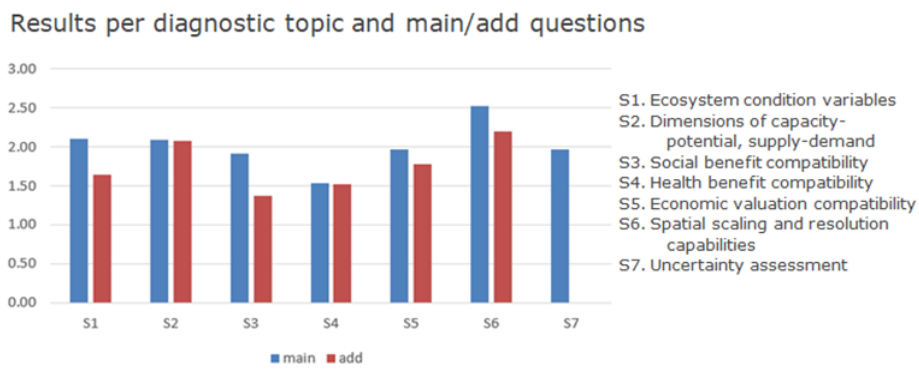


Figure 9: Results per diagnostic topic and main/additional questions (from D4.1).

The results per assessment step (**Fig. 10**) again show quite similar scores between the different steps and the type of question. Therefore, there is reason to apply different approaches based on the diagnostic topics or assessment steps.

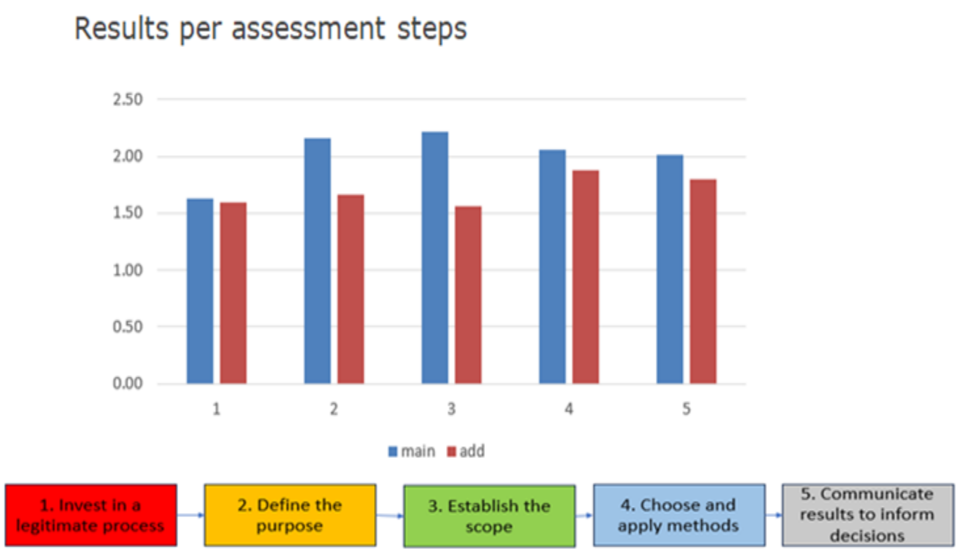


Figure 10: Results per assessment step.

The distribution of the scores (**Fig. 11**) shows that 21 questions have the highest group of scores (between 2.5 and 3) which can be selected as highly relevant to the hydrology and water related ES group.

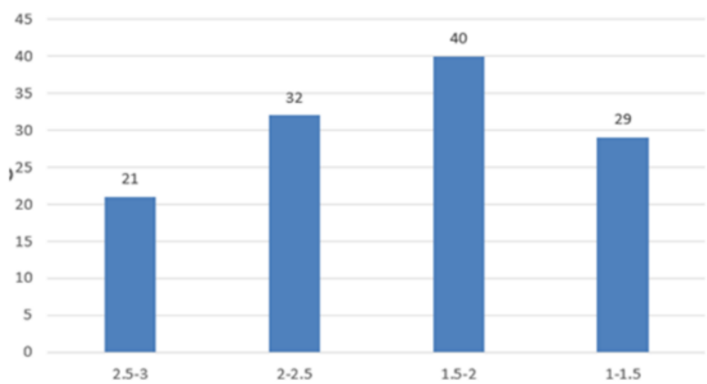


Figure 11: Number of questions per score distribution.

The results about the possibility for consolidation show 92 out of 123 questions suggested for consolidation. The correspondence between the suggestions for consolidation was quite bad which raised several problems to be solved before starting the consolidation procedure. Firstly, there were suggestions for consolidation from different topics and assessment steps. Secondly, there were suggestions for consolidation with two or more different questions. Therefore, the diagnostic questions were grouped according to the assessment score and the suggestions for consolidation into several groups which were cross-walked to reduce the repeating suggestion and to arrange the most appropriate combinations. After several iterations 13 diagnostic questions were selected to the final list without consolidation. The rest of the highly rated questions (8) were combined with one or two other questions suggested for consolidation. Furthermore, the selected 21 questions were cross-walked with the proposed checklist question / ToR item. The resulting checklist for self-evaluation of the models in the hydrology and water related ES group contains 34 questions.

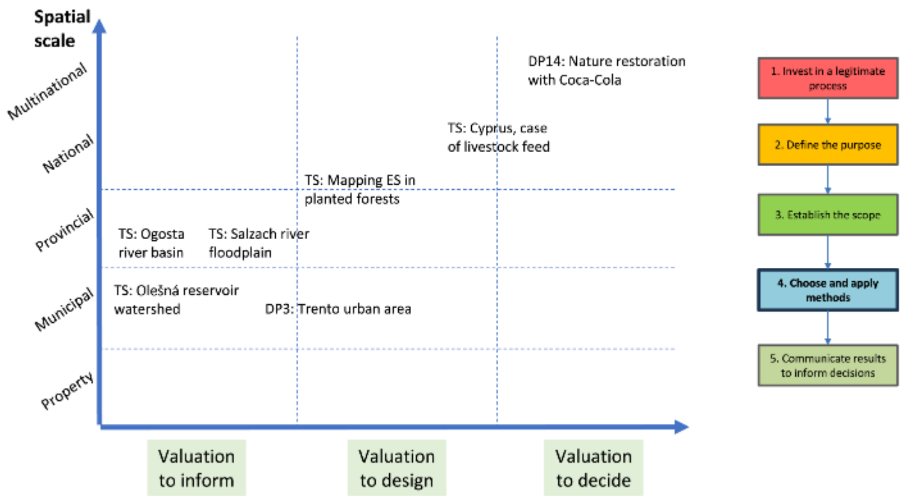


Figure 12: Working group T4.2.1 DP/TS distribution on spatial scale and methods application stage.

6.1.2 Selected "Best practice" model applications testing draft ToR

Best practice case 1: Mapping and assessment of flood regulation ES in Ogosta River Basin (Partner: NIGGG-BAS, Test site 22)

Caption: Ogosta River
Photo: Velimira Stoyanova

The Ogosta river basin Test Site is a part of the field research site developed in NIGGG-BAS during the last 15 years. It combines several previous and ongoing activities and projects (Nikolov et al., 2022; Petkova et al., 2022; Marcheva et al., 2023).

The Test Site covers the upper part of the Ogosta river basin, upstream of the Ogosta reservoir. The basin's area comprises 517.9 km^2 and the elevation is varying from 202 to 2009 m. The Neozoic and Mesozoic underlying rocks of the Ogosta River floodplain in the study areas are covered by alluvial deposits with a two-layer structure: a lower layer built of gravels and boulders with sand, and an upper layer of sandy-clayey deposits. The climate is temperate-continental characterized by relatively warm summers and cold winters. The annual precipitation varies from 600 and 800 mm. For this study, we utilized the ArcSWAT, which is a river basin/watershed scale model developed to predict the impact of land management practices on water, sediment, or agricultural yields in large complex watersheds with varying soils, land, and management conditions over a long period. It requires specific information about the topography, land management practices, vegetation, soil properties, and weather in the watershed. The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. are directly modelled by SWAT using input data. The input information for each subbasin is organized into the following categories: climate, hydrologic response units (HRUs), ponds/wetlands, groundwater, and the main channel draining the subbasin. The assessment of flood regulation supply is based on a 0 to 5 relative scale where: 0 is no capacity; 1 indicates low relevant capacity, 2 relevant capacity, 3 is medium capacity, 4 for high relevant capacity, and 5 for very high relevant capacity. Based on these assessments, estimation values representing the capacity of ecosystem services are calculated. For this purpose, we use the ArcSWAT result table, regarding the HRU (Hydrological response units). For each HRU there is information for a number of different indicators including the specified ones. The calculation of the assessment scores is made by a tool, which extracts data for the specified indicators from ArcSWAT results for a user-preferred date.

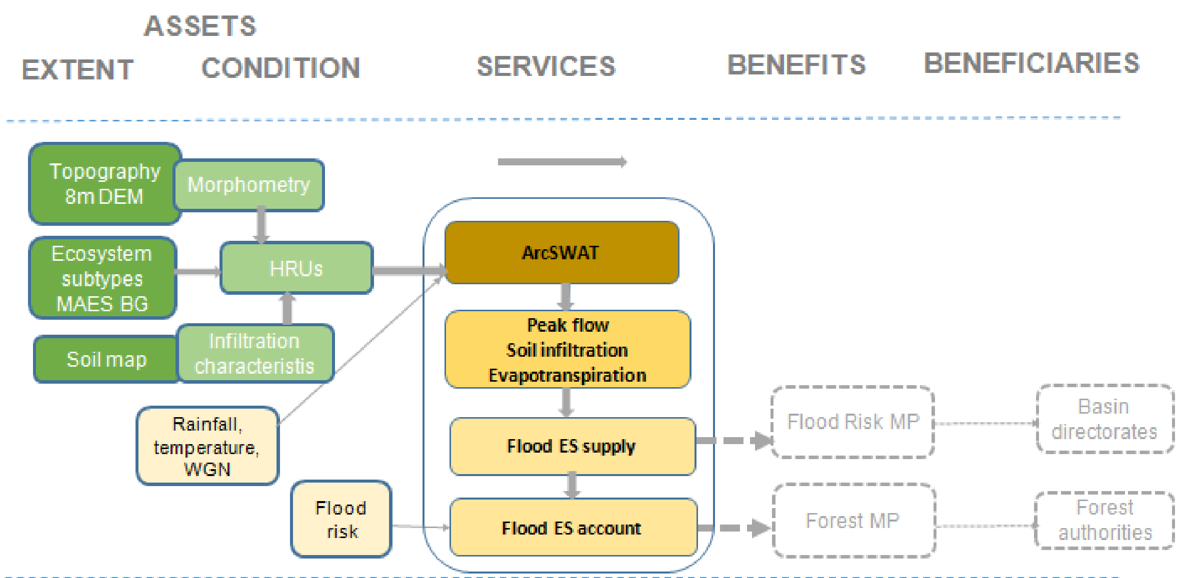


Figure 13: Ogosta river basin Test Site ES assessment chain (model application).

Best practice case 2: Assessment of stormwater regulation to support the drafting of an Urban Greening Management Plan in the city of Trento, Italy (Partner: University of Trento/Municipality of Trento, Demonstration Project 03)

Caption: Trento's urban area
Photo: Municipality of Trento

The Trento Demonstration Project (DP03) builds on previous initiatives to map and assess ecosystem services in urban areas. (Cortinovis & Geneletti, 2020). The DP is currently complementing these assessments with additional information to aid in drafting an Urban Greening Management Plan (UGMP) and regulations for public and private green spaces. The proposal for this plan is motivated by the need to provide a strategic tool for improving the existing coverage of urban green spaces. Furthermore, the plan will use data on current vegetation cover, biodiversity, and other environmental information to facilitate short- and long-term management and strategic prioritisation of interventions, including nature-based solutions (NbS) implementation and sustainable landscaping strategies.

Among the ES modelling efforts that will inform the drafting of the plan, priority is given to assessing stormwater regulation in the valley floor, the most urbanised area of the city characterised by a high concentration of impervious surfaces, including major commercial and industrial areas, as well as residential zones and transport infrastructures. Due to these features, the area is prone to recurring urban flooding events which the UGMP could address through NbS. To support the identification of priority areas and the assessment of possible interventions, the EPA Storm Water Management Model (SWMM) simulation capabilities have been employed in a test area in the northern part of the city. The simulations are currently being expanded to the whole valley floor. This modelling effort can address several diagnostic topics for ecosystem service model design, aligning with the objectives outlined in the Terms of Reference. Due to this reason, DP03 has volunteered to serve as a "best practice" example for the ecosystem service of stormwater regulation.

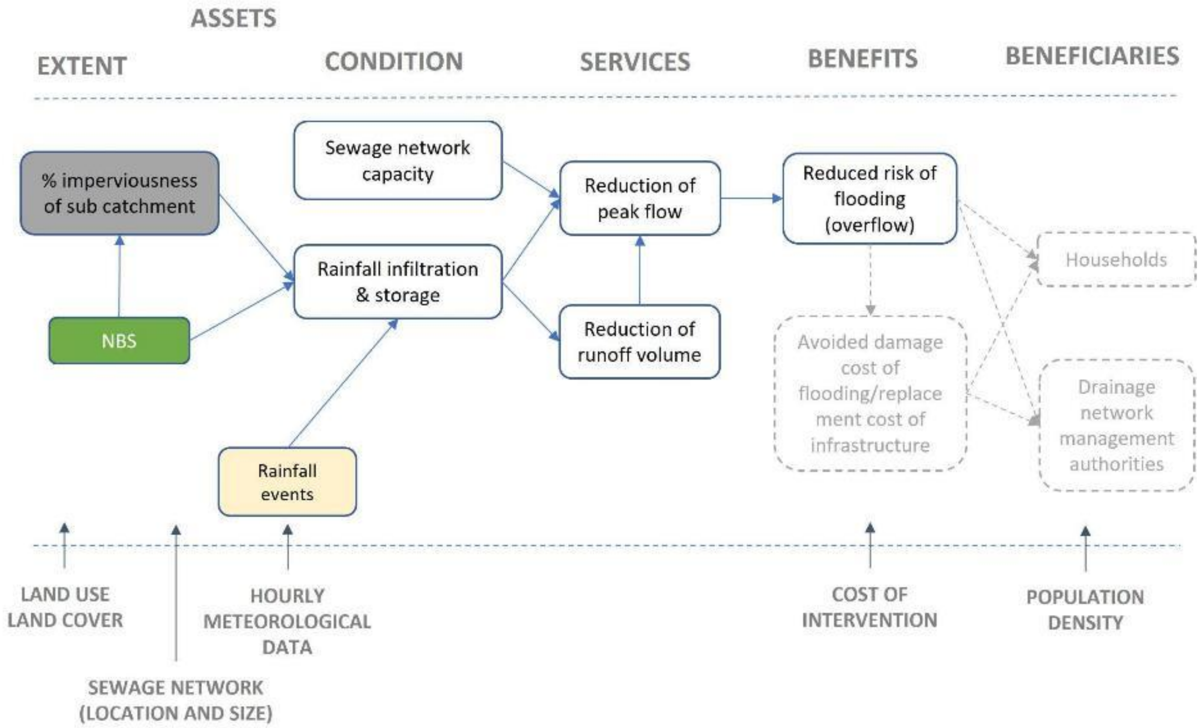


Figure 14: Trento's Demonstration Project ecosystem service assessment chain for stormwater regulation (model application).

The ES assessment chain in **Fig. 14** provides an overview of variables and models being considered for the demonstration project in Trento. The Demonstration Project reflects best practice in urban stormwater regulation ES assessment for the following reasons:

ES models for different application purposes:

- **Identification/prediction of areas at risk of urban flooding:** The model combines information on land cover (permeable vs. impermeable) and sewage network location and size to identify critical areas at risk of flooding under different rain events. By considering expected climate scenarios, the simulation can also predict the risk under future rain events.
- **Combination of green and grey solutions for infrastructure enhancement**: By coupling hydrological and hydraulic performances of different scenarios that consider both nature-based solutions and infrastructure interventions, the municipality can identify the most (cost-)effective strategies or combinations of them for reducing urban flood risk.
- **Impact evaluation of NBS scenarios**: To inform Trento's municipality about the effectiveness of two different types of NbS (green roofs and permeable parking) and alternative spatial distributions for stormwater management and flood risk mitigation. This predictive capability allows decision-makers to plan and design strategies to minimise flood damage.

- **Cost-effectiveness assessment of alternative options**. Even if this has not yet been considered in the testing application of the model, results can be assessed in economic terms considering both the cost of nature-based solution interventions and the avoided costs of flood damages and/or the replacement costs of infrastructure retrofitting.

Diagnostic topics reflecting "best practice" in the case:

(i) Spatial-temporal resolution

Model inputs in terms of drainage network's sub-catchments, conduits, and outfalls were extracted using a 2 m resolution lidar-based digital terrain model and the municipal map of land use land cover complemented by additional information at the same resolution. Modelled rain events were have a duration of 15 mins and return period between 20 and 100 years.

(ii) Uncertainty documentation

This study did not explicitly document uncertainty, but potential sources of uncertainties were identified. The main source of uncertainty lies in the exact location, size, and characteristics of the pipelines, which are largely unknown. Other sources of uncertainty include data limitations (e.g., the actual permeable coverage of residential areas) and model simplification.

(iii) Ecosystem condition enabling ES assessment

The key parameter the model considers in terms of EC is the share of permeable vs. impermeable areas in each sub-catchment. The location and size of the drainage infrastructure are also crucial inputs for the model.

(iv) Capacity-potential-supply-demand in ES assessment

The analysis focused on stormwater regulation supply, examining the impacts of specific types of nature-based solutions like green roofs and permeable parking areas on runoff mitigation. The study progressed from baseline to full implementation scenarios, with nature-based solutions coverage increasing by 10%. Combined scenarios were also considered, with three criteria used for comparison: runoff quantity, peak volume reduction, and conduit fullness. The baseline scenario representing the current conditions provided key information to identify areas at higher risk of infrastructure collapse. This parameter was considered to illustrate those areas with higher ES demand and use to guide the location of nature-based solutions in the scenarios.

(v) Economic valuation compatibility

Even if the study did not address the economic value of flood risk mitigation, the potential economic benefits of implementing NbS for risk reduction are related to their capacity to reduce the frequency and severity of flooding events, hence, to mitigate property damage and lower infrastructure maintenance or replacement costs.

(vi) Social benefits compatibility and dimensions of justice

While social benefits and justice dimensions were not explicitly addressed in the study, the flooding analysis using SWMM generated maps of the areas of the city where flooding events are more likely to happen under the simulated rain conditions. These maps could be used to highlight potential disparities in exposure and susceptibility across different communities and to prioritize the implementation of nature-based solutions where they can have the most significant social impact.

(vii) Health benefit compatibility

The connection between health and urban flooding in the analysed context is not significant, being the outcomes of flood events limited to damages to properties and temporary disruptions to infrastructures. Therefore, the health perspective was not included in the study.

Best practice case 3: Assessment of water flow and quality regulation in the Olešná reservoir watershed under agricultural management scenarios (Partner: Global change research institute of the Czech academy of sciences)

Caption: Olešná reservoir
Photo: Petr Krpec

This test site includes a watershed contributing to Olešná reservoir located in the Czech Republic (area of 33 km^2). This reservoir plays a role in flood prevention, industrial water supply, and recreational activities like swimming and fishing. A hydrological modeling study focused on the Olešná water reservoir watershed uses the SWAT model approximating main hydrological processes and some other in several subbasins and hydrological response units. The model was set up using locally available data encompassing soil properties and agricultural practices. Calibration involved comparing model predictions with observed stream flow and nitrate nitrogen loads, with some assessment also performed on phosphorus and sediment loads. Various agricultural management scenarios, such as no-till tillage, contour tillage, and the inclusion of winter cover crops, were developed to estimate their impact on the reservoir's nitrogen, phosphorus, and sediment loads.

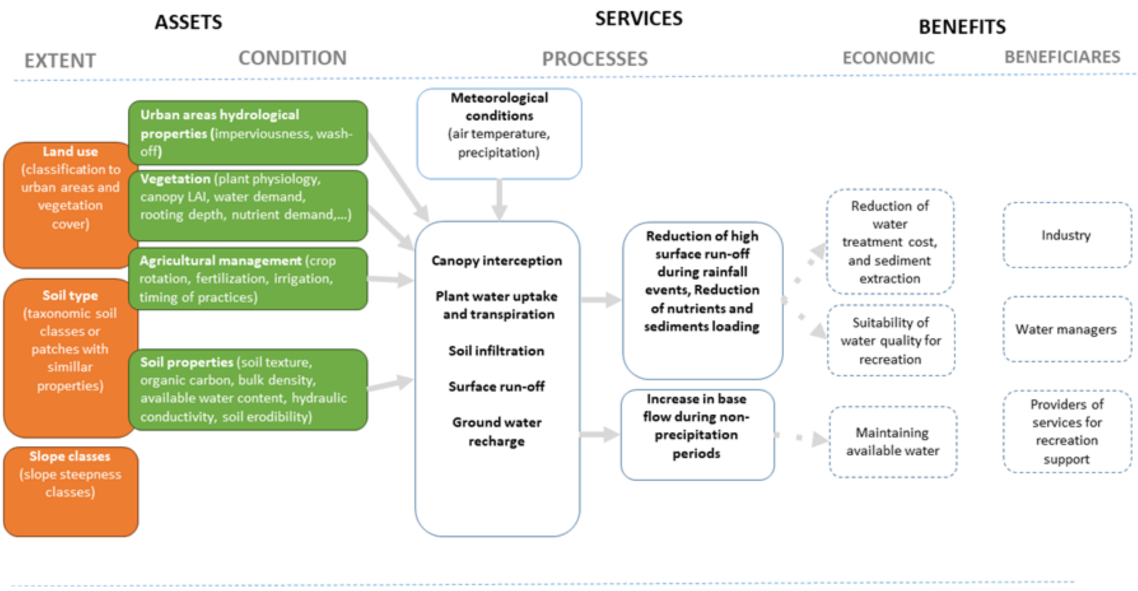


Figure 15: Olešná reservoir watershed assessment chain for water flow and quality regulation (model application).

Checklist applied to this test site:

(i) **Spatial-temporal resolution.** The spatial discretization for hydrological response units (HRUs) was carried out using the most detailed data available. These units, or patches, are expected to exhibit homogeneous responses. Land cover information was derived from the interpretation of current orthophotos. Soil data were generated using a machine learning approach, utilizing locally available legacy data. A high-resolution LiDAR digital terrain model was employed to capture the terrain details. To accurately reflect agricultural management practices in the area, the HRUs were further subdivided into specific fields, allowing for detailed management settings. The temporal resolution for process simulation is set to daily intervals. This approach simplifies significant sub-daily hydrological processes but facilitates long-term continuous simulation over multiple years.

(ii) **Uncertainty documentation.** To reduce uncertainty, the most precise input data available were collected. During the calibration and validation process, model simulation outputs were compared with measured data, and model parameters were adjusted to minimize discrepancies. But exact quantification of uncertainty intervals is not provided.

(iii) **Ecosystem condition enabling ES assessment.** The model simulates a complex structure of ecohydrological processes, including sediment loading and nutrient cycling. It is designed to capture agricultural management in detail, covering aspects such as crop rotation, fertilization, and tillage practices. While the model can also detail soil conditions, this study relies on legacy data due to a lack of current data.

(iv) **Capacity-potential-supply-demand in ES assessment**. The capacity-to-demand chain can be effectively assessed using this approach. Specific patches where regulation services are provided can be identified at the HRU level. The impact of management scenarios can be estimated by modifying particular fields. However, the model lacks a sufficient module for water quality processes in reservoirs, which is necessary for quantifying benefits related to water treatment and recreation.

(v) **Economic valuation compatibility.** If the model can eventually capture effects on water quality, such as nutrient concentrations, algal blooms, and sediment aggradation, it will be possible to assess differences in water treatment costs and the economic benefits of services related to recreation (e.g., food, traffic). This assessment requires collaboration with beneficiaries who can provide insights into the economic benefits for them.

(vi) **Social benefits compatibility and dimensions of justice and** (vii) **health benefit compatibility.** The test site has not addressed social nor health benefits.

Best practice case 4: Mapping and assessment of water regulation service in multi-purpose planted forests (Partner: The University of Haifa, Test-Site)

Caption: Hakdoshim Forest, Jerusalem mountains
Photo: Alon Lotan

Most planted forests in Israel are controlled and managed by the private foundation of JNF. in recent decades, due to natural processes and forest fires, mono-species and even-aged stands are becoming mixed-species and multi-aged ones, making their management more challenging and controversial. According to the JNF Forest Management Policy, the multi-purpose forest areas are supposed to cover most of the area of forest lands in Israel and its main purpose is to provide a variety of ecosystem services, relying on natural processes and minimal management activities. However, the preferred services are not explicitly defined, nor are the appropriate management practices for their conservation and maintenance.

The main goals of that project were: 1) Develop a model to map major vegetation types in JNF managed forests using open satellite data; and 2) Develop a model to map runoff and assess the contribution of JNF managed forests to water regulation service. The project was carried out in four forests that have an approved master plan, in the Jerusalem Mountains and the northern area of Biriya.

Mapping of vegetation types was carried out by using the Random Forest machine learning algorithm based on Sentinel-2 channels, training the model with field knowledge and high-resolution orthophoto of the forest areas. The resulting spatial classification of vegetation was accurate in more than 95% of the validation sites. A final LULC map was created by adding spatial information from additional sources, including the management units of the master plans of the studied forests.

Runoff rates and volumes (indications for water regulation service) were assessed using the HEC-HMS hydrologic modelling system which integrates precipitation and various runoff processes in watersheds. A main character of this model is the Curve Number (CN), reflecting the direct runoff proportion from a given rainfall event. When validated, using permanent hydrometric station's data, the model outputs of most examined rain events showed runoff volumes and hydrographs that matched the actual values, despite the large size and LULC variability of the watersheds.

The developed model was also used to assess the effect of forest fires on runoff by comparing between model outputs before and after the forest fire that took place in the Judean Mountains in August 2021. In this analysis changes in vegetation cover due to fire spatial distribution and severity were taken into account by recalculating the post fire CN.

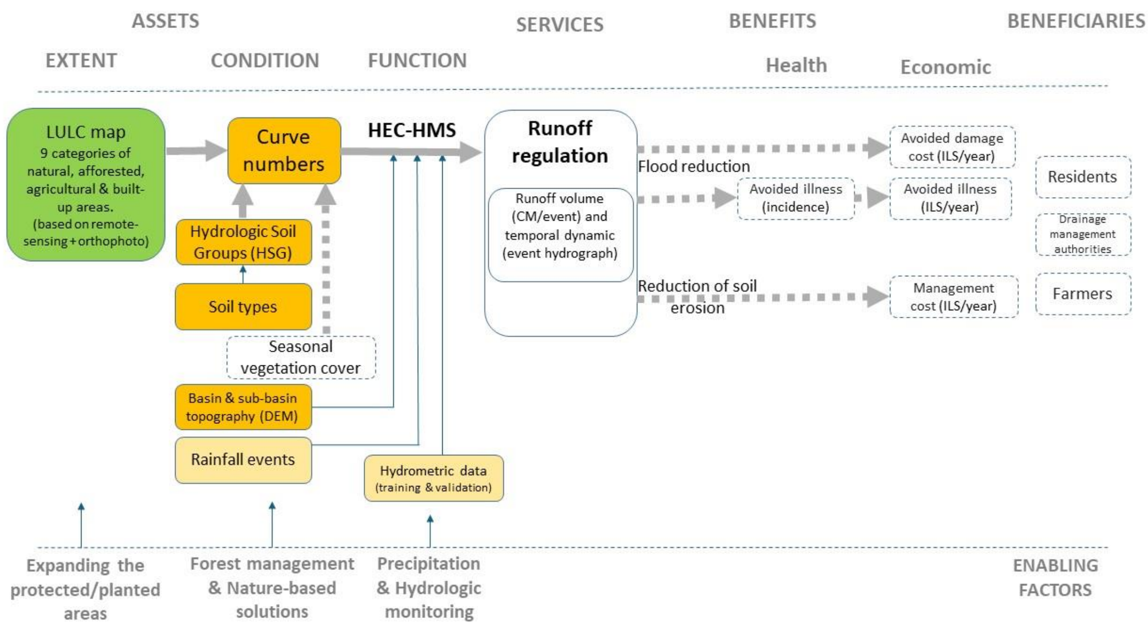


Figure 16: mapping and assessment of water regulation service in planted forest, Israel (model application).

Diagnostic topics reflecting "best practice" in this case:

(i) **Spatial-temporal resolution.**

For modelling water runoff regulation, the most spatially accurate and up to date data were used as the model input: natural and semi-natural vegetation types were modelled using machine learning algorithm based on remote sensing (10m resolution), training the model with field information and high-resolution orthophoto (0.5m). Different types of agricultural land (field crops, deciduous and evergreen grooves), built-up areas and soil map were taken from the national information centre. A DEM layer of high resolution (1m) was used to generate the sub-basins for each examined basin. 10-minutes-intervals of rain event measurements were also used in the model.

(ii) **Uncertainty documentation.**

The model was developed and validated using data from long-term hydrometric stations at several watersheds. Uncertainty was not explicitly calculated in this case, but the differences between model and measured hydrographs were presented.

(iii) **Ecosystem condition enabling ES assessment.**

A main character of this model is the Curve Number (CN), reflecting the direct runoff proportion from a given rainfall event, depending on land cover and soil type. The specific CN for each LULC type (11 types in our case) combined with soil type (classified as Hydrologic Soil Group) was generated by adjusting the respective numbers taken from the literature with local characteristics.

These CN numbers, as well as the developed and adjusted full model can then be used by forest planners and managers to improve their management practice taking into account the effect on the water regulation service. The effect of forest fires can be also evaluated.

(iv) **Capacity-potential-supply-demand in ES assessment**.

The analysis is focused on water flow as an indicator for the supply of water runoff regulation service, assessing the contribution of different LULC and vegetation types to this service. There is no clear approach for assessing other dimensions, however, applying this model for future scenarios or in other forest areas in the region can indicate the potential supply of the service.

(v**) Economic valuation compatibility.**

Using this model, the reduction of soil erosion and flood risks can be also assessed. These two benefits can be economically valued using common methods such as avoided damage cost and management cost, but more information has to be collected in order to apply it.

(vi) **Social benefits compatibility and dimensions of justice and** (vii) **health benefit compatibility.**
The test site has not addressed social nor health benefits.

6.1.3 Draft Terms of Reference proposal from ES group

Table 6: Working group on hydrology and water quality related ES developed draft Terms of Reference for ecosystem service assessment.

ToR questions useful in any context		
Diagnostic topic	**Question:**	
Spatial and temporal scaling, resolution and uncertainty of ES assessments	Does the spatial scale of the ES assessment align with the objectives of the management or policy decision it aims to inform?	Yes/No
Uncertainty	Does the study validate the ES model? (e.g. model intercomparison, external observations, sensitivity analysis)	Yes/No
Uncertainty	Does the study use data of appropriate accuracy (temporal, spatial resolution)?	Yes/No
ToR questions useful in some contexts (or require reformulation)		
Ecosystem condition	Develop standardised condition assessment methods and accessible, interoperable databases to overcome fragmented data inventory reality faced by policymakers?	Yes/No
Ecosystem condition	Does the application establish clear indicators for ecosystem condition and services at national, regional, or local levels for monitoring and evaluation in policy development?	Yes/No
Ecosystem condition	Does the application develop user-friendly tools, such as plugins and software, enabling policymakers and practitioners to analyse, visualise, and interpret data on ecosystem condition and services?	Yes/No

Ecosystem condition	Does the application present well-defined methods for assessing impacts of ecosystem condition on services?	Yes/No
Ecosystem condition	Develop user-friendly tools, such as plugins and software, enabling policymakers and practitioners to analyse, visualise, and interpret data on ecosystem condition and services?	Yes/No
Spatial and temporal scaling, resolution	Does the assessment take into account the spatiotemporal dynamics and potential future changes of ES?	Yes/No
Spatial and temporal scaling, resolution	Are the methods used to assess ecosystem services appropriate for the complexity of the ecosystem services evaluated?	Yes/No
Spatial and temporal scaling, resolution	Are maps of the study area recent and do they reliably document recent land use and land cover changes at a relevant spatial scale?	Yes/No
Spatial and temporal scaling, resolution	Are the spatial scale and extent of the ecosystem services assessment explicitly stated?	Yes/No
Spatial and temporal scaling, resolution	Are spatially explicit indicators used to assess ecosystem services?	Yes/No
Spatial and temporal scaling, resolution	Are spatially explicit indicators used to assess ecosystem condition?	Yes/No
Spatial and temporal scaling, resolution	Is the spatial resolution of the applied ecosystem condition indicators appropriate for the scale of the assessment?	Yes/No

Spatial and temporal scaling, resolution	Does the study develop recommendations for appraisal of alternative policy options?	Yes/No
Spatial and temporal scaling, resolution	Are common frameworks (e.g. CICES, Essential variables, MAES) considered in order to homogenise comparisons?	Yes/No
Spatial and temporal scaling, resolution	Are metadata for spatial scales and resolutions included and following the INSPIRE directive?	Yes/No
Spatial and temporal scaling, resolution	Are the limitations on the spatial scales and resolutions clearly identified and justified?	Yes/No
Spatial and temporal scaling, resolution	Is the spatial resolution of the applied indicators transparently stated?	Yes/No
Dimensions of capacity-potential, supply-demand	Does the study clarify indicators for each ES and each dimension?	Yes/No
Dimensions of capacity-potential, supply-demand	Does the study present clear approaches for assessing each dimension?	Yes/No
Dimensions of capacity-potential, supply-demand	Does the study define the concept(s) following an established standard terminology?	Yes/No
Economic valuation	Does the study use a biophysical quantification of ecosystem services as the basis for the economic valuation?	Yes/No

Economic valuation	Do the scales (temporal, spatial, beneficiaries) of the biophysical quantification of ecosystem services match the economic valuation?	Yes/No
Economic valuation	Does the study develop recommendations on policy responses in light of its findings?	Yes/No
Uncertainty	Does the study elucidate uncertainties associated with each of the assessed dimension(s) (and indicator(s))?	Yes/No
Uncertainty	Does the study explicitly state the simplifying (model) assumptions and underlying uncertainties?	Yes/No
Uncertainty	Does the study assess and address uncertainties associated with the valuation, providing a clear indication of the confidence level in the results?	Yes/No
Uncertainty	Does the study monitor risks?	Yes/No
Uncertainty	Does the study communicate uncertainty in the assessment results by expressing variation in the results?	Yes/No
Uncertainty	Does the study explicitly state the simplifying (model) assumptions and underlying uncertainties?	Yes/No

6.2 Climate & air quality related ecosystem services

6.2.1 Summary of ES group approach

The climate and air quality related ES group worked exclusively with the questions from D4.1 referring to the "ecosystem conditions". A total of four Demonstration Projects and five Test Sites contributed to this working group. While one Test Site volunteered to test the check-list questions on its actual ES model applications, all members tested the checklist at the theoretical level. The case studies modelling climate and air quality related services are highly diverse in terms of scale and purposes of their ES models. They are also diverse in terms of maturity of ES model applications. This presented a challenge in consolidating the check-list questions but also in finding a volunteer to test the checklist on a concrete case.

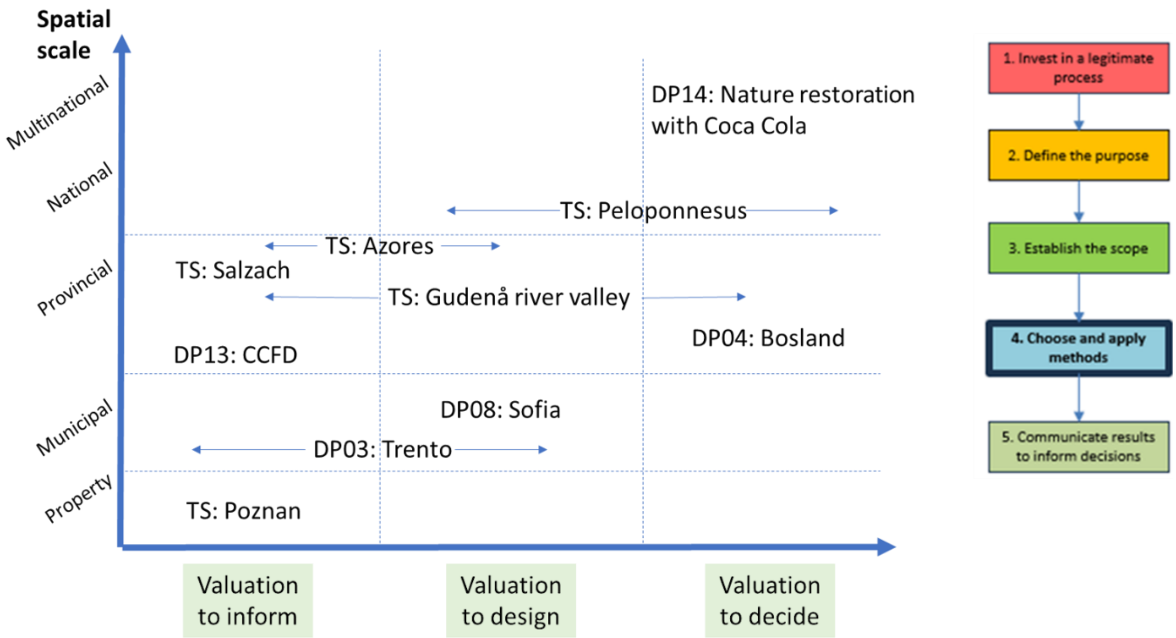


Figure 17: Preliminary representation of the spatial scale and position within the policy cycle of the members (demonstration projects (DP) and Test Sites (TS)) of the climate and air quality related ES working group.

The working group started by making an inventory of the objectives, and methodological approaches among the group members. It resulted in an inventory of all models that were expected to be used or that were implemented. The inventory was complemented with a detailed overview of the methodological bottlenecks encountered by the group members. A peer learning consultation allowed us to solve or contribute to solving some of these challenges.

In a second stage, the working group followed the logical process used to create the D4.1 checklists to establish the criteria which the robust ecosystem services assessment should meet, tailored to the climate and air quality related ecosystem services. This step resulted in a new checklist that covers all parts of assessments (from data to validation), i.e. broader than the ecosystem condition D4.1 checklists. Then, the working group members assessed the D4.1

checklist, on a theoretical level and adjusted it when necessary. The new checklists, generated by the working group, were compared and merged with the adjusted D4.2 checklists on ecosystem conditions.

Finally, after a bilateral discussion, the checklist from D4.2. was tested with a best case practice for São Miguel island, Azores (Portugal), considering the relevant role of this Test Site in the ongoing development of Task 5.2. in enhancing the spatial and temporal resolution of ecosystem accounts, with focus on carbon sequestration accounting. It is worth noting that most of the DPs and TSs in the working group have been in the process of selecting a model or of starting to develop it. For that reason, testing the checklists on them did not seem appropriate.

The creation of the draft ToR was done in two main steps: first the members of the working group brainstormed, based on their experience and respective needs in their DPs and TSs, on what criteria should be met by robust assessment tools meet. This step resulted in 16 checklist questions that were classified under four themes, namely: “Documentation and process”;, “Data”;, “Outputs”;, and “Validation and uncertainty”. In a second step, members of the working group assessed the checklists provided in Deliverable 4.1, with a focus on ecosystem conditions.

Individually, five members of the working group assessed the ecosystem conditions checklists. This step was done at the theoretical level, i.e. without applying them to their own models. Five DPs and TSs scored the relevance of each question, using a 0-5 scale with 0 = not relevant to 5 = highly relevant. Each score was explained and, when necessary, suggestions were made to merge or to reformulate some of the questions. From the five individual scores, the mean score was computed for each of the 15 checklist questions, as well as the number of scores that equalled 0 or 1 (not relevant or very little relevance, respectively) across the five individual scores. Were selected as (very) relevant, Questions that scored 3.8 or more, and had no score = 1 or below, were selected as very relevant. One exception was question #12 on the development of a standardised framework for integrated assessment of ecosystem condition and services. This question scored high (4.0) but was judged as being relevant only in some cases, as some studies may apply or rely on existing frameworks, and therefore may not need to develop any. One question from the original checklists was, judged as irrelevant and was removed (Question #1- “Does the model advocate for ensuring access to sufficient funding to support the implementation of new condition assessment approaches/standards, including training and incorporating new professionals?”).

The two sets of checklists, i.e. the ones resulting from an internal brainstorm and the ones adjusted from D4.1, were merged into a final set of checklists that is tailored to the ES group of climate regulation and air quality.

6.2.2 Selected "Best practice" model applications testing draft ToR

Best practice case 1: Mapping and monitoring carbon sequestration in São Miguel, Azores (Portugal)

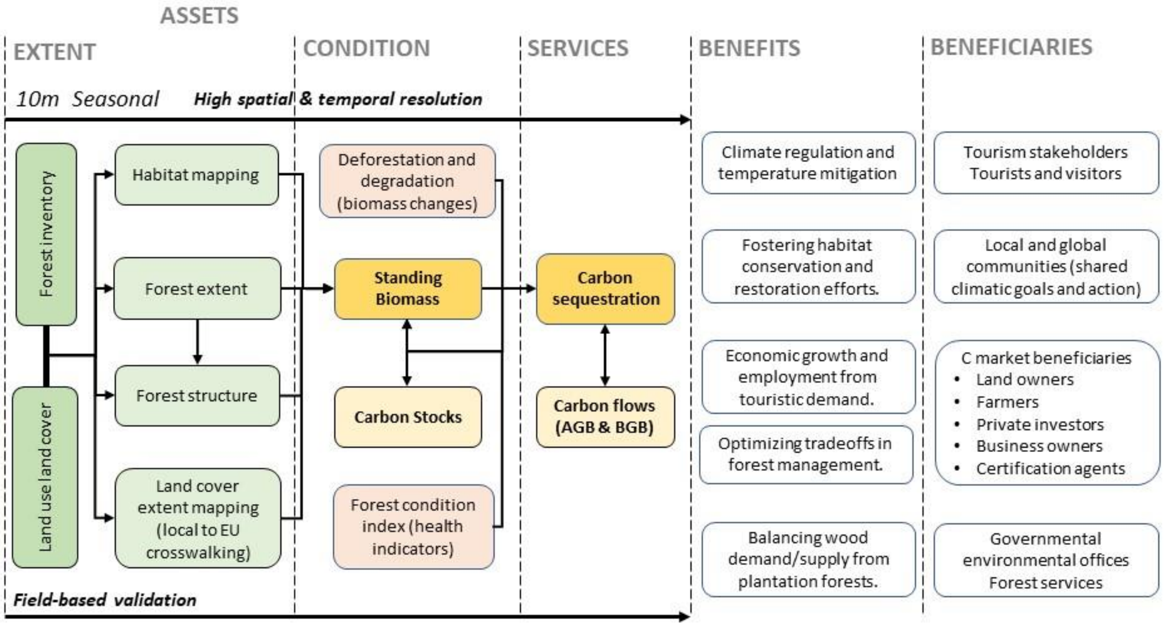


Figure 18: São Miguel Test Site ES assessment chain (model application). Seasonal temporal resolution might be necessary to capture differences between summer and winter. The overall spatial resolution is 10 meters, although both spatial and temporal resolution may vary across datasets. Co-benefits include e.g., maintenance and restoration of biodiversity, are not included in this graph.

The ES assessment chain in **Fig. 18** provides an overview of key variables actually used in the sets of models developed in the Azores TS. The models are still under development being constantly validated and iteratively improved by integration of local knowledge and validation with field data.

ES models for different application purposes (Fig. 19, below)

- **Current and past trends of standing biomass and carbon sequestration (Assessment of vegetation condition-service):** to inform the forestry services and other stakeholders of the conditions and trends of the standing biomass and their impacts of the capacity of trees to sequestrate carbon, as well as on the loss of biomass and therefore of carbon sequestration capacity. Information on carbon sequestration could be linked to carbon market values.
- **Designing policy options:** spatial information on the types of habitats, species mixtures and their ability to sequestrate carbon, may give relevant information to target most appropriate decisions on where to direct e.g., restoration measures like, or afforestation, planting of native species and mitigation of invasive alien species.

- **Biomass (loss) and carbon monitoring**: The new carbon market may lead to an increased biomass cover on the island, with new forested areas (as part of a farmland) and restoration of degraded forests.
- **Impact evaluation of afforestation, restoration, and forest clear-cuts**: to inform forestry services about the impacts of forest dynamics on carbon sequestration.

For all these stages, all models are related to statistical (spatial) analysis of changes over time and space of standing biomass and carbon sequestration, either from past or current perspective, under different policy scenarios. It should be noted that the carbon market is likely to lead to increasing policy interest, which could lead to further intake of the model's outputs.

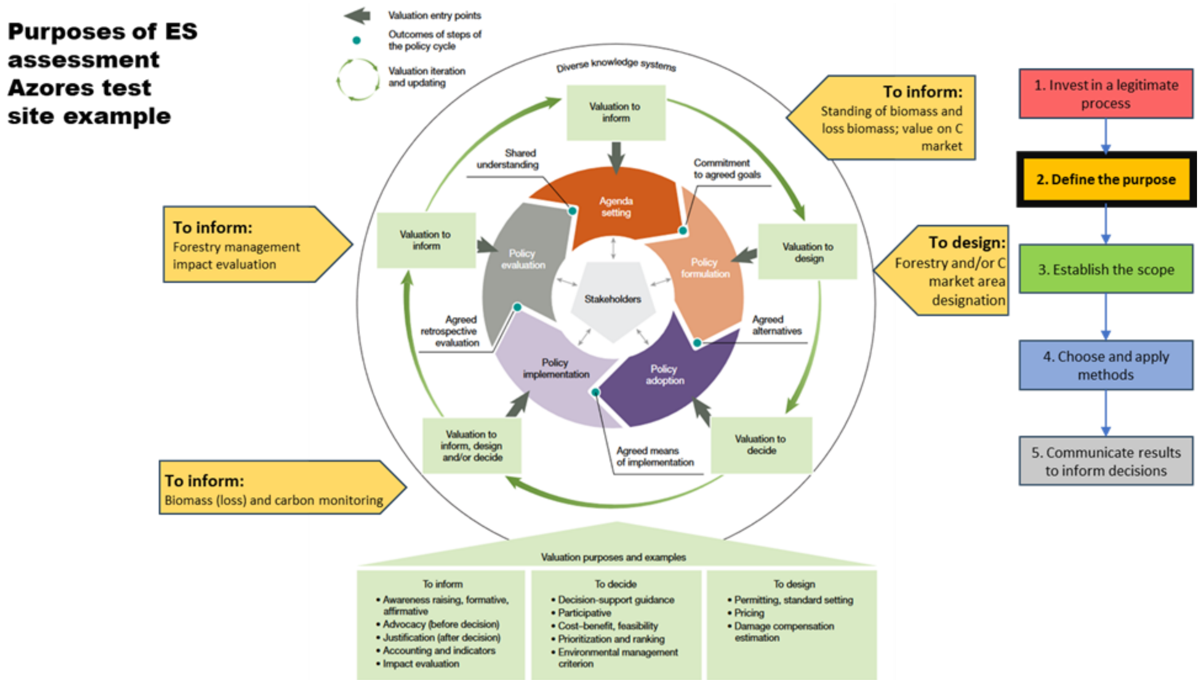


Figure 19: ES assessment purposes of the Azores Test Site. Source: adapted from Pascual et al. (2023). Note: plural valuation as shown in the figure includes ES assessment.

Photo of an east-facing panoramic lookout at São Miguel Test Site.
Attribution: Google Street View.

The Test Site Test site São Miguel (Azores) has been selected to implement the subtask 4.2. on climate regulation and air quality ecosystem services. São Miguel, Azores, has historically endured forest degradation and deforestation activities that have impacted forest extent and condition. In turn, these activities have affected carbon sequestration by forests. The Test Site aims at providing a spatially explicit assessment of biomass, carbon stocks and flows.

The Test Site focuses on the capacity and potential to capture and store carbon in the forests, using near real time monitoring of forest changes and carbon sequestration accounts. The Test Site aims at providing an assessment that does not rely on worldwide datasets but that are locally tailored instead, both to the species present on the island, the management of the forests and their location. It aims at providing quick validation of near real-time monitoring of forest extent, biomass and carbon stocks, which is very challenging for remote sensing techniques with constant cloud cover, and with the mountainous profile and predominance of evergreen vegetation that reduces radar accuracy.

The assessment combines multi source data, including satellite and field data to map forest and other vegetated habitats on the island, based on the forest structure, species composition, forest management and degradation level. The Test Site also aims at identifying and accounting for processes in deforestation and forest degradation (natural vs. manmade) for a specific period (2021-2023). Each step is validated using an extensive field data inventory.

The D4.1 checklists were applied and tested in this Test Site.

(i) **Spatial-temporal resolution.** Multisource data at high spatial resolution (10m) allows detailed considerations of several environmental aspects of the forest conditions. The scale of the assessment matches the scale of decision-making, in terms of covered area, while the spatial resolution allows for consideration of spatial variation across the island. The data is seasonal to capture seasonal changes in forest biomass and corresponding fluctuations in carbon sequestration are monitored for the study period. The multisource data allows constant validation and ensures data availability that despite constants cloud cover. The data is not all open source, and its processing requires technical skills, limiting the potential to update the analyses.

(ii) **Uncertainty documentation.** Habitat maps, which are intermediary outputs, are tested against existing maps, high resolution imagery and field-based surveys. Forest inventory data are both used to feed in the models (identification of forest types) and to validate the model and other input data, such as land use and land cover maps.

(iii) **Ecosystem condition enabling ES assessment.** The models rely on scientifically agreed upon equations or relationships between variables that are commonly used to assess carbon sequestration. Spatially explicit information that includes land use, land cover maps and forest inventories data (e.g. forest structure, forest degradation surveys) are combined to allow for near-real time quantification of biomass loss, which is then linked to carbon sequestration. While several ES and biodiversity are likely to be synergistic to carbon sequestration provided by standing biomass, they are not accounted for in this assessment. Nevertheless, by feeding carbon sequestration information into the new carbon market, which will prioritise initiatives that, along with sequestration credits, generate environmental co-benefits and protection of the natural capital, this assessment will contribute to positive impacts on biodiversity and other key ES.

(iv) **Capacity-potential-supply-demand in ES assessment**. Impact of deforestation and forest degradation on the standing biomass and potential carbon stocks and sequestration is assessed. Actual supply, demand and use were not assessed at this time.

(v) **Economic valuation compatibility.** The study area and the models have high potential to link to the economic valuation of carbon. The need for economic valuations has arisen at several spatial scales, and for several stakeholders, especially since the very recent implementation of the carbon market in the country. The economic valuation through carbon credit trading requires accurately and continually estimating carbon stocks that this model provides.

(vi) **Social benefits compatibility and dimensions of justice and** (vii) **health benefit compatibility.** The test site has not addressed social nor health benefits. Throughout the application of the model, local knowledge and perspectives are integrated in the assessments (although not specifically on social not health benefits). Moreover, with the new carbon market, which promotes projects generating carbon credits with potential socioeconomic benefits, such as new business models, more employment, technological innovation and raising income for forest owners, the assessment of carbon sequestration may be linked to new or increased sources of incomes and new power relations between stakeholders. Additionally, the model outputs could also be linked to other ecosystem services and economic sectors, such as recreation and tourism (co-benefits), as a result of higher standing biomass and larger forest cover which could be further linked to social and economic benefits.

Some challenges related to the creation and evaluation of the models using the checklists, as well as possible challenges linked to policy uptake were mainly conceptual (e.g., i.e. linked to the use and definition of the terminology) and methodological (e.g., linked to the difficulty to monitor disturbed ecological dynamics, and to develop new allometric equations). Due to the involvement of stakeholders in the development of the model, their availability was critical but sometimes limited, especially to go on the field. This could constitute a continuous issue, as the model encompasses frequent field work as a validation procedure.

These challenges were minor as the stakeholders have been involved in the project and are very knowledgeable about the ecological dynamics and issues. In addition, the overall objectives of the modelling are fully aligned with European directives, to ensure policy uptake. This alignment has ensured that the project keeps evolving and should help during the implementation phase of policy based on the model, especially to increase the likelihood of acceptance and involvement of business partners. In that respect, the role and the continuous involvement of the forest service in building and running the model, as well as implementing policy based on its output, is critical, to prevent possible conflicts. Yet, challenges could still rise from policy decisions linked to the outcomes of the model. For instance, the decision of expanding the network of protected areas to restore and protect the forest cover could lead to issues with different stakeholders groups as a result of competition for space.

6.2.3 Draft Terms of Reference proposal from ES group

Table 7: Draft terms of Reference as agreed by the working group members to evaluate climate regulation and air quality models. The questions under the green row are applicable under any ES modelling context. Those under the blue row are relevant only in specific contexts. Those under the yellow row were deemed less relevant but might be improved upon in further development in Task 4.3. Those under the grey banner require further review in collaboration with stakeholders in Task 4.3.

ToR questions useful in any context		
Diagnostic topic	Does the model application:	
Ecosystem condition	Present well-defined and standardised methods for assessing impacts of ecosystem condition on services?	Yes/No
Ecosystem condition	Highlight priority ecosystem condition aspects, services, and their benefits, helping policymakers focus on impactful aspects of their decisions?	Yes/No
Ecosystem condition	Promote restoration targets based on ecosystem condition needs and emphasise the importance of improving degraded ecosystems?	Yes/No
Ecosystem condition Capacity-Potential, Supply-Demand	Use clear and robust indicators for ecosystem condition and services (and dimension, i.e. capacity, supply, demand) at national, regional, or local levels for monitoring and evaluation in policy development?	Yes/No
Spatial and temporal scale and resolution	Use spatial data to visually present ecosystem condition and services data for policymakers?	Yes/No
Spatial and temporal scale and resolution	Allow the assessment of the changes in time and space (e.g. future data assessment, historical time series)?	Yes/No
Spatial and temporal scale and resolution	Allow the use of datasets at various scales?	Yes/No

Spatial and temporal scale and resolution	Allow to upscale the results?	Yes/No
Uncertainty	Provide documentation with clear definitions and explanations of terms related to ecosystem condition and services, ensuring consistency and better understanding?	Yes/No
Uncertainty	Provide guidance and tools that enable the preparation and manipulation of data?	Yes/No
Uncertainty	Provide guidelines for assessing the added benefits of ecosystem-based nature-based solutions compared to other types of interventions?	Yes/No
Uncertainty	Rely on accessible, interoperable databases to overcome fragmented data inventory reality faced by policymakers?	Yes/No
Uncertainty	Function in a technically and economically accessible way to users?	Yes/No
Uncertainty	Clearly specify the adequate uses for it (what the model should (or not) be used for)?	Yes/No
Uncertainty	Consider or at least *mention* other ecosystem services and their trade-offs?	Yes/No
Uncertainty	Provide outputs that are easily usable and comprehensible by stakeholders or include a good translation of the results to the stakeholders (' needs)?	Yes/No
Uncertainty	Give information about the uncertainty/confidence at/for every step of the modelling process (from data to output)?	Yes/No
Uncertainty	Consider reference data for assessment?	Yes/No
Social benefits and dimensions of justice	Allow some co-creation from the beginning?	Yes/No
ToR questions useful in some contexts		

Ecosystem condition	Involve the development of a standardised framework for integrated assessment of ecosystem condition and services to aid policymakers in understanding and utilising information?	Yes/No
Uncertainty	Rely on user-friendly tools, such as plugins and software, enabling policymakers and practitioners to analyse, visualise, and interpret data on ecosystem condition and services?	Yes/No
Social benefits and dimensions of justice	Encourage participation and collaboration among stakeholders in the design and implementation of strategies like conservation, ecotourism, and monitoring of ecosystems?	Yes/No
ToR questions with less usefulness		
Ecosystem condition	Emphasise the integration of biodiversity conservation within the evaluation of ecosystem conditions and services?	Yes/No
Social benefits and dimensions of justice Health benefits	Emphasise the integration of well-being assessment within the evaluation of ecosystem conditions and services?	Yes/No
ToR questions requiring further review		
Ecosystem condition	Comply with the knowledge and skills of policymakers and supporting scientists/technicians on agreed condition assessment approaches?	Yes/No
Ecosystem condition	Present practical case studies and examples illustrating successful integration of ecosystem condition and services into decision-making processes?	Yes/No

6.3 Amenity & recreation related ecosystem services

6.3.1 Summary of ES group approach

The amenities & recreation group worked exclusively with the questions from D4.1 referring to the "methods" step of plural valuation. A total of 3 Demonstration Project and 5 Test Sites in the ES group volunteered to test the check-list questions on their actual or proposed ES model applications. The case studies modelling amenities & recreation services are highly diverse in terms of scale and purposes of ES models. They are also diverse in terms of maturity of ES model applications. This presented a challenge in consolidating the check-list questions - looking across the diversity of cases, most of the questions remained relevant to at least one of the model applications.

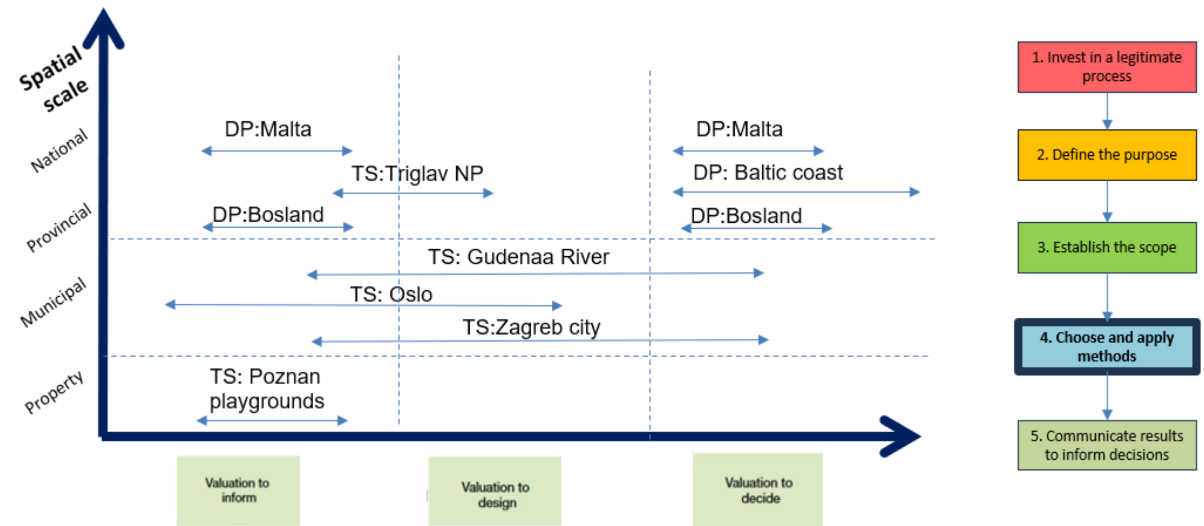


Figure 20: **Preliminary representation of the spatial scale and position within the policy cycle of the members (demonstration projects (DP) and Test Sites (TS)) of the amenity & recreation related ES working group.**

6 studies provided illustrations of their ES model logic chains as a basis for illustrating main variables and ES model outcomes of policy relevance. These studies provided narratives exemplifying how the diagnostic questions could be used to identify "best practice" study design. These are preliminary examples of how diagnostic topics could structure terms of reference to be developed in D4.3. All 8 cases in the group tested the checklist using the "traffic light" system in the template to assess the usefulness of the questions. Where relevant alternative questions formulations were proposed. This constitutes material for further consideration in developing consolidated ToRs for D4.3.

6.3.2 Selected "Best practice" model applications testing draft ToR

Best practice case 1: Mapping and valuing outdoor recreation for multiple policy purposes in Oslo, Norway (Partner: NINA, Test Site)

Caption: Oslo peri-urban forest.
Photo: David N.Barton

The Oslo Test Site combines the results from several previous and ongoing studies in other projects (Venter et al. 2020; 2021; 2023). It is an example of a "best practice" case study in terms of addressing several of the diagnostic topics for ES model design that may increase likelihood of uptake and specified in the draft Terms of Reference. In particular, the example highlights "best practices" for (i) different statistical models applied for a range of *purposes* that support management of Oslo's peri-urban forest, *(ii)* the statistical modelling of *condition* variables as predictors of recreation activity, and (iii) the potential for improving the policy relevance of the case by also modelling benefits, including *health* outcomes and *economic* value (**Fig. 21**).

This example also reports on the Test Site's performance on all the 7 diagnostic topics, based on the testing of the ToR template for this case.

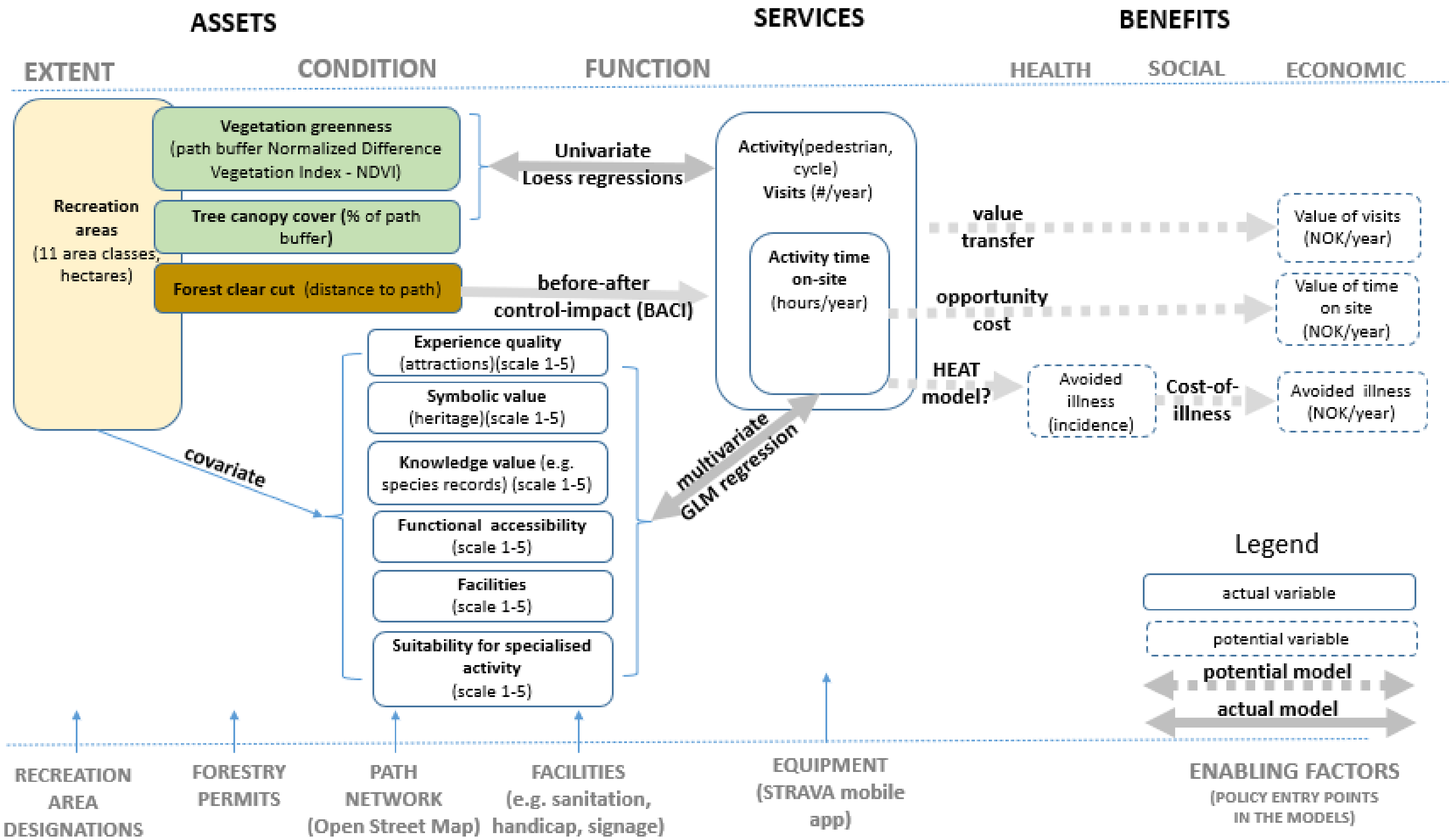


Figure 21: Oslo Test Site ES assessment chain (model application).

The ES assessment chain in **Fig. 21** provides an overview of key variables actually used in published models, as well as potential variables/models that could increase the policy relevance and likelihood of uptake in planning and management. The Test Site currently reflects best practice in recreation assessment in Norway for the following reasons:

ES models for different application purposes (Fig. 22, below)

- **Impact evaluation of forest clear-cuts:** to inform Oslo Urban Environment Agency forestry management about the recreational impacts of clear-cuts near paths. *Model*: before-after-control-impact (BACI) statistical analysis

- **Assessment of vegetation condition-use:** information can support decisions about tree canopy and vegetation maintenance along recreation paths. *Model*: Loess regressions of vegetation indicator - activity level correlations with confidence bands; correlations between time on-site and qualitative condition variables used in decisions about designating recreation areas. *Model*: GLM multivariate regression

- **Recreation use accounting:** to inform the general public on the recreation activity use of the peri-urban forest in total and by recreation area designation type. *Model*: GIS analysis was used to aggregate STRAVA Open Street Map path use to accounting tables for the municipality as a whole and designated recreation areas.

- **Recreation area use monitoring:** to inform Oslo Urban Environment Agency on the increased benefits of a pressure on peri-urban forests during pandemic lock-down. *Model*: GIS analysis of STRAVA Open Street Map path use, was corrected for population bias and time series of path activity mapped before and after lock-down regulations.

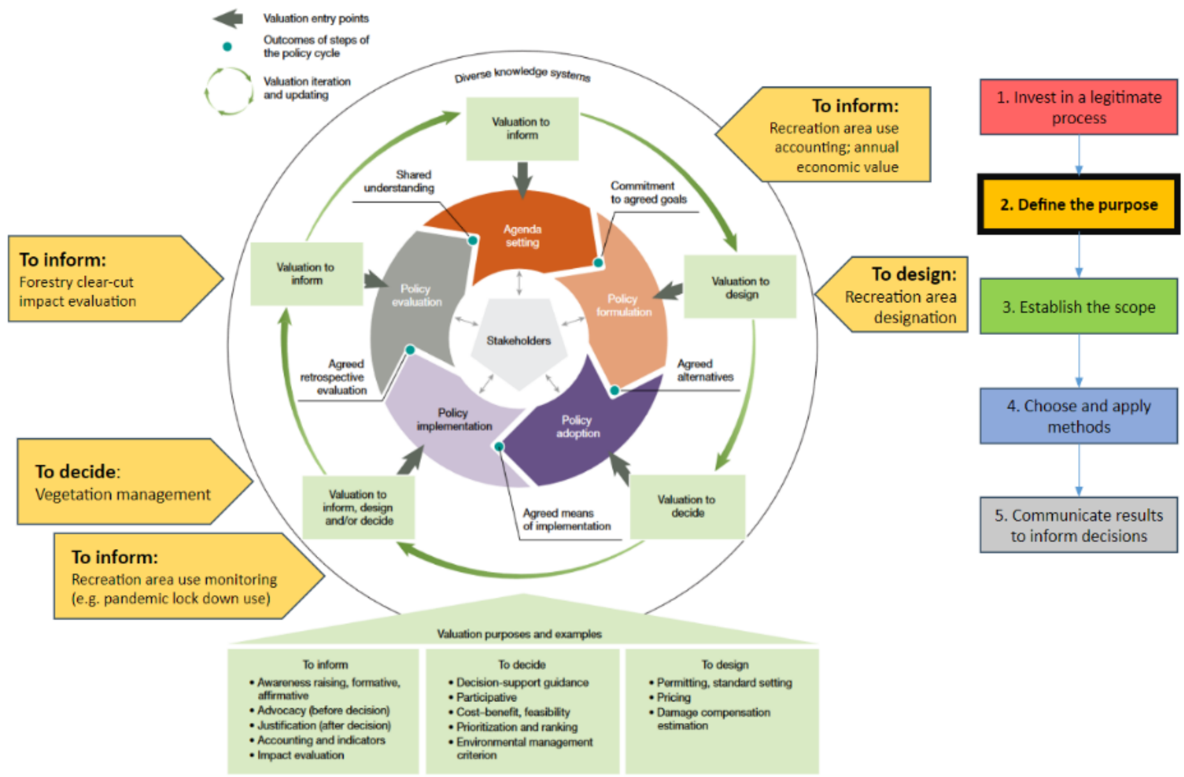


Figure 22: ES assessment purposes of the Oslo Test Site. Source: adapted from Pascual et al. (2023). Note: plural valuation as shown in the figure includes ES assessment.

Overview of diagnostic topics in the case:

The following section summarises the reasons for considering this a "best practice" case in the Oslo, Norway context, considering a hypothetical commissioner of the ES assessments as the Oslo Urban Environment Agency. This summary is based on a self-diagnosis of our case with the help of the TOR template with the 7 diagnostic topics applied to ES models in Oslo:

(i) **spatial-temporal resolution.** Use STRAVA mobility data with resolution at Open Street Map path segments; landcover at 10m resolution using open-source Global Forest Watch data. The STRAVA data is not open source, limiting the potential to update the analyses.

(ii) **uncertainty documentation.** Confidence intervals on estimates are reported and communicated graphically. Sampling biases in STRAVA data are assessed and corrected. Alternative recreation activity data / model types were not tested - comparison with PPGIS data would improve robustness of the analysis; sensitivity analysis of model assumptions was not conducted also limiting the robustness of the findings.

(iii) **Ecosystem condition enabling ES assessment.** GIS mapped condition variables were used in ES models included NDVI, tree canopy cover and path proximity to forest clearcuts. Qualitative variables of condition derived from the Norwegian methodology for recreation area mapping and valuation (Miljødirektoratet M98-

2013) included experience quality, symbolic value, knowledge value, functional accessibility, facilities, and suitability for specialised uses. *Model*: GLM multivariate regression. The condition data used in the modelling makes this a “best practice” case.

(iv) **capacity-potential-supply-demand in ES assessment**. Impact of forest clear-cuts on recreation demand is assessed. Recreation congestion or carrying capacity was not assessed. This may limit the prediction of future recreation activity and net present value calculations of forest asset value for recreation.

(v) **economic valuation compatibility.** The study area has further ‘best practice’ potential by including modelling of economic value of recreation activity visits (*Model*: value transfer); value of time on-site (*Model*: opportunity cost of time)

(vi) **social benefits compatibility and dimensions of justice.** Not assessed. STRAVA recreation data do not assess socio-economic or other social strata. Other methods such as survey based PPGIS would be needed to improve best practice on this topic.

(vii) **health benefit compatibility.** The study area has further ‘best practice’ potential by connecting recreation activity levels to health outcomes, using evaluation of avoided illness incidences (*Model*: HEAT epidemiological functions *Kahlmeier et al.2017*) and their economic value (*Model*: cost-of-illness (COI)).

Best practice case 2: Assessment of preschool garden conditions and their impact on ES in Poznań, Poland (Partner: AMU, Test Site)

Caption: Preschool gardens in Poznań, Poland
Photo: Iwona Zwierzchowska

The natural playgrounds in preschools in Poznań Test Site combine the results from previous studies in the Connecting Nature project (Dumitru et al. 2021; Zwierzchowska, Lupa 2021). It is an example of a "best practice" case study in terms of addressing several of the diagnostic topics for ES model design that may increase likelihood of uptake and specified in the draft Terms of Reference. The example illustrates:

- (i) the assessment of ecosystem conditions enabling outdoor play and education in contact with nature in preschools gardens
- (ii) the pilot assessment of societal benefits, including health outcomes and economic impact of natural playground intervention
- (iii) the recognition of demands and needs in preschool garden transformation
- (iv) the potential for statistical modelling of condition variables as predictors of duration, frequency of outdoor activities in contact with nature during stay in preschools

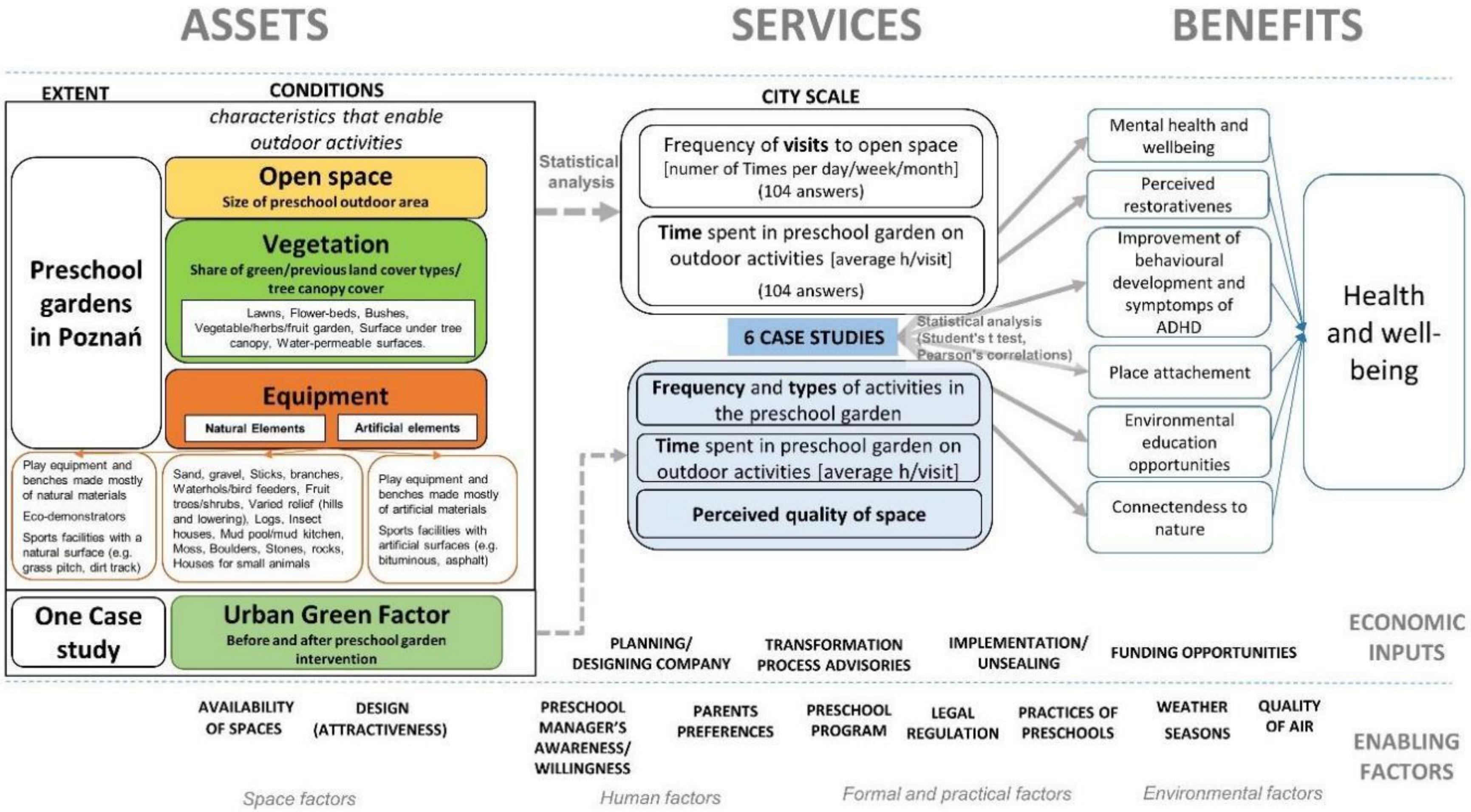


Figure 23: Poznan Test Site ES model chain.

The ES assessment chain in **Fig. 23** provides an overview of key variables actually used in published studies, as well as potential variables/models that could increase the policy relevance and likelihood of uptake in GI/NBS planning and management. The Test Site reflects best practice in assessment of preschool garden conditions for leisure & education activities in contact with nature in Poland for the following reasons:

(i) the assessment of ecosystem conditions enabling outdoor leisure and education in contact with nature in preschools. Condition variables used included size of preschool outdoor area, tree canopy cover, share of various green space types, presence of natural elements enabling contact with nature and presence of artificial facilities enriching the play area. These variables enabling activities promoting health, recuperation or enjoyment through active or immersive interactions and enabling children education and development. The model informs policymakers about the potential for contact with nature in preschools and highlights the priority of preschools for transformation into natural playgrounds/playspaces. **Model: GIS mapping, survey in preschools**

(ii) the pilot assessment of societal benefits, including health outcomes and economic impact of natural playground intervention to inform City and Preschool Authorities. The study test three health and wellbeing indicators based on 3 experimental groups (preschools with natural playgrounds) and 3 control groups (preschools without natural playgrounds). The indicators include: Mental health and wellbeing (Instrument: General Health Questionnaire (GHQ-12) (Goldberg et al. 1997)); Improvement of behavioural development and symptoms of attention-deficit/hyperactivity disorder (ADHD) (Instrument: Strengths and Difficulties Questionnaires (SDQ, Goodman, 1997)); Perceived restorativeness of public green space (Perceived Restorativeness Scale (the short, PRS - 11) (Pasini et al., 2014)). The data were analysed with the IBM SPSS 25.0 statistical package. The analyses included the calculation of descriptive statistics, comparisons of means through Student's t test, and Pearson's correlations. The model can inform preschool managers how their preschool outdoor area impact children’s wellbeing and health and can show the impact of transformation in this respect. **Model: survey in experimental and control groups (preschools) and statistical analysis of data**

(iii) recognition of demands and needs in preschool garden transformation for providing leisure & education in contact with nature in preschools. The model informs policymakers about preschools' willingness to transform their outdoor spaces and what is needed to support this transformation. It is crucial information to plan the long-term strategic support for preschools for up-scale natural playgrounds/playspaces creation. **Model: survey in preschools and data analysis**

(iv) the potential for statistical modelling of condition variables as predictors of duration, frequency of outdoor activities in contact with nature during stay in preschools. Not done yet but have a potential for support decision-making in transformation of preschool outdoor spaces into natural playgrounds/playspaces which is particularly valuable in dense urban tissue with limited opportunity for contact with nature for children. It could inform policymakers on increasing ES flow (children's outdoor activities) in preschools by planning, designing, and creating more attractive natural outdoor spaces. **Potential model: statistical analysis (to be developed)**

Best practice case 3: Characterising nature-based tourism/recreation in Malta

Caption: Malta's cliffs in the island of Gozo.
Photo: Martha V. Arámbula Coyote

The Malta demonstration project combines the results from a previous study (Balzan et al., 2018; Balzan & Debono, 2018; Costadone & Balzan, 2023). By leveraging different crowdsource datasets, we assess, and map sites associated with high natural-based recreation and tourism visitation, and landscapes of unique social-ecological value. It addresses several of the diagnostic topics for ES model design that may increase likelihood of uptake and is specified in the draft Terms of Reference. The example highlights "best practices" for (i) statistical models applied to analyse crowdsource datasets*, (ii)* the evaluation of *condition* variables in assessing recreation use (the sites), and (iii) the potential for assessment of societal and economic benefits (**Fig. 24**).

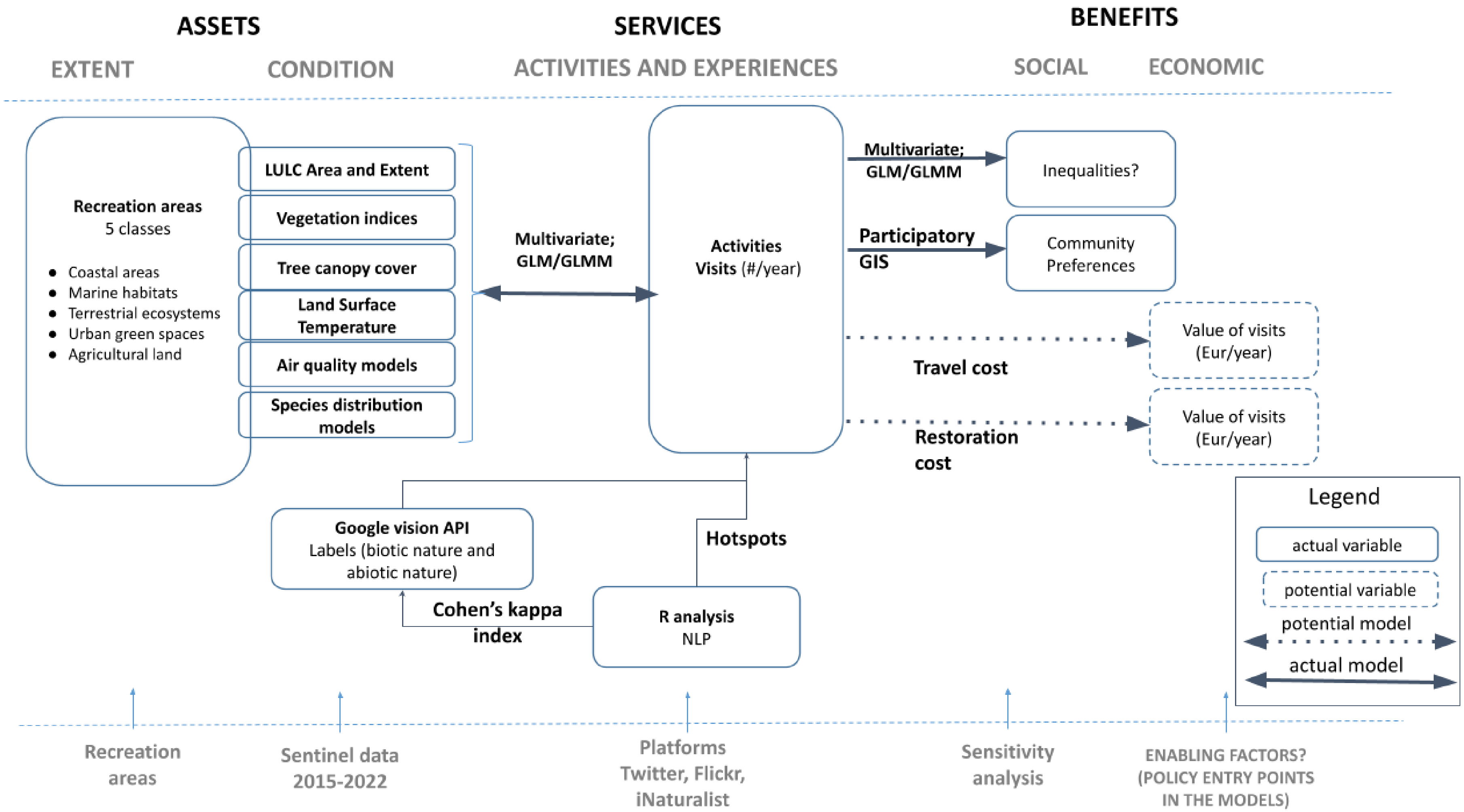


Figure 24: Malta demonstration project ES assessment chain.

The ES assessment chain in **Fig. 24** provides an overview of the variables and models being considered for the demonstration project in Malta. The demonstration project reflects best practice in recreation assessment in the context of Malta for the following reasons:

ES models for different application purposes:

- **Assessment of ecosystem condition:** LULC, Vegetation Indices, Tree canopy cover, Land Surface Temperature, air quality models, species distribution models. Model: GIS analysis according to the variable.
- **Assessment of ES flows:** the ES assessment measures site visitation as a proxy for ES flows and tourism benefits. Model: GLM/GLMM multivariate regression. GIS analysis (hotspots were used to map Twitter posts of the recreation areas visited). Natural Language Processing was carried out to know the activity done on the site.
- **End User engagement**: we are working with business stakeholders, e.g. the Malta Business Bureau, to map visitation and assess values using PPGIS.

Overview of diagnostic topics in the case:
This section briefly explains the relevance of the Maltese case-study to key diagnostic topics:

(i) **spatial-temporal resolution.** Use crowdsourced data from Twitter, Flickr, and iNaturalist; LULC at 10 m resolution using Sentinel-2 images. Twitter API is no longer free for research projects.

(ii) **uncertainty documentation.** Enhancing data robustness by comparing crowdsourced data with PPGIS data.

(iii) **Ecosystem condition enabling ES assessment.** GIS-mapped condition variables were used in ES models including LULC, Vegetation Indices, Tree canopy cover, Land Surface Temperature, air quality models, and species distribution models. Model: GLM/GLMM multivariate regression.

(iv) **economic valuation compatibility.** The inclusion of economic value modelling of the recreation activities adds up to the best practice potential of the demonstration project in Malta. Model: value transfer

(v) **social benefits compatibility and dimensions of justice.** Community preferences were assessed through PPGIS which gives it further best practice ability to the project. Model: PPGIS

(vi) **health benefit compatibility:** Not assessed. Other methods would be needed to develop the best practice on this topic.

Best practice case 4: Bosland

Caption: Cycling through the Trees at Bosland Forest, Belgium

In May 2023 Bosland received the status of National Park. Bosland is one of the biggest forest areas in the North of Belgium (Flanders). It is approximately 29000 ha big of which 9000 ha forests and open nature areas (heathland, inland dunes, wetland). It has a large recreational network with hiking, bicycle, mountain bike and horse-riding networks. In its ambitions it wants to create an ecological valuable ecosystem with strong biodiversity, that is climate robust and with enough space to bring people close to nature and make entrepreneurship possible. This process happens in co-creation with partners and stakeholders.

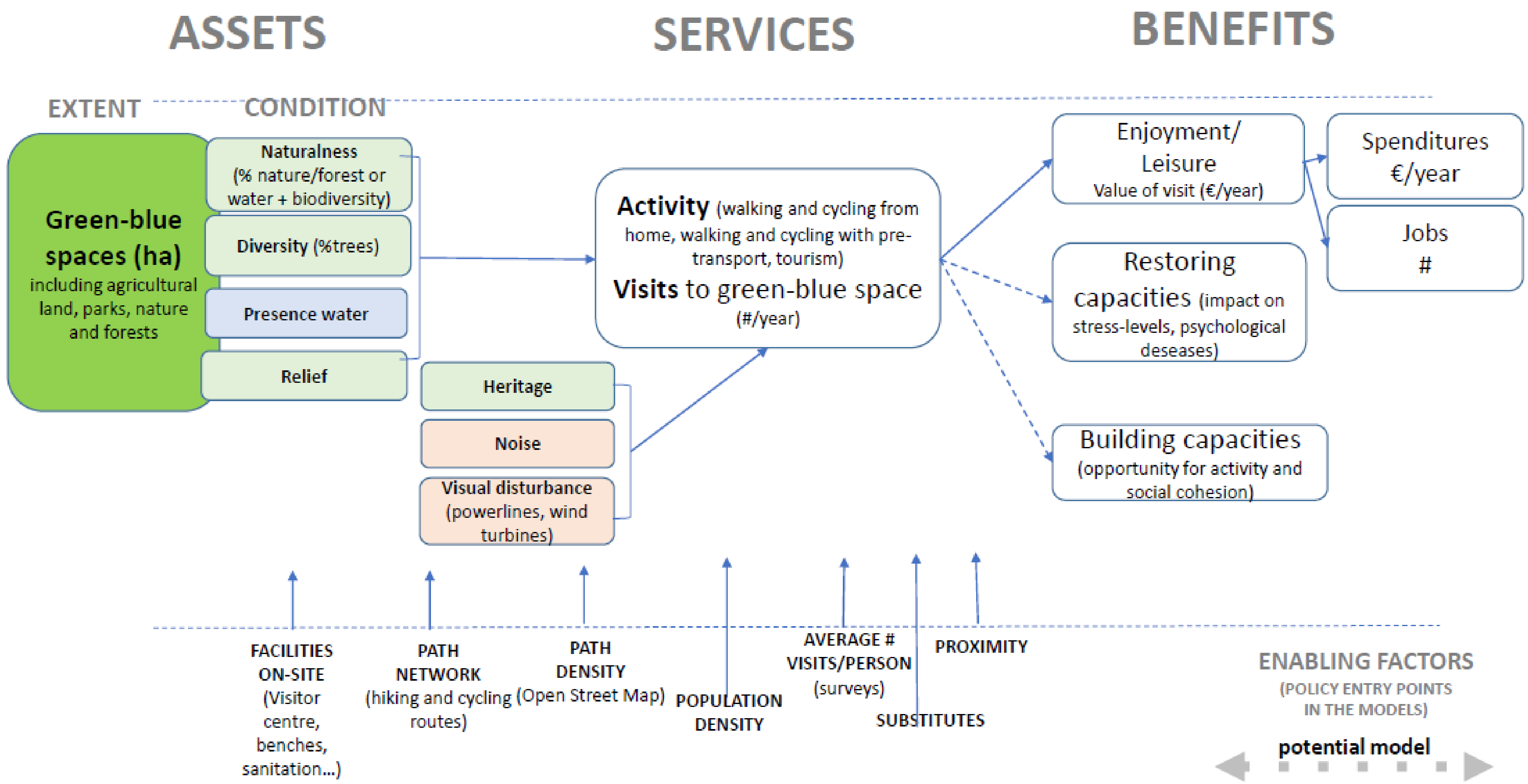


Figure 25: Test case Bosland Recreation model chain.

The ES assessment chain in **Fig. 25** provides an overview of the variables being considered in the recreation assessment for Flanders and in particular the demonstration project Bosland. The demonstration project reflects best practice in recreation assessment for the following reasons:

ES models for different application purposes:

- **Assessment of impacts on ecosystem condition:** the model uses some condition variables. results can be used to see where the biggest pressures on the ecosystems are and combined with condition parameters, biodiversity monitoring see what the impact of recreation is and can be used in decisions about designating recreation areas.

- **Recreation use accounting:** to inform the general public on the recreation activity use of different areas in Bosland and benefits derived from it (expenditures and job creation in the recreational sector).

- **End User engagement**: the model is created based on preferences of end-users (choice experiment) and can be used in combination with condition maps to discuss where and how to designate recreation areas.

Overview of diagnostic topics in the case:
This section briefly explains the relevance of the Bosland demonstration project to key diagnostic topics:

(i) **spatial-temporal resolution.** Use of Open Street Map and hiking and bicycle networks. Land use and other parameters on resolution of 10 m. Parameters can be updated over time to see evolution.

(ii) **uncertainty documentation.** The model was validated with counting numbers in different nature areas. But no sensitivity analysis was performed on the assumptions made.

(iii) **Ecosystem condition enabling ES assessment.** GIS mapped condition variables used in ES models included ecosystem type, naturalness (% forest and nature areas) presence of water, % tree surface, heritage value. But also, some humans induced factors were implemented in the model such as functional accessibility, facilities, noise levels, visual hindrance.

(iv) **capacity-potential-supply-demand in ES assessment**. Supply (attractiveness for recreation) and demand (no of visits to green-blue areas per inhabitant per year) were assessed and combined. Recreation congestion or carrying capacity was not assessed. This may limit the prediction of future recreation activity and net present value calculations of forest asset value for recreation.

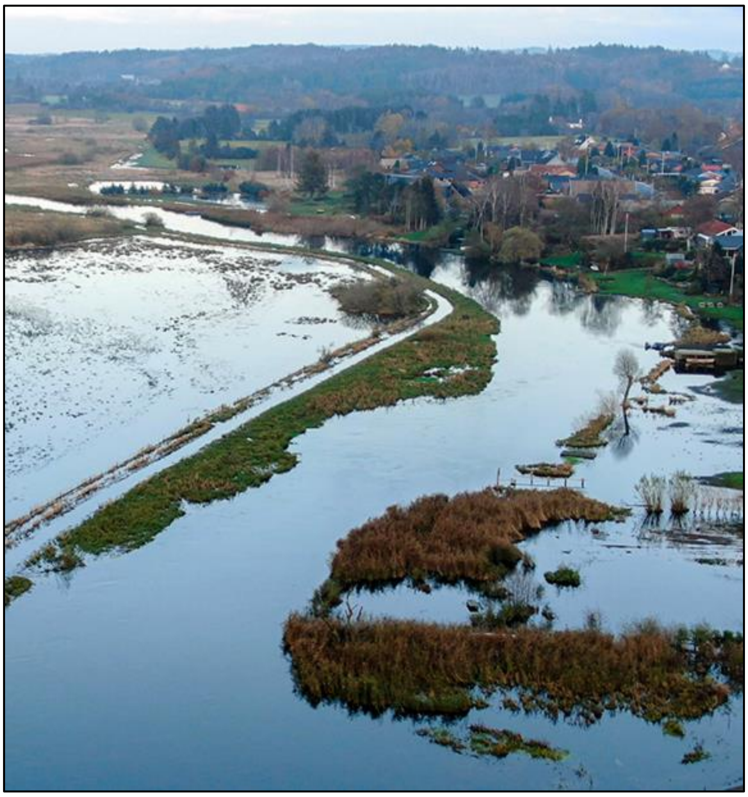
(v) **economic valuation compatibility.** The study area has further 'best practice' potential by including modelling of economic value of recreation activity visits (*Model*:

value transfer: perceived value or expenditures) and translating this to jobs in hotels, restaurants, and cafes.

(vi) **social benefits compatibility and dimensions of justice.** Not assessed. We did adapt the number of yearly visits to the number of green-blue spaces available (higher when a lot of green-blue spaces available) and the number of children/elderly within the population (recreate less).

(vii) **health benefit compatibility.** The study area has further 'best practice' potential by connecting recreation activity levels to health outcomes, using evaluation of avoided illness incidences and their economic value (cost-of-DALY)).

Best practice case 5: Mapping flood areas, potential carbon capture areas, potential and extant biodiversity, and potential outdoor recreation options for climate related flood control along the Gudenaa River (Partner: University of Copenhagen, Test Site)



Caption: Gudenaa River with winter flooding.
Photo: Silkeborg Municipality

The ES assessment chain in **Fig. 26** illustrates the variables employed in the conceptual models. The Gudenaa River Test Site reflects the use of best practice when assessing recreational services in Denmark.

Links between land cover types and the intensity of recreational use and facilities. *Model*: Land cover predict recreational use

Links between river and lake navigability and recreational use: information support decision regarding the potential water related recreational use. *Model*: Width and depth of rivers and depth of lakes predict recreational use.

The Gudenaa River test case represents “best practice” in a Danish context. It represents a real-life analysis commissioned by the Gudenaa River Committee, which consists of all municipalities in the catchment area. The aim of the analysis was to support decisions regarding flood control and climate mitigation strategies with the aim of creating multifunctional solutions with the inclusion of biodiversity and recreation. The basis for this evaluation is our own ex post evaluation of the project.

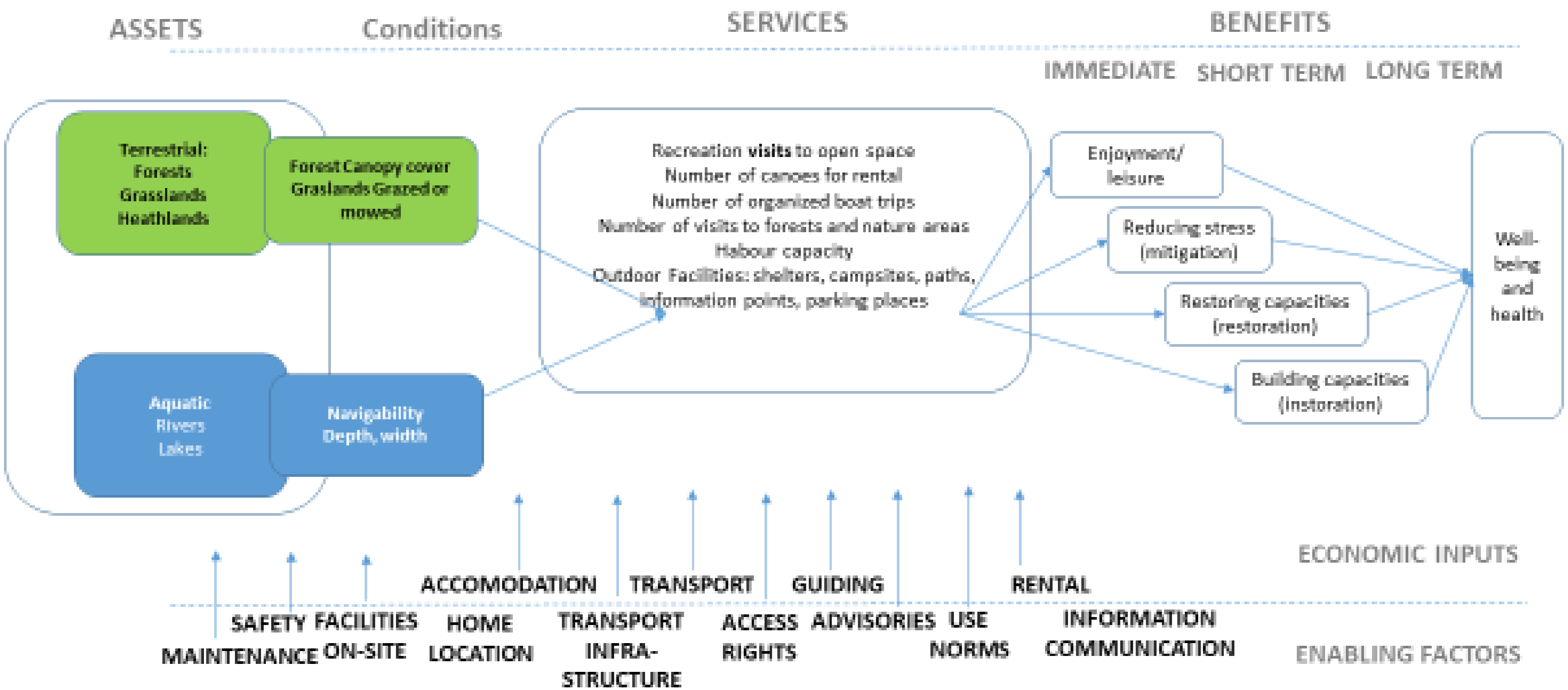


Figure 26: Test case Gudenaa River ES model logic chain.

Ecosystem conditions predict ES. GIS based mapping revealed land cover types which are closely related to recreational use. The evidence for this link is provided by five decades of national and local inventories on recreational users preferences. The land cover condition variables (permanent grasslands, heath land, forests and nature areas) were inputs in ES models. Inventories include preferred aesthetic qualities, worse-and-best experiences, accessibility, and facilities. *Model*: The land cover types known as the most preferred predict recreational use.

The Gudenaa River Test Site encompasses the results from a comprehensive study on the possibilities for solving climate change related extensive floods in combination with strengthening carbon capture, biodiversity, and outdoor recreation (Andersen et al., 2023). It stands as an example of best practice as it links the presence of rivers and lakes, forest, grass and heath land cover with registered recreational use and facilities, and links that to possible health benefits. These links may increase the likelihood of uptake. The case highlights "best practices" for (*i*) linking landscape qualities with intensity of outdoor recreation and the potentials for strengthening recreation and health benefits *(ii)* the potential for enhancing the policy relevance of the case by pointing at relevant win-win situations where recreation can be strengthened by climate mitigation efforts.

Best practice case 6: Assessing coastal cultural ecosystem services for the Long Term Thematic Plan on Coastal Public Infrastructure Development (Coastal Plan) in Latvia (Partner: BEF, DP 07)

Caption: The coast of the Baltic Sea in Latvia.
Photo credit: Agnese Reke

The Latvian case study focuses on integrated assessment of coastal cultural ecosystem services (CES) at the national scale in Latvia. It is a part in a wider study – Demonstration Project 07 on uptake of ecosystem service information in the interim evaluation and update of the Latvian Maritime Spatial Plan and the Long-Term Thematic Plan on Coastal Public Infrastructure Development (Coastal Plan). The case combines two studies conducted by the Baltic Environmental Forum: (i) an ongoing assessment of landscape qualities and their contribution to CES supply by adopting the landscape character assessment method , originally developed in Scotland and England (Swanwick 2002, Tudor 2014) and later on tested and validated in Latvia (Veidemane et al. 2024); (ii) assessment of the of CES by participatory GIS (PGIS) method with focus on the actual use (demand) and potential, as well as perceived well-being benefits linked to cultural ES – previous study conducted in 2021 within the framework Interreg project MAREA.

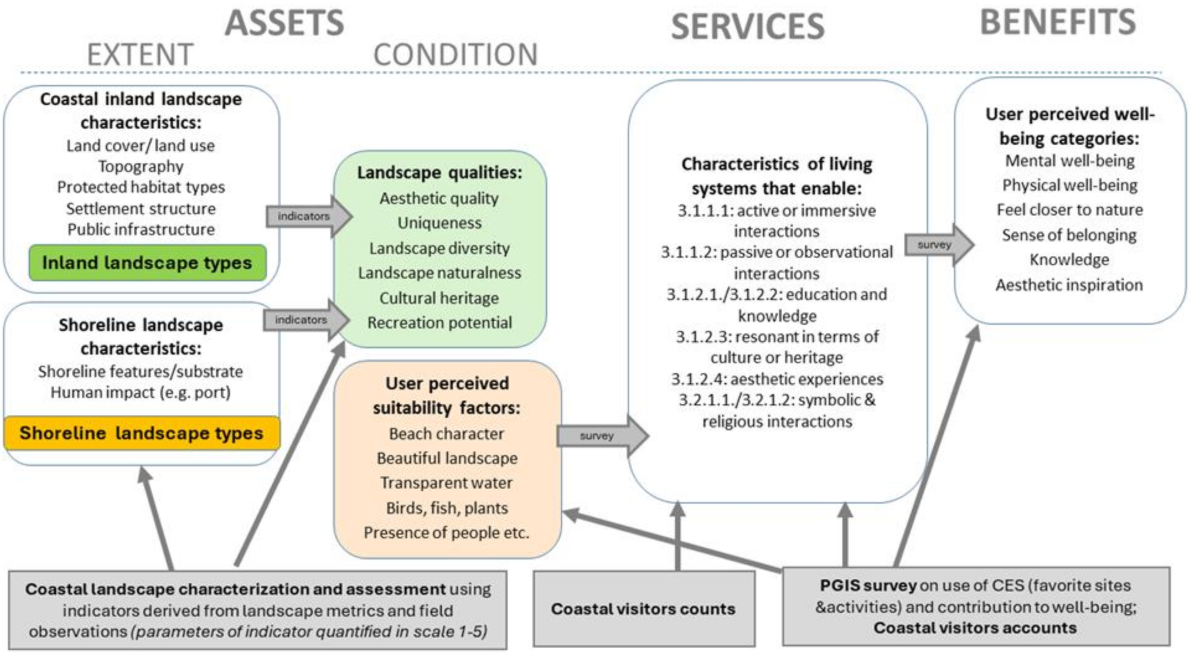


Figure 27: The logic chain of the Latvian case study for coastal CES assessment/model

Relevant diagnostic topics reflecting "best practice":

The demonstration site reflects 'best practice' in landscape and CES assessment in the context of sustainable coastal development in Latvia for the following reasons:

(i) **ES models/methods for guiding national, regional and local authorities in sustainable tourism development planning: (see Fig. 27**)

- **Assessment of landscape qualities:** A comprehensive indicator-based landscape quality assessment allows pinpointing areas with distinct natural, cultural, and aesthetic significance. This aids decision-makers in devising place-specific strategies for sustainable recreation and tourism development that safeguards ecosystems, preserves place identity, and upholds the intangible values cherished by local communities. *Model:* Landscape character assessment (Swanwick, 2002).

- **Assessment of use of the coastal areas for recreation and other CES:** Online and face-to-face PGIS survey of the coastal CES users to identify favourite activities, their geographical distribution, as well as perceived well-being benefits and other aspects important for coastal visitors. The use of this method enables integration of stakeholder values into the coastal development planning. *Model:* Participatory GIS survey

(ii) **Ecosystem condition enabling ES assessment:** Both models/methods include ecosystem condition aspects in defining the suitability or potential of the coastal areas for recreation and other CES related activities. The landscape quality assessment includes quantitative and qualitative variables reflecting aesthetic qualities (e.g. landscape openness, scenic views, visual pollution), landscape diversity (e.g. land use/land cover diversity) and naturalness (e.g. presence of natural microrelief, naturalness of water streams, share of semi-natural habitats). Indicator values for assessment of landscape qualities are derived from the analysis of landscape metrics, shoreline features, as well as field observations. PGIS survey detects the environmental variables (e.g. presence of species, water transparency, beach substrate and vegetation) that people find important for practicing certain CES related activities.

(iii) **Capacity-potential-supply-demand relation in ES assessment:** Landscape quality assessment is targeted to ecosystem capacity-potential for CES supply: abiotic and biotic features of landscape in combination with human inputs/ anthropogenic structures like settlements, cultural heritage, tourism infrastructure, accessibility determines the potential and capacity for enjoyment of CES. Supply-demand relationship is represented by the actual use of the service – the favourite coastal sites for practicing CES related activities and actual observed number of visitors at certain locations/ coastal stretches. PGIS survey on use of CES demonstrates the supply-demand relation, also highlighting the importance of accessibility (infrastructure, proximity to settlements) which highly impacts the actual use of the services.

(iv) **Public engagement and close cooperation with decision makers:** Throughout all stages of the case study, there is active public engagement and collaboration with decision-makers to ensure that the outcomes align with their requirements.

Overview of diagnostic topics in the case:

The following section summarises the case the Baltic Sea coast in Latvia, considering ‘best practice’ from the hypothetical perspective of uptake by the commissioner of the ES assessments as the Latvian Ministry of Environmental Protection and Regional Development. This summary is based on a self-diagnosis of our case with the help of the TOR template with the 7 diagnostic topics applied to ES models in the Latvian coast:

(i) **spatial-temporal resolution.**

The case study is implemented at the national scale. Landscape assessment is conducted on the level of landscape areas – relatively homogenous spatial units identified to match the scale and need of the required decision support. For the identification of landscape areas, maps of various scales were used to ensure accuracy of results.

(ii) **uncertainty documentation.**

Uncertainty in PGIS: the conducted survey is not a nationally representative survey. It was conducted as a targeted survey (target group – recreational coastal users); given the absence of official data regarding unique coastal visitors in Latvia, the required minimum number of respondents was calculated based on the total population (min. required ~600 respondents (Cl 95%, MoE 4%), reached – 808). Due to method specifics, uncertainty is not documented in landscape assessment.

(iii) **ecosystem condition enabling ES assessment.**

Condition was assessed by landscape characterisation method that evaluates landscape qualities such as landscape naturalness that is tightly linked to ecosystem condition. Condition related variables are also included in the PGIS survey to identify environmental features that are important for visitors of the coast.

(iv) **capacity-potential-supply-demand in ES assessment.**

Capacity and potential are addressed by landscape characterisation method. Supply-demand relationship is represented by the actual use of the service by mapping the favourite coastal sites for practicing CES related activities (PGIS data) and actual observed number of visitors at certain locations/ coastal stretches (on-site visitor counts).

(v) **economic valuation compatibility.**

Currently not assessed. Other methods would be required to improve best practice on this topic.

(vi) **social benefits compatibility and dimensions of justice.**

Partially assessed by PGIS survey targeted to recreational coastal users. The survey identified perceived well-being benefits that are linked to CES related coastal activities, as well as environmental features users of the coast see as important (e.g. presence of species, water transparency, landscape etc.). The study has further 'best practice' potential by including in-depth social benefit analysis, as well as justice aspects in access and use of CES.

(vii) **health benefit compatibility.**

Partially assessed via targeted participatory GIS survey by linking recreational activities to perceived well-being benefits (including improving and maintaining physical and mental health). The study has further 'best practice' potential by connecting coastal recreation activities to more concrete health benefits.

6.3.3 Draft Terms of Reference proposal from ES group

In this section we provide a tabular summary of the revised check-list questions on methods that have been reviewed by the amenities and recreation services group. The table contains an assessment of questions that are useful as is, and questions that could be useful if they were reformulated. Suggestions for reformulation of questions are provided. This is a starting point for work in D4.3.

In summarising recommendations from the group on amenities & recreation we included some questions as "useful in any context", although there were a few exceptions, notably, "are economic / social / health benefits relevant outcomes for decision-support in your case study?" was evaluated as only sometimes relevant by 2-3 case studies. This requires further diagnostics in those cases (see Annex 3).

Table 8: Draft terms of Reference as agreed by the working group members to evaluate amenity and recreation models. The questions under the green row are applicable under any ES modelling context. Those under the blue row are relevant only in specific contexts. Those under the yellow row were deemed less relevant, but might be improved upon in further development in Task 4.3. Those under the grey banner require further review in collaboration with stakeholders in Task 4.3. The column on the right includes additional comments from group members for potential further development.

ToR questions useful in any context		
Diagnostic topic	**Draft ToR questions**	**Question reformulations**
Ecosystem condition	What methods for assessing impacts of ecosystem condition on services does your assessment use?	
Spatial and temporal scaling, resolution and uncertainty	What is the spatial scale of the decision-support needed from the ES assessment?	
Spatial and temporal scaling, resolution and uncertainty	What are the spatial units used in the assessment?	
Capacity-potential, supply-demand	What indicators for ecosystem service (ES) supply-demand does the study use?	
Social benefits and dimensions of justice	Are social benefits a relevant outcome for decision support in your study? Why/ not?	consider formulation of follow-up to address exceptional cases where not relevant

Health benefit compatibility	Are health benefits a relevant outcome for decision-support in your study? Why/ not?	consider formulation of follow-up to address exceptional cases where not relevant
Economic valuation	Are economic benefits a relevant outcome for decision-support in your study? Why/ not?	consider formulation of follow-up to address exceptional cases where not relevant
ToR questions useful in some contexts (or require reformulation)		
Spatial and temporal scaling, resolution and uncertainty of ES assessments	Are metadata for spatial scales and resolutions included and following the INSPIRE directive?	Are input and output variables publicly Findable, Accessible, Interoperable, Reusable (FAIR?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	What common frameworks (e.g. CICES, Essential variables, MAES) are used to defined and communicate ES?	Is a standardised definition of ES used?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	Were the methods used to assess ecosystem services selected to match the complexity of the decision-support needed (e.g. to inform, to decide, to design?)	Is the method choice justified for a specific purpose and user? Were the methods for assessment selected to match the need of the decision-support?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	Which spatially explicit indicators used to assess ecosystem services?	Does the spatially explicit data represent the intended service?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	What third spatial dimension (e.g. elevation above sea level, relief, or slope) are considered in the ES assessment?	Does the ecosystem service depend on elevation, relief or slope?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	Does the spatial resolution of ecosystem condition indicators match the scale of the ES assessment?	Does the resolution of condition variables match the resolution needed to assess benefits to ES beneficiaries?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	How has a sensitivity analysis to understand their implications on ecosystem services been considered?	Has sensitivity analysis of model or data uncertainties been conducted?

Spatial and temporal scaling, resolution and uncertainty of ES assessments	How has a sensitivity analysis of mapping at different spatial scales and their implications on ecosystem services been considered?	Is the highest spatial resolution available used in the ES model? Perhaps include question: "Does the study perform sensitivity analysis - why or why not" first?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	How are the spatial interdependencies between different ecosystem services within the study area assessed and reported?	Are trade-offs between ES assessed?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	How does the assessment take into account the spatiotemporal dynamics and potential future changes of ES?	What period of change does the assessment consider?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	How does the study consider multiple models or model ensembles, and the possibility of a range of ES outcomes?	Are alternative ES models used to test robustness of recreation estimates?
Spatial and temporal scaling, resolution and uncertainty of ES assessments	How does the study consider future scenarios in study context, and the possibility of a range of ES outcomes? ?	
Spatial and temporal scaling, resolution and uncertainty of ES assessments	Does the study model risks for beneficiaries (ES benefits x probabilities)?	Does the study quantify uncertainty in ES outcomes?
Ecosystem condition	How does your study emphasise the integration of biodiversity conservation within the evaluation of ecosystem conditions and services?	Are biodiversity indicators used in ES models?
Ecosystem condition	How does the study emphasise the integration of well-being assessment within the evaluation of ecosystem conditions and services?	Are well-being metrics linked to condition or service variables in the model?
Capacity-potential, supply-demand	What indicators for ES capacity-potential does the study use?	Is carrying capacity for the ES assessed?

Dimensions of capacity-potential, supply-demand	How does the study consider the relationship between ES capacity-potential and supply-demand?	
Dimensions of capacity-potential, supply-demand	What sustainability thresholds for ES supply-use are relevant to the study (e.g. minimum safe standards, precautionary policy)?	Is carrying capacity for the ES assessed?
Dimensions of capacity-potential, supply-demand	How is uncertainty in ES supply-demand addressed?	
Economic valuation	At what scales (temporal, spatial, beneficiaries) is there a need for economic valuation ?	Split into temporal, spatial
Economic valuation	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)? <valuation is only theoretically correct for changes>	
Economic valuation	How does the study assess and address uncertainties associated with the valuation?	
Economic valuation	How does the study assess long-term dynamics in ecosystem capacity, supply and demand in order to measure the sustainability of ES use and values?	Combine with question under condition
Economic valuation	How does the study measure the contribution of ES to economic development indicators (e.g. employment, growth)?	
Social benefits and dimensions of justice	How does the study identify or assess disparities in who is affected positively or negatively by changes in ES supply or access to ES benefits?	
Social benefits and dimensions of justice	How does the study consider existing social disadvantages (e.g.	

	socio-economic, gender, race/ethnicity/ disabilities etc) that are related to ES inequalities?	
Social benefits and dimensions of justice	How does the study evaluate the potential impacts of different policy actions on the distribution of ES benefits among various societal groups?	
Social benefits and dimensions of justice	What indicators have been developed which are specifically social benefit-relevant? Have these social benefit indicators been developed or determined by the engagement of stakeholders?	Have these social benefit indicators been developed or determined by the engagement of stakeholders?
Social benefits and dimensions of justice	How does the study consider the intergenerational aspects of ES and their implications for future well-being (e.g., impacts of policies or activities)?	
Health benefit compatibility	Are health benefits a relevant outcome for decision-support in your study? Why/ not?	
Health benefit compatibility	What distinct pathways between ecosystem structure / function / ecosystem services have been explored or identified for those health aspects?	
Health benefit compatibility	How does the study identify disparities in access to / benefits from health-benefit ES and attempt to understand the drivers and consequences of such disparities?	Wording and concepts “health-benefit ES”? Question about drivers as a separate question for policy purposes
Health benefit compatibility	How does the study assess the current and / or potential future distributive impacts of policies or activities on ecosystem management?	Generic - not health; this would be covered through the pathways question. Does the ES model/mapping make it possible to assess distributive impacts on health ?
Health benefit compatibility	How does the study account for existing formal and informal	Generic - not health related; A question no related to ES

	governance mechanisms relevant to ES in the study area?	modelling; belongs in scoping step
Health benefit compatibility	How are the study scenarios / models / inputs / outputs validated against local knowledge or perspectives?	Generic to economic, social, economic
Health benefit compatibility	What indicators are specifically relevant to health benefits ? (were they determined by engagement with stakeholders?)	
Health benefit compatibility	What indicators are specifically relevant to health benefits ? (were they determined by engagement with stakeholders?)	Were indicators of health benefits determined by engagement with stakeholders?
ToR questions with less usefulness		
Economic valuation	What biophysical quantification of ecosystem services are relevant for economic valuation of ES?	Redundant question - ES is a biophysical quantification. If ES is correlated with condition so is economic value.
Health benefit compatibility	How does the study include an assessment of the stocks and flows of health relevant ES?	ES is not a stock; redundant covered by the question above
ToR questions requiring further review (incl. new questions)		
Spatial and temporal scaling, resolution and uncertainty of ES assessments	Are maps of the study area used to visualise the assessment results?	
Spatial and temporal scaling, resolution and uncertainty of ES assessments	Are the data and knowledge needs already known & discussed with the potential user of the results?	
Ecosystem condition	Are stakeholders consulted to decide which specific condition indicators (e.g. species, variety, naturalness, management-level, noise level…) are taken into account in the model?	

Dimensions of capacity-potential, supply-demand	Are stakeholders involved in the model building?
Economic valuation	Are different types of beneficiaries/users considered to develop the demand site model?
Economic valuation	What is the distribution of privately and publicly owned land?

6.4 Agriculture & forestry provisioning ecosystem services

6.4.1 Summary of ES group approach

The SELINA group of studies dealing with ES in agriculture and forest systems assess a wide range of ecosystem services from these systems, including various regulating services. This means that the validation of the diagnostic topics check-list gathers the experiences from a heterogeneous and diverse group of ES assessments. The check-lists have been evaluated by eight DP/TS which include the assessment of the following ES, although not exclusively: food and timber provision, pollination, soil erosion control, global climate mitigation, habitat provision for native flora and fauna and services related to soil water holding capacity. The assessments also vary in terms of their geographical scope, from the national to the local level, and in terms of the policy/decision-making purpose of the assessment (**Fig. 28**). In some cases, the assessment has a local focus to develop methodologies, but with the aim of upscaling at the national level. This means that the validation of the diagnostic topics check-list gathers the experiences from a heterogeneous and diverse group of ES assessments, which can enable the consolidation of a minimum set of questions of general validity.

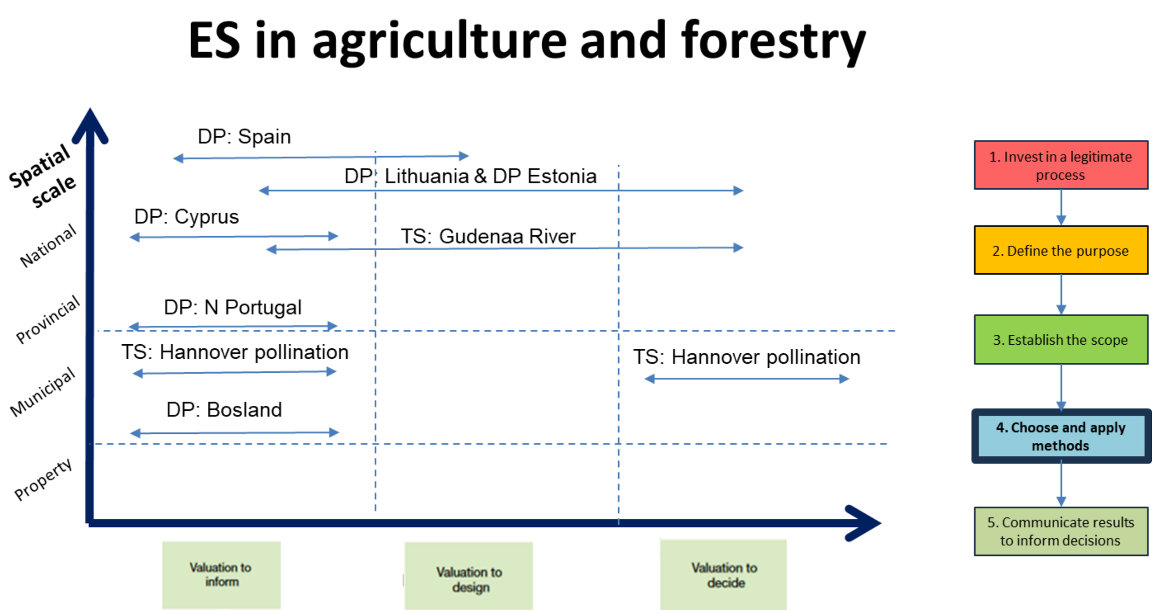


Figure 28: Spatial scales and the policy-relevant purpose of eight Demonstration projects / Test sites ecosystem services assessments in agriculture and forest systems. The arrows indicate the range of the policy cycle steps the assessments aim to inform.

We provide background to the check-lists validation by this group of ES assessments to enable a better understanding of the responses:

(i) In several instances, the scope of the ES assessment does not include all the components of the ES cascade/logic chain. The validation of the diagnostic topic questions refers then to questions within the scope.

(ii) Several assessments deal exclusively with methodological developments on specific components of the ES assessment (i.e. exploratory or research and development driven assessments), so not all valuation components have been a priori thought through. The list of diagnostic topics can raise awareness about why the methodological developments are needed.

(iii) There is a predominance in this set of studies on a focus on the biophysical components of ES assessment. Hence, for the validation, direct experience refers to this group of diagnostic topics.

(iv) In two examples, i.e. crop yields in Denmark and the risks of fires in managed forest in Northern Portugal, there is an explicit economic valuation element, relevant for decisions in the private sector/businesses. However, other assessments (soil water holding capacity in cropland in Cyprus, fodder production in semi-natural grasslands in Estonia, and pollination services potential in Germany) have relevance for private sector decisions.

The evaluation reveals that there is still the need to harmonize the use of concepts in ES assessments. This refers for instance to distinctions between e.g. 'social groups vs. stakeholder groups' or 'stakeholder groups vs. interest groups', 'social actors', or other combinations, but also questions about how to deal with differences among ES assessment frameworks. There is a need for harmonization and agreement about definitions and models emerging from existing frameworks (e.g. SEEA EA, CICES, MAES, etc.).

Evaluation within and across checklists. A general comment that emerges from the evaluation is that the same or similar questions appear both within a check-list (addressing different steps of the assessment) and in different check-lists, hence at a second stage of consolidation, a recommendation is to ensure that each list maintains the most important questions, and that those duplicated (sometimes these are slightly differently worded, but have similar content) in other lists are removed. There seems especially to be overlap between the lists of questions regarding 'Ecosystem Condition' and those on 'ES Potential, Capacity, Supply and Use', but also within a single checklist.

6.4.2 Selected “Best practice” model applications testing draft ToR

Best practice case 1: Modelling pollination potential in Lower Saxony (Germany) for a sustainable regional landscape management (LUH, Test Site 11)

SELINA Test Site no. 11 is focused on assessing the potential for the regulating ecosystem service ‘crop pollination’ in the Region of Hanover (Germany), by modelling the potential habitat suitability for wild bees (Hinsch et al. 2024). The modelling approach combines ESTIMAP modules (Vallecillo et al. 2018) with ecosystem condition indicators to increase the sensitivity of model outcomes against changing habitat conditions for pollinators. The assessment purpose is to provide a decision-base for an improved biotope management in cultural landscapes and protected areas by deriving recommendations, e.g. for priority areas for conservation measures. Model development and implementation were embedded in a participatory approach with experts and stakeholders to ensure practical relevance of outputs.

The Test Site thus serves as a best practice example for (i) including different ecosystem condition scenarios to improve the pollination potential model, (ii) the stakeholder involvement and result communication and (iii) the potential for enhancing policy relevance by building upon the results for further assessments.

Despite the mentioned strengths, some challenges were encountered at the Test Site. Model-related issues included the low resolution of condition indicator data and the lack of comprehensiveness from using only one indicator, which are, however, not case-specific problems. The main specific challenges at this Test Site refer to the involvement of experts and stakeholders. First, finding wild bee experts for scoring model input parameters was difficult. The initial aim was to include only local experts to ensure scores suited local biotope types, but the number was too low. This issue was addressed by extending the group to national experts. Second, involving farmers in the discussion of results was challenging. Despite explicit invitations, no representatives from this stakeholder group attended the final event. Consequently, the discussion of results and their applicability was limited to local and regional authorities, NGOs, researchers, and planners. It is assumed that participation was difficult for farmers because the event occurred during working hours and was unpaid, which is challenging for self-employed farmers. This issue was partially mitigated by a representative from Lower Saxony’s Chamber of Agriculture, who could further distribute the discussed information.

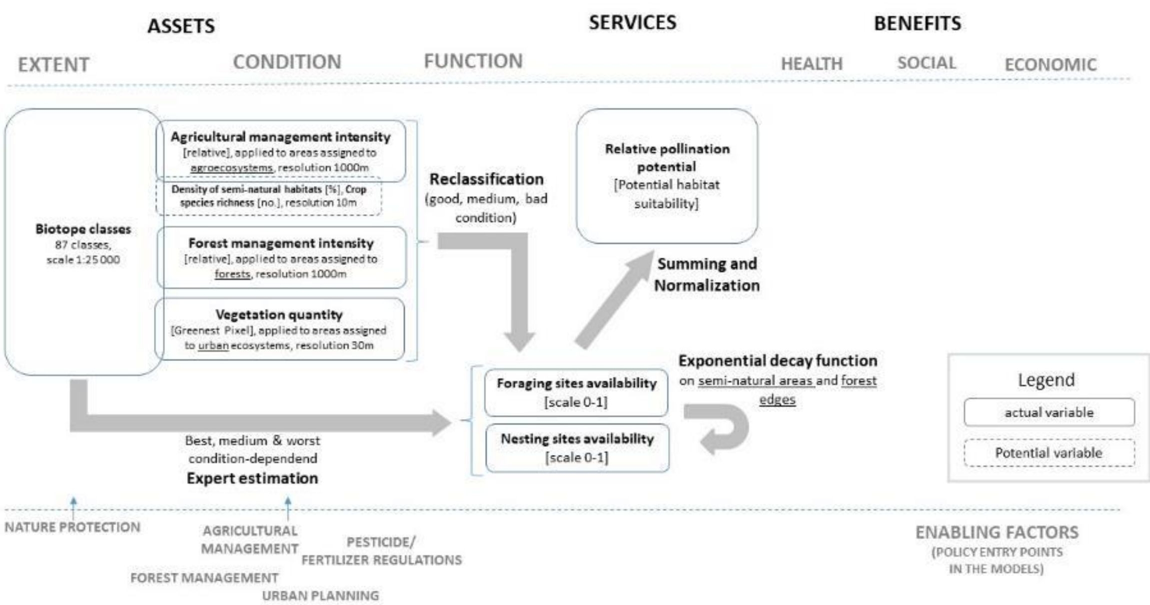


Figure 29: Test site "modelling pollination potential" model chain.

The ES assessment logical chain in **Fig. 29** provides an overview of variables actually used in the model, as well as variables/models that could potentially increase the policy relevance and likelihood of uptake in planning and management. The Test Site currently reflects best practice in pollination assessment in Germany in the following application contexts:

- **Including ecosystem condition scenarios**: Different habitat conditions were considered in the expert scoring process, suitable condition indicators were selected for three distinct ecosystem types within the Test Site area (agricultural land use intensity, forest management intensity, quantity of urban green) and the variables were classified into three condition scenarios to create an ecosystem condition map as input for the ES model.
- **Biophysical valuation of ES potential:** The ESTIMAP model (Vallecillo et al. 2018) was enhanced by the consideration of ecosystem condition scenarios and the final indicator 'potential habitat suitability for wild bees' constitutes a reliable biophysical measure for the ecosystem potential to provide pollination.
- **Stakeholder engagement:** Wild bee experts and non-expert stakeholders from policy, administration, consulting, nature conservation, and agriculture were involved in the model adjustments and plausibility checking. The model thus considers practitioners needs and expectations and provides best possible outcomes for a meaningful application.

The following section briefly explains the relevance of the Test Site approach to the 7 diagnostic topics:

(i) **Ecosystem condition enabling assessment**. The ESTIMAP model (Vallecillo et al. 2018) was enhanced by considering different scenarios of ecosystem condition during the expert scoring and by applying different spatially explicit condition indicators for distinct ecosystem types. Selected indicators were agricultural intensity, forest management intensity and quantity of urban green space. The integration of condition indicators, and the potential to refine it by including other or more indicators, makes the Test Site a best-practice example. Optional variables for agroecosystems, that were identified as suitable ecosystem condition indicators to be included in the future, are for instance crop species diversity or density of semi-natural habitats.

(ii & iii) **Dimensions of justice and health assessment.** In our estimation, our pollination ecosystem service model application has only little direct justice or health dimensions, which therefore were not explicitly considered in the assessment. However, the Test Site had a strong participatory approach by including experts and local stakeholders during the entire assessment process in a series of workshops. The workshops were conducted at different stages and aimed at involving stakeholders during data selection, model implementation and to verify plausibility of intermediate results. Stakeholders from research, policy, administration, consulting, nature conservation, and agriculture were invited for the presentation and discussion of results. Results were discussed regarding their significance for policy and planning support, alongside discussions on potential measures to enhance habitat suitability, their benefits, and feasibility. Furthermore, the used communication media and potential communication channels were discussed. The Test Site thus represents an example of best practice in terms of stakeholder involvement and communication. This could also be used to highlight possible justice or health aspects more explicitly, by setting the focus on different stakeholder groups' needs (e.g. organic versus conventional farmers).

(iv) **Spatial scaling and resolution.** Biotope type data from 2020 provided by the Region of Hanover on a 1:25 000 scale was used as a baseline dataset to estimate nesting and foraging capacity. The dataset exhibits a sufficient spatial resolution for the assessment purpose, as confirmed by experts in a workshop prior to the assessment. With regards to the condition data, the urban condition indicator ‘quantity of urban green spaces’ was provided in a 30m resolution. The used datasets on agricultural and forest management intensity were not sufficiently resolved for local assessments, but the model approach allows for easy replacement of indicators. The above mentioned optional additional variables crop species diversity and density of semi-natural habitats are available, for instance, in 10m resolutions.

(v) **Uncertainty documentation**. Results plausibility was discussed and generally confirmed by experts. However, reliability of outcomes would be increased by a validation, which could for example be done in a sample mapping approach of wild bees in the modelled areas. Simplifying model assumptions and underlying uncertainties (such as too coarse resolution of two of the condition indicators) were explicitly stated during result communication with stakeholders and in the associated publication. However, the robustness of findings is limited as no uncertainty measures (confidence intervals, sensitivity analysis) were provided.

(vi) **Capacity-potential-supply-demand in ES assessment.** The Test Site only dealt with assessing the potential for pollination by modelling pollinator habitat suitability.

Demand was not assessed. However, the stakeholder involvement approach holds potential to assess the demand, e.g. by identifying and modelling spatial distribution of pollinator dependent crops and vegetation.

(vii) **Economic valuation compatibility**. Not assessed. The study area has further 'best practice' potential by modelling economic value of pollination, e.g. by modelling economic losses in case of crop failure due to lack of pollination (Model: damage cost avoided). An economic valuation is however not the purpose of the Test Site assessments, which aim at a biophysical quantification for landscape management.

Best practice case 2: Modelling soil retention loss by forest fires in Northern Portugal (Test Site 17)

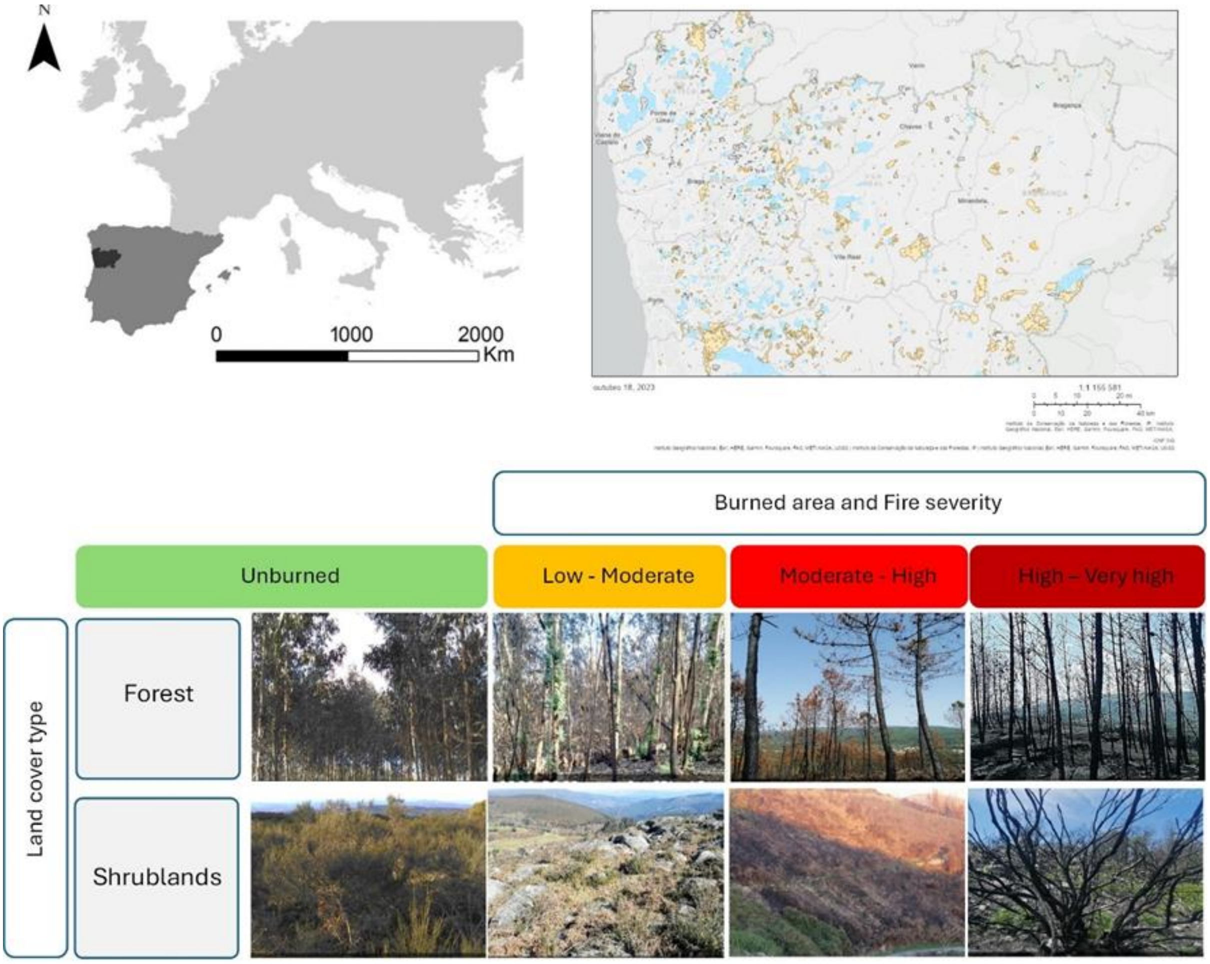


Figure 30: Location of the focal area in NUTS-II Northern Portugal (top left panel). Burned area in the focal area between 2015 and 2018 (top right panel). Forest and shrublands cover types in pre-fire (unburned) and post-fire environments according to different levels of fire severity (bottom panel). Photo credit: SeverusPT project (FCT, ref. nr.: PCIF/RPG/0170/2019).

Background: Forest fires in Portugal can be seen as negative externalities associated with practices and socioeconomic changes in the agricultural and forest sectors, such as 1) neglected forest management (e.g., lack of fuel management); 2) intensified forest management (e.g., monoculture plantations), 3) inappropriate afforestation (e.g., very flammable species in former croplands/pasturelands); 4) farmland abandonment (Mateus and Fernandes 2014). Uncontrolled forest fires can reduce pre-existing ecosystem services (ES), such as soil retention by fostering soil erosion (Sil et al. 2019).

Aim: The aim of the Northern Portugal Test Site (SELINA Test Site 17) is to demonstrate how reduced ES (timber production, carbon sequestration, soil retention and visitation) from forest fires can be accounted for using the NUTS II - Northern Portugal as the focal area. Here we demonstrate the example of the impact of forest fires on soil retention ES in burned forest and shrubland areas by applying a modelling approach using the Morgan-Morgan-Finney (MMF) soil erosion model (Morgan 2001).

Model description and application: MMF predicts soil erosion rate, i.e., the amount of soil loss (kg/m^2) in a given year (Morgan 2001). The model uses soil properties, topography, precipitation, and land cover as major inputs. Soil erosion is modelled based on 1) the water phase: which determines the energy of the rainfall available to detach soil particles from the soil mass and the volume of runoff; 2) the sediment phase: rates of soil particle detachment by rainfall and runoff are determined along with the transporting capacity of runoff; 3) then, predictions of total particle detachment and transport capacity are compared and erosion rate is equated to the lower of the two rates (Morgan 2001). MMF has been applied in Portugal to predict post-fire soil erosion due to fire-induced changes in vegetation according to burn severity levels in shrublands and forests (Parente et al. 2022). The novelty of MMF application within the Northern Portugal Test Site is the incorporation of observed fire severity based on satellite-based spectral indices (i.e., the NBR - Normalized Burn Ratio) from Sentinel-2 and field plots (Gonçalves et al. 2024). Three classes of burn severity from 2017 wildfires in Northern Portugal were considered under calibration model parameters based on previous work of Parente et al. (2022).

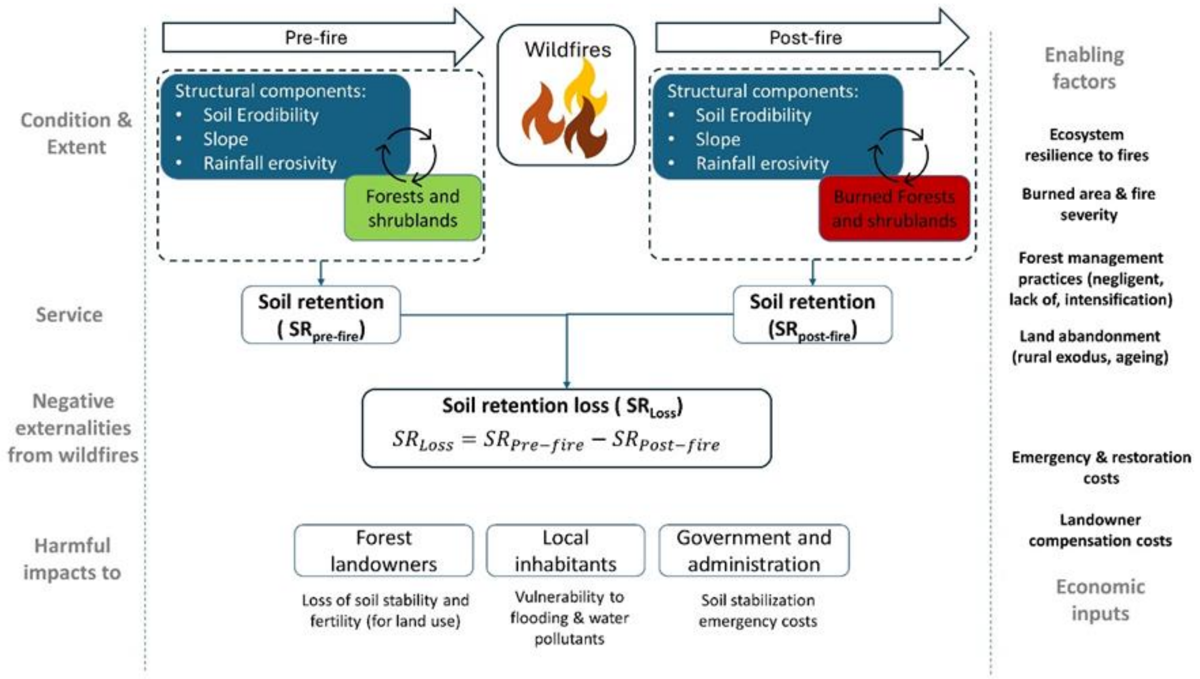


Figure 31: Logic chain for modelling soil retention loss by forest fires in Northern Portugal Test Site.

The logic chain in **Fig. 31** provides an overview of the application of the Morgan-Morgan-Finney (MMF) soil erosion model to modelling soil retention ES in pre-fire and post-fire environments and the loss of soil retention ES due to wildfires (negative externality) according to different levels of fire severity. Potential enabling factors and socio-economic harmful impacts from soil retention ES loss are shown. Soil retention ES loss is estimated as the difference between 1) the ecosystem's capacity to retain soil in the pre-fire environment, calculated by subtracting structural soil erosion (i.e. in the absence of vegetation) and the fraction of soil eroded in the presence of unburned vegetation and 2) the ecosystem's capacity to retain soil in the post-fire environment, calculated by subtracting structural soil erosion (i.e. in the absence of vegetation) and the fraction of soil eroded in the presence of burned vegetation according to fire severity levels.

Relevance: Different levels of the policy cycle would benefit from our study, for example, policy formulation, adoption and implementation 1) by providing insights into planning and management of fire-prone landscapes (e.g., Landscape Design and Management Programmes or Forest management plans) regarding adequate management practices to mitigate severe wildfires and ecological and socioeconomic post-fire harmful impacts; 2) by incorporating soil retention loss predictions to evaluate impacts, prioritize post-fire erosion emergency measures, as well as their potential costs, and devise eventual damage compensation plans.

Challenges: The main challenges identified in the application of the MMF model to the Test site, thereby limiting its uptake by policymakers and stakeholders, were: 1) the high demand for spatial inputs compared to other approaches, e.g., RUSLE equation; 2) the need for field-work measurements to calibrate model parameters (e.g., effective hydrological depth in burned areas) to adequately simulate post-fire soil erosion according to different levels of fire severity and types of vegetation; 3) the need to address uncertainty associated with model inputs (e.g., ERA interim vs. ERA 5 rainfall data; Parente et al. 2022).

Diagnostic topics reflecting "best practice":

When going through all the check-list questions through the seven diagnostic topics, many of them were not considered in our Test Site development, and therefore there is room for improvement in the development of our Test Site study that can still be implemented. However, there are many questions that were considered without prior acknowledgment of the checklist and can be identified as a "best practice" for decision uptake. Here some details in each diagnostic topic:

i) Spatial scaling and resolution capabilities and models – all the spatial scaling and resolution questions applicable to our modelling approach were well addressed. The Morgan-Morgan-Finney (MMF) erosion model was applied at the regional scale, i.e., NUTS - II Northern Portugal (21,515 km^2). The spatial resolution of model inputs and outputs was set to 20m pixel size.

ii) Ecosystem condition variables in ES - ecosystem condition variables were included in the modelling process based on several parameters required by the Morgan-Morgan-Finney (MMF) soil erosion model, namely: 1) land cover types and extent (i.e., forest area (37% of the total surface) and shrublands (22% of the total surface)) and vegetation proprieties (i.e., rainfall interception, canopy cover, plant height, evapotranspiration, crop cover management, ground cover); 2) soil proprieties (i.e., bulk density, effective hydrological depth of soil; maximum soil moisture storage capacity; soil detachability soil surface cohesion); 3) landform (i.e., slope steepness); 4) precipitation (i.e., annual rainfall, days with rain, rainfall erosivity); 5) fire extent and severity (i.e., burned areas at different severity classes: low - moderate; moderate - high; high - very high).

iii) Capacity, potential & actual supply, use, demand - ecosystems capacity, supply and use were addressed in the Test Site by applying the Morgan-Morgan-Finney (MMF) soil erosion model to assess soil retention ES supply and loss due to forest fires (negative externality) and potential harmful impacts. On the demand side, the Test Site identified potential stakeholders who benefit from the study. However, the Test Site did not consider the involvement of stakeholders from the beginning, nor training for professionals, which can be seen as a caveat on the study uptake for decision-making.

iv) Economic valuation compatibility – in our Test Site the biophysical quantification of ecosystem services will be the basis for the economic valuation under WP5, including the total ES flow and changes in ES flow. A final workshop for stakeholders to present the policy recommendations is planned.

v) Social benefit compatibility and dimensions of justice – the questions related to this diagnostic topic were not considered, especially because stakeholders were not included from the beginning, but are indeed very relevant.

vi) Health benefit compatibility - we do not consider health compatibility, although very important when having fire as the main driver of impact.

vii) Uncertainty assessment - the uncertainty was considered through all modelling approaches under the modelling evaluation when considering fire impact under 3 classes of fire severity and not only the fire itself, using calibrated values for forest fires in Portugal (Parente et al., 2022).

Best practice case 3: Modelling habitat provision for waders and fodder supply in coastal wetlands in Estonia (EMU, Test Site 18)

Photo depicting one of the study sites in the Estonian west coast.
Photo credit: Volha Kaskevich.

SELINA Test Site nr. 18 addresses ecosystem services supplied by coastal wetlands (Annex I habitat type: Boreal Baltic Coastal Meadows, 1630) in the west coast of Estonia. More specifically, the Test Site focuses on the role of these coastal wetlands in supporting biodiversity, supplying habitat for breeding wader species (e.g. Baltic Dunlin, Common redshank) (**Fig. 32)**. In addition, the Test Site also assesses the capacity of coastal wetlands to maintain grazing cattle, modelling the quantity and nutritional values of fodder supplied by the meadows. The modelling approach builds primarily on drone-derived data (e.g. multispectral imagery), field data (vegetation surveys and hatching success data), and lab data (nutrient content). The assessment purpose is to better understand the ecological role of coastal meadows. However, the results of these models could potentially be used in fine-tuning meadow management strategies, e.g. adjusting grazing loads to ensure habitat supply for wader species. The models further utilise machine learning techniques to handle the large amounts of input data and provide spatially explicit predictions on the targeted ecosystem services.

The main challenges in this TS are related with two aspects, namely: the large amount of data required and limited uptake of the information generated in current management practices. In terms of data needs, statistically reliable outputs demand large quantities of *in-situ* data, used in both training and validation of the remote sensing models. This may constitute a challenge due to remoteness of study areas and labour-intensive fieldwork. The uptake of the models in ongoing protected area management practices has been limited thus far. This is likely due to the lack of expertise in public organisations and a certain reluctance to adopt new solutions. Moreover, there are evident needs for user-friendly tools that can help turn processed information into readily usable GIS-based decision-support tools and platforms, an area of development that is beyond the capacity and competence of the academic sector.

Test site nr. 18 can be considered best practice in terms of:

1. Very high spatial resolution, targeting the scale of ecosystem processes relevant for habitat supply and fodder production.

2. Explicit validation of modelling outputs with in-situ data.

3. Potential to provide management-relevant information for both protected area managers and landowners/farmers.

Although this Test Site is strongly driven by the need to better understand the connections between coastal wetland condition and the survival of breeding wader populations, the outputs show potential applications into various policy/management realms:

- **Coastal wetland management:** The models provide valuable information about the effects of grassland management practices on grassland condition and consequently, on wader populations. These modelling outputs constitute a valuable insight for protected area managers regarding the adjustment of management practices.
- **Monitoring policy performance:** Spatially explicit information on the effects of agri-environmental payment schemes on biodiversity.

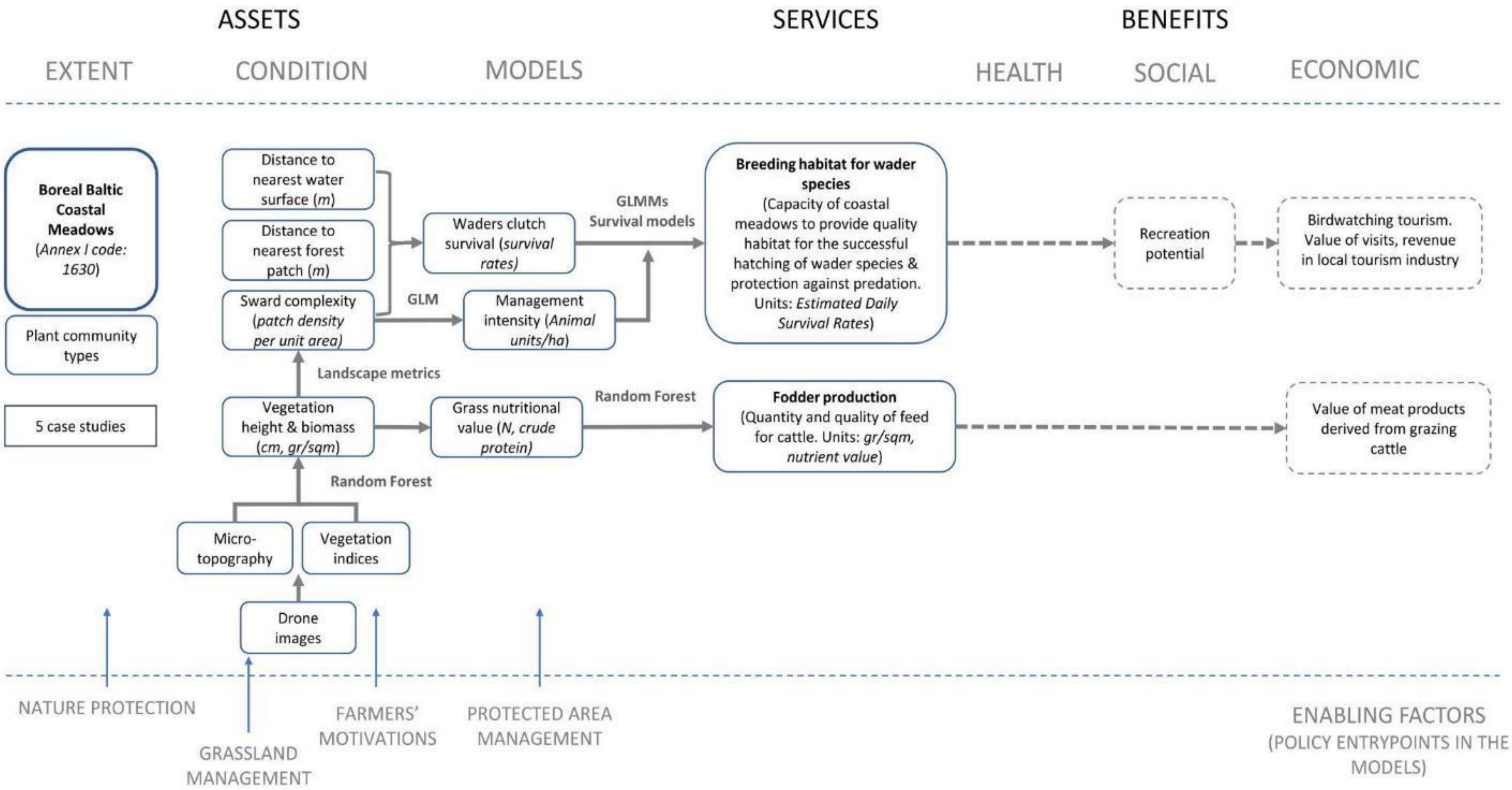


Figure 32: Summary of the main workflows utilised in the habitat supply and fodder production models, depicting input data, intermediate products, statistical models, and final ES outputs.

This best practice aligns with the 7 diagnostic topics as follows:

(i) **Ecosystem condition enabling assessment.** Ecosystem condition was included in the models using a set of four indicators, namely: Vegetation height/biomass, grassland sward complexity, distance to forest, and distance to water surfaces. These condition indicators were selected based on expert knowledge on wader ecology and predation dynamics. However, the models are not restricted to this set of indicators and could potentially include other condition-relevant variables such as topsoil moisture and grassland phenology dynamics.

(ii) **Dimensions of justice and health assessment.** The Test Site did not explicitly address dimensions of justice and health in the assessment.

(iii) **Spatial scaling and resolution.** The assessment is characterised by very high-resolution raster data, stemming from the use of drone imagery. The five study sites were selected using the Natura 2000 habitats map of Estonia, provided at a scale of 1:10 000. The final resolution of the models is 10 cm per pixel, built upon multispectral drone images. The very fine resolution of this assessment allows targeting relevant ecosystem processes that drive habitat suitability for wader species. The Test Site also presents a high potential to upscale the drone-based models to satellite resolutions, which would allow to resolve subpixel heterogeneity while encompassing large extents of assessment.

(iv) **Uncertainty documentation:** This best practice addresses uncertainty using in-situ data to assess the robustness of the models and validate the outputs. By doing so, the models include a statistical quantification of deviation from actual values. However, beyond standard model validation, machine learning models utilising remotely sensed data are still subject to a large degree of uncertainty. Future updates of this Test Site (or similar modelling approaches) should estimate uncertainty as the degree of variation (e.g. coefficient of variation) of multiple, iterated, model outputs.

(vi) **Capacity-potential-supply-demand in ES assessment:** The Test Site addressed actual supply of ecosystem services. Demand was not addressed.

(vii) **Economic valuation compatibility:** Not assessed within this Test Site. However, there is a clear potential of undertaking an economic valuation assessment of both ecosystem services assessed in this case. In the case of fodder provision, the economic valuation could be addressed in terms of the value of meat products derived from the cattle grazing in the study sites. In the case of habitat supply for wader species, the valuation could focus on the economic value associated to bird watching tourism.

Best practice case 4: Agricultural provisioning services in the Gudenå basin and at national level for Denmark (Test Sites 10 and 27)

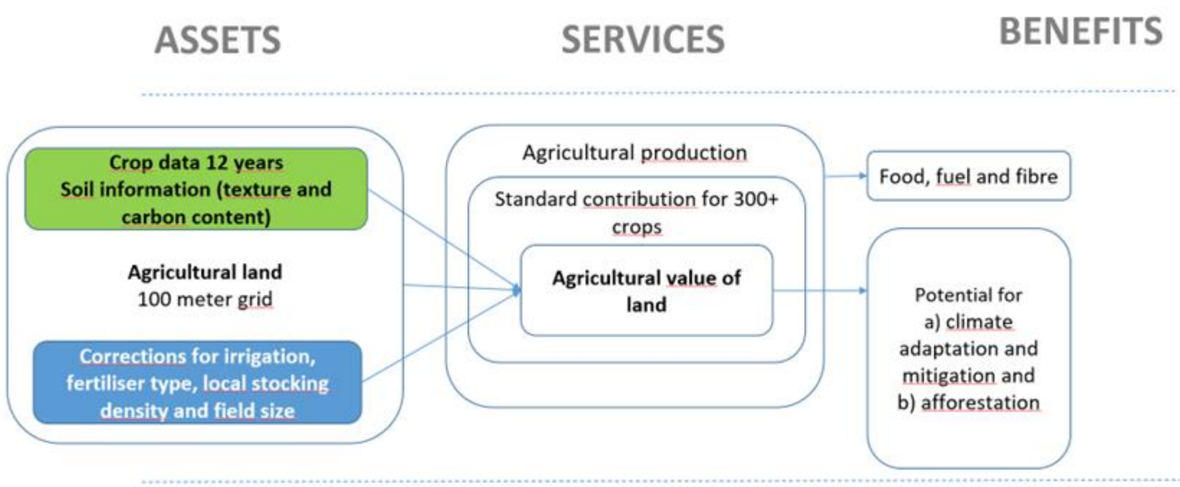


Figure 33: ES model logic chain for agricultural provisioning services in the Gundenå basin, illustrating the assessment of the agricultural provisioning service to estimate the agricultural value of land.

Aims of the assessments:

- **Crop provision ES assessment of agricultural value of land for spatially explicit trade-off/synergies** between food provision, other provisioning services and global climate mitigation (carbon emissions/uptake) in afforestation in Denmark (Test site 10). Test case 10 on synergies in afforestation was commissioned by the Danish Agricultural Agency with the aim to identify the areas most suitable for afforestation in Denmark based on the assessment of a number of services.

- **Assessment of impacts/synergies between food provision and global climate mitigation (carbon emissions/uptake)** when re-wetting agricultural land in the Gudenå river valley (Test site 27). TS 27 on the Gudenå river valley was commissioned by the Gudenaa River Committee, which consists of all municipalities in the catchment area. The aim of the analysis was to support decisions regarding flood control and climate mitigation strategies with the aim of creating multifunctional solutions with the inclusion of biodiversity protection and opportunities for recreation.

The assessment was performed without significant challenges as the assessment team had full control of the process. Minor challenges, delineation of the river valley for assessment and a new biodiversity approach, were not linked to the assessment of agricultural provision service.

Diagnostic topics reflecting "best practice" in the case:

The assessment uses standard contribution values for different crops on different soil types (texture and carbon content) to assess the value of the agricultural provisioning service and uses this as an indicator on the value of the agricultural land.

(i) Spatial-temporal resolution

The assessments cover all agricultural land in Denmark in 2021 at a 100 meters grid as service providing units. It is based on 12 years of data on crops at field level with corrections for irrigation, fertilizer type, local stocking density and field size. Details on the methodology for the calculation can be found in Pedersen (2022). The application of the methodology in test case 10 is described in Juul Jessen et al. (2022). The application in test case 27 is described in Andersen et al. (2023).

(ii) Uncertainty documentation

This study does not explicitly document uncertainty, but it should be noted that the strength of the methodology is in screening exercises, i.e. in both TS the aim has been to identify the most suitable areas for climate adaptation and mitigation and afforestation respectively. For actual project implementation at a local level, more detailed methods must be applied, including assessment of levels of uncertainty.

(iii) Ecosystem condition enabling ES assessment

The methodology is based on the actual agricultural provisioning services from a larger number of fields in Denmark – data collected by the agricultural services. These are then calculated in a 100 metres grid for all agricultural land in Denmark in 2021. This is based on field level data on crops (12 years) and soil conditions (texture and carbon content). Some corrections are applied related to fertilizer type (artificial/manure), irrigation, field size and local stocking densities.

(iv) Capacity-potential-supply-demand in ES assessment

The ES models do not consider specific variables to quantify independently the ES cascade components "cropland capacity for food provision", "cropland potential for food provision" and "cropland food supply". The "demand of food provision" is equal to "cropland food supply" for a specific area.

(v) Economic valuation compatibility

The outcome of the ES assessment is expressed as the economic value of agricultural land in EURO. Hence, the assessment of ES is compatible with economic valuation.

(vi) Social benefits compatibility and dimensions of justice

Social benefits and justice dimensions were not explicitly addressed in the study, but both TS stand as best practice examples in the integration of multiple services in the assessments. Furthermore, both cases have been commissioned by public authorities, increasing the likelihood of weighing different societal benefits. Especially in the Gudenå TS there has been a process of stakeholder engagement in the assessment. These conditions are likely to increase legitimacy in the process and increase the likelihood of uptake in the policy process.

(vii) Health benefit compatibility

The assessments have not had an explicit aim of evaluating health benefits.

6.4.3 Draft Terms of Reference proposal from ES group

Table 9: Draft terms of Reference as agreed by the working group members to evaluate agriculture and forestry provisioning related ES models. The questions under the green row are applicable under any ES modelling context. Those under the blue row are relevant only in specific contexts. Those under the yellow row were deemed less relevant, but might be improved upon in further development in Task 4.3. Those under the grey banner require further review in collaboration with stakeholders in Task 4.3.

ToR questions useful in any context		
Diagnostic topic	Does the model application:	
Spatial and temporal scale and resolution	Assess ecosystem services appropriate for the complexity of the ecosystem services evaluated?	Yes/No
Capacity-potential, supply-use	Present clear approaches for assessing each dimension?	Yes/No
Capacity-potential, supply-use	Clarify indicators for each ES and each dimension?	Yes/No
Capacity-potential, supply-use	Link and/or integrate the ES dimensions considered in it?	Yes/No
Capacity-potential, supply-use	Elucidate uncertainties associated with each of the assessed dimension(s) (and indicator(s))?	Yes/No
Capacity-potential, supply-use	Elucidate the (spatial) relations between the assessed dimensions?	Yes/No
Uncertainty	Include validation? (e.g. model intercomparison, external observations, sensitivity analysis)	Yes/No
ToR questions useful in some contexts		
Spatial and temporal scale and resolution	Clearly define and justify the spatial units used in the assessment?	Yes/No
Spatial and temporal scale and resolution	Use spatially explicit indicators to assess ecosystem services?	Yes/No

Spatial and temporal scale and resolution	Use spatially explicit indicators to assess ecosystem condition?	Yes/No
Spatial and temporal scale and resolution	Use an appropriate spatial resolution of the applied ecosystem condition indicators for the scale of the assessment?	Yes/No
Spatial and temporal scale and resolution	Consider common frameworks (e.g. CICES, Essential variables, MAES) in order to homogenise comparisons?	Yes/No
Spatial and temporal scale and resolution	Include a sensitivity analysis to understand the effects of varying spatial resolutions?	Yes/No
Spatial and temporal scale and resolution	Assess and report the spatial interdependencies between different ecosystem services within the study area?	Yes/No
Spatial and temporal scale and resolution	Consider potential trade-offs between different spatial scales and their implications on ecosystem services?	Yes/No
Spatial and temporal scale and resolution	Address and document temporal variability in ecosystem services?	Yes/No
Spatial and temporal scale and resolution	Include metadata for spatial scales and resolutions following the INSPIRE directive?	Yes/No
Spatial and temporal scale and resolution	Present well-defined methods for assessing impacts of ecosystem condition on services?	Yes/No
Spatial and temporal scale and resolution	Emphasise the integration of biodiversity conservation within the evaluation of ecosystem conditions and services?	Yes/No
Uncertainty	Use scenarios?	Yes/No
Uncertainty	Monitor risks?	Yes/No

Uncertainty	Include contingency measures to offset risks of high uncertainty in model outcomes, e.g. risk multipliers.	Yes/No
Social benefits and dimensions of justice	Account for confounding social, economic, cultural and environmental factors which mediate the relationships between ES and social benefit and justice outcomes?	Yes/No
Social benefits and dimensions of justice	Evaluate the potential impacts of different policy actions on the distribution of ES benefits among various societal groups?	Yes/No
Social benefits and dimensions of justice	Include indicators which are specifically social benefit-relevant as determined by the engagement with stakeholders?	Yes/No
Health benefits	Explore or identify distinct pathways between ecosystem structure / function / ecosystem services for health aspects?	Yes/No
Health benefits	Include an assessment of the stocks and flows of health relevant ES?	Yes/No
Health benefits	Identify disparities in access to / benefits from health-benefit ES and attempt to understand the drivers and consequences of such disparities?	Yes/No
Health benefits	Assess the current and / or potential future distributive impacts of policies or activities on ecosystem management?	Yes/No
Health benefits	Account for existing formal and informal governance mechanisms relevant to ES in the study area?	Yes/No
Health benefits	Validate the study scenarios / models / inputs / outputs against local knowledge or perspectives?	Yes/No
Health benefits	Develop indicators which are specifically relevant to health benefits, as determined by engagement with stakeholders?	Yes/No
Health benefits	Account for confounding social, economic, cultural and environmental factors which mediate the relationships between ES and health outcomes?	Yes/No
Economic valuation	Use scales (temporal, spatial, beneficiaries) of the biophysical quantification of ecosystem services that match the economic valuation?	Yes/No

Economic valuation	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)?	Yes/No
Economic valuation	Provide information on equity implications?	Yes/No
Economic valuation	Assess and address uncertainties associated with the valuation, providing a clear indication of the confidence level in the results?	Yes/No
Economic valuation	Assess long-term dynamics in ecosystem capacity, supply and demand in order to measure the sustainability of ES use and values.	Yes/No
Economic valuation	Assure the contribution of ES to economic development indicators (e.g. employment, growth)?	Yes/No
ToR questions with less usefulness		
Ecosystem condition	Emphasise the integration of wellbeing assessment within the evaluation of ecosystem conditions and services?	Yes/No
ToR questions requiring further review		
Spatial and temporal scale and resolution	Take into account the spatiotemporal dynamics and potential future changes of ES?	Yes/No
Spatial and temporal scale and resolution	Consider the third spatial dimension (e.g. elevation above sea level, relief, or slope)?	Yes/No
Spatial and temporal scale and resolution	Use recent maps of the study area and do they reliably document recent land use and land cover changes at a relevant spatial scale?	Yes/No
Capacity-potential, supply-use	Address sustainability aspects of ES dimensions?	Yes/No
Uncertainty	Use multiple models leading to a range of outcomes?	Yes/No
Uncertainty	Perform model ensembles?	Yes/No

Uncertainty	Use data of appropriate accuracy (temporal, spatial resolution)?	Yes/No
Uncertainty	Use the precautionary principle?	Yes/No
Social benefits and dimensions of justice	Identify ES beneficiaries and assess disparities in access and distribution of benefits?	Yes/No
Social benefits and dimensions of justice	Consider the intergenerational aspects of ES and their implications for future wellbeing (e.g., impacts of policies or activities)?	Yes/No

6.5 Fisheries, aquaculture & marine provisioning ecosystem services

6.5.1 Summary of ES group approach

The Demonstration project "DP07 Latvia: Maritime spatial planning & thematic planning of coastal public infrastructure" has been selected to implement the subtask 4.2.5. on Fisheries, aquaculture and marine harvest. Other DPs and Test Sites on marine ecosystems have been addressing either regulating or cultural ecosystem services, thus these are not within the scope of this ES group.

The Latvian Maritime Spatial Plan (MSP) 2030 was adopted by the Government of Latvia in 2019. The Latvian MSP 2030 was developed according to the EU Maritime Spatial Planning Directive 2014/89/EU, which aims to establish and implement MSP by applying an ecosystem-based approach. The MSP Directive highlights that healthy marine ecosystems and their services, if integrated into planning decisions, can deliver substantial benefits in terms of food production, recreation and tourism, climate change mitigation and adaptation, shoreline dynamics control, and disaster prevention. Since 2020 Latvian governmental regulations on development procedures on the MSP explicitly require that MSP includes MAES results in the explanatory (descriptive) chapter of the plan. It is important to note that the first Latvian MSP and its strategic environmental assessment integrated the wild fish provisioning ES assessment in a spatially explicit way (Veidemane et al. 2017).

By the end of 2023, the interim evaluation of the Latvian MSP was conducted, including the update of relevant information on mapped and assessed ecosystem services provided by marine and coastal ecosystems. The evaluation also included collecting up-to-date information and knowledge on fish provision and the potential development of aquaculture, which shall be further used in evaluating the implementation of planning solutions and proposing revisions to the Latvian MSP if needed.

A review of D4.1 checklists was conducted from the Maritime Spatial Planning (MSP) perspective of Mapping and Assessment of Ecosystems and their Services (MAES), focusing on the provisioning of wild animals (fish) and aquaculture products (plants and animals). The review of fishery demonstrated the current approach to the provisioning of wild commercial fish in the Baltic Sea, which is strongly regulated by the EU Common Fishery Policy. Meanwhile, aquaculture was depicted as having the potential to use the marine ecosystem to deliver provisioning services in situ.

The discussion about the fish provisioning ES in light of DP07 Latvia was organised during workshop session No. 9 in Leiden, the Netherlands on February 6, 2024. The focus was on the question of how to improve the decision relevance of the fish provisioning examples by enhancing knowledge of ecosystem condition in their ecosystem service assessment methods. Input from the SELINA partners supported further work on the best practice case for the development of Terms of Reference (ToR). The approach and experience in mapping and assessing fish provisioning ecosystem services (1.1.6.1. Wild animals used for nutritional purposes) for the interim evaluation of the Latvian Maritime Spatial Planning has been selected as a "best practice" example. This is because the example can be replicated in other countries of the Baltic Sea region due to commonly agreed international methodologies in data collection on commercial fish species.

6.5.2 Selected “Best practice” model applications testing draft ToR

Best practice case 1: Mapping and assessing fish provisioning ecosystem services for the interim evaluation of the Latvian Maritime Spatial Planning (Partner: BEF, Demonstration Project 07)

Caption: Fishing vessels in the port Liepaja, Latvia.
Photo credit: Kristina Veidemane

The Latvian DP serves as a 'best practice' case study, exploring the characteristics of the marine ecosystem that determine fish provisioning ecosystem services and their relevance to marine-related policies. While the Latvian DP primarily focuses on MSP, the provisioning of fish is currently governed by fishery policies, such as the EU Common Fishery Policy, which dictate the total allowable catch per year per fishing sub-basin and per country.
MSP, which establishes spatial and temporal limitations for sea uses, can impact fish provisioning by either excluding certain areas (e.g., offshore wind park areas) from fishery or vice versa, restricting other sea uses, such as offshore wind park development, in areas essential for fish species and fishery. Nature conservation policies, through the establishment and management of marine protected areas (MPAs), may also restrict certain activities. Marine environment policies have set the goal to achieve good environmental status, which must also be considered by MSP. Thus, MSP plays a crucial role as a key and umbrella policy to ensure the sustainability of fish provisioning through effective planning solutions.

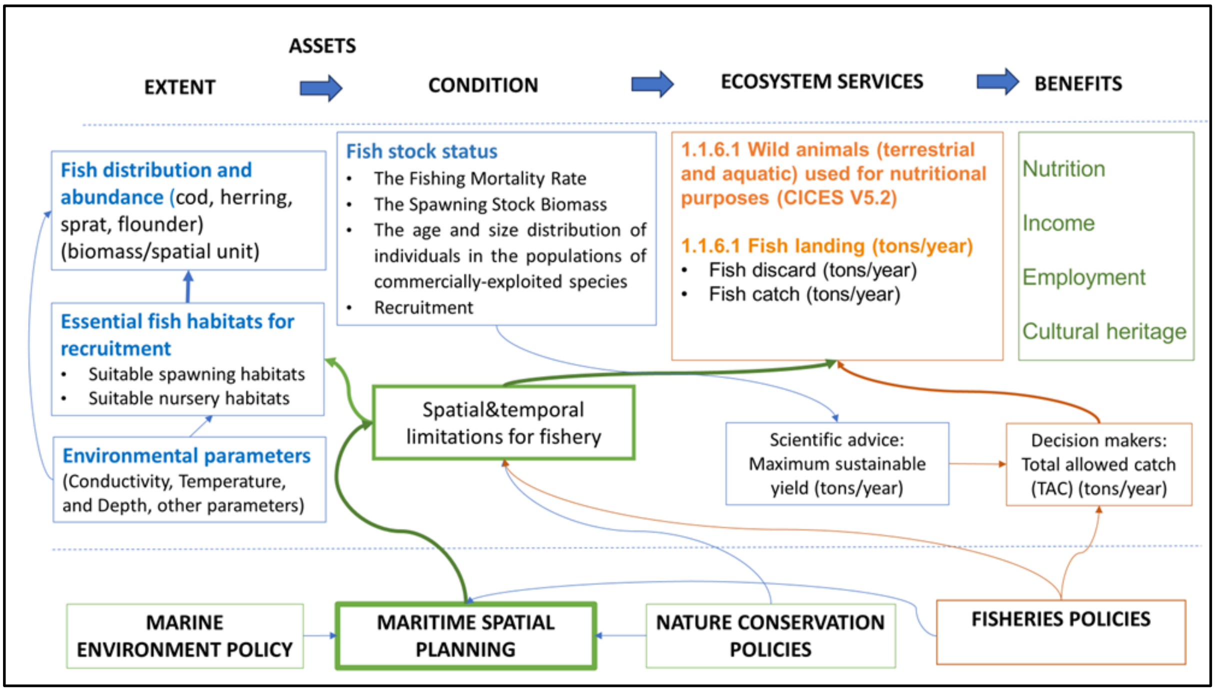


Figure 34: An assessment chain for fish provisioning ES integration in Maritime Spatial Planning.

The Latvian DP addresses key commercial fish species – herring and sprat (pelagic), flounder (benthic), and cod (demersal) – highlighting the link between fish stock condition and extent variables and fish provisioning variables. As fish species are mobile and have different habitat needs during different life stages, ensuring the sustainability of provisioning ecosystem services requires MSP to consider areas for spawning and nursing, which goes beyond mere information on fish distribution and abundance, or fish catch or landing. It has been a major challenge to identify and select indicators that spatially explicitly describe the condition of fish populations, making them suitable for incorporation into maritime spatial planning. There is a mismatch in the spatial assessment units used for ecosystem services (ES) and the condition assessment of fish stocks. A key challenge for spatially explicit economic and/or social valuation is the existing rules on data confidentiality, given the limited number of fishery companies.

(i) **spatial-temporal resolution.** This aspect is highly significant as the ES assessment results are used for Maritime Spatial Planning, where spatial information is crucial. Fish landing (CICES classification; 1.1.6.1) are presented at two scales for different spatial units: 1) open sea data – (tons/km^2/year); 2) coastal sea data – per relevant administrative unit, up to 20 m depth. The basemaps are based on ICES sub-basins or basins, which are management units for fisheries. The fish landing maps represent annual and longer time periods, spanning at least 10 years, as the spatial fish abundance between years might change due to climatic parameters. The data present fish landing according to single commercial species as well as in total. Fishermen's logbooks are the data source used to produce spatial maps on fish landing. Fish landing as an ecosystem service is dependent on the availability and quality of essential fish habitats, as well as on different environmental parameters. However, due to the mobile nature of species throughout their lifetime, the spatial interdependencies are not straightforward.

(ii) uncertainty documentation. The information from open sea fishing logbooks and the integrated control and information system of Latvian fisheries was used to process the spatial data on fish landings. Errors in spatial coordinates entered in fishermen's logbooks for open sea fishery are noted. During the period 2014-2022, these errors accounted for approximately 6% of the total records or 4.6% of the total fish landing of open sea fishery. The erroneous data are excluded from the map visualisations.

(iii) Ecosystem condition enabling ES assessment. The impacts of ecosystem condition are assessed through the ICES methodology on fish stock assessment of single commercial species per subbasin. This stock assessment serves as the basis for establishing scientific advice on Maximum Sustainable Yield (tons/year) which is used to establish Total Allowable Catch. MSFD also conducts a nationwide assessment on the state of the environment (Descriptor 3), which includes the same indicators as the ICES methodology. The fish stock assessment includes the following condition indicators: the Fishing Mortality Rate, the Spawning Stock Biomass, the age and size distribution of individuals in the populations of commercially-exploited species, and Recruitment. The annual fish stock assessment is carried out for larger ICES units – sub-basins of the Baltic Sea. Therefore, it is not conducted at the same spatial resolution as fish landing. However, this cannot be enhanced due to the natural characteristics of fish stock.
The Latvian DP highlights the importance of spawning and nursery habitats through mapping essential fish habitats. The same map is also used to present information on regulating services.

(iv) **capacity-potential-supply-demand in ES assessment**. In Latvian MSP, fish landing (tons/km2/year) (catch minus discard) is used as an ES supply indicator. However, this indicator does not include fish import, which would be included in ecosystem accounting. Latvia imports a significant number of different fish products, although it also has significant exports, with exports exceeding imports. Fishery is strictly regulated due to limited resources resulting from past overexploitation and environmental impacts such as eutrophication in the Baltic Sea. Therefore, the actual demand for fishery resources is not fully assessed. The demand indicator, “Total Allowed Catch - TAC” (tons/year), is established taking into account the scientific advice indicator known as "Maximum Sustainable Yield - MSY". However, the TAC indicator is not used in MSP because it provides only one total value per stock per sub-basin without further spatial distribution. Capacity is measured by "Maximum Sustainable Yield", which represents the largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. Similar to MSY, this indicator is also not utilized in MSP due to its single total value per stock per sub-basin without further spatial distribution.

(v) economic valuation compatibility. Fish landing (tons/year) is directly applicable for economic valuation. Based on the market value of fish (per species), the total annual market value can be estimated. Price data at the national scale are published by the Statistical Office. Therefore, only national-scale estimation can be used. MSP also incorporates various socio-economic indicators related to the fishery sector. However, the interim assessment of Latvian MSP only illustrates two statistics: the number of shipping vessels and the number of fishing companies at the national level. These numbers are not directly linked ES provisioning. The economic performance of the fishery sector is calculated and reported annually according to the "Guidelines for the analysis of the balance between fishing capacity and fishing opportunities according to Article 22 of Regulation (EU) No 1380/2013 of the European Parliament and the Council on the Common Fisheries Policy." However, these numbers have not yet been integrated into the MSP.

(vi) **social benefits compatibility and dimensions of justice.** The Latvian MSP has not addressed social benefits. However, for coastal fishermen, fishing is not merely an economic activity but also a lifestyle and a cultural heritage topic (another ecosystem service), as generations of fishermen have been engaged in this activity for a hundred years. Traditional fishery practices are at risk due to decreasing fish stocks, which is also a cultural issue. Employment-related indicators could indeed be valuable for social assessment, but they often lack spatial character due to confidentiality rules.

(vii) **health benefit compatibility.** The nutritional value of fish and fish products could be a relevant indicator to measure health benefits. However, the Latvian MSP has not explored health benefits in this manner. Furthermore, the current trend shows that Latvians are not inclined to regularly consume Baltic Sea fish but prefer to consume common aquaculture species, which are mainly imported. Assessing impacts on health aspects could be conducted through the Strategic Environmental Assessment (SEA) process of MSP. However, this has not been implemented in practice yet.

6.5.3 Draft Terms of Reference proposal from ES group

Table 10: Draft ToR in the context of wild fish provisioning. The questions under the green row are applicable under any fish provisioning related policy context, including maritime spatial planning. Those under the yellow row are relevant only in some cases or specific contexts. It is important to note that the EU Common Fishery Policy addresses the sustainability and resilience of the EU's fisheries including fish stock management at maximum sustainable yield for all managed stocks based on scientific advice. Therefore, use of well-established scientific cooperation at the sea basin level (e.g., ICES) shall be also integrated when setting the ToR for MAES of fish provisioning.

ToR questions useful in any context		
Diagnostic topic	**Draft ToR questions**	**Additional considerations**
Ecosystem condition	What **methods** for assessing impacts of ecosystem condition on services does your assessment use?	Consider international methodologies, like ICES methodology on fish stock assessment of single commercial species. Descriptors of MSFD are also applicable to assess the condition of fish stocks
	How does your study emphasise the integration of **biodiversity conservation** within the evaluation of ecosystem conditions and services?	Consider data and knowledge obtain through habitats directive, e.g. essential fish habitats
	How does the study emphasise the integration of **well-being** assessment within the evaluation of ecosystem conditions and services?	
	Which **spatially explicit** indicators used to assess ecosystem **condition**?	ICES methodology on stock assessment has established spatially explicit condition indicators
Capacity-potential,	What **indicators for ecosystem service (ES) supply-demand** does the study use?	Fishery sector is strongly regulated by Common

supply-demand	How does the study consider the **relationship** between ES capacity-potential and supply-demand?	Fishery policy, through which various indicators are established.
	How is **uncertainty** in ES supply-demand addressed?	
Spatial and temporal scaling, resolution and uncertainty	What is the **spatial scale and resolution of the decision-support needed** from the ES assessment?	Different spatial scales and resolutions might be needed even for one policy planning case
	What year are the **maps** of the study area?	Consider that maps of marine areas need different variables, for example isolines showing depth of waters
	What are the **spatial units** used in the assessment?	Consider how the spatial units fits to international division of marine waters as the ES depends on existing assessment units
	Are **metadata** for spatial scales and resolutions included and **following** the **INSPIRE** directive?	
	What **common frameworks** (e.g. CICES, Essential variables, MAES) are used to defined and communicate ES?	
	Were the **methods** used to assess **ecosystem services** selected to match the **complexity** of the decision-support needed (e.g. to inform, to decide, to design?)	

	Which **spatially explicit** indicators used to assess ecosystem **services**?	Consider the use fish landing (tons/year/km2) for international comparability
	What **third spatial dimension** are considered in the ES assessment?	Consider depth as a criteria
	Does the spatial **resolution** of ecosystem condition indicators **match** the **scale** of the ES assessment?	
	How are the **spatial interdependencies** between different ecosystem services within the study area assessed and reported?	Consider links between provision and regulating services as they might be lined to setting extent and condition of provisioning service.
	How does the assessment take into account the **spatio-temporal dynamics** and potential future changes of ES?	It is essential to include long-term trends and annual variability spatially
Uncertainty	How does the study consider future **scenarios** in study context, and the possibility of a range of ES outcomes?	
Social benefits	Are social benefits a **relevant outcome for decision support** in your study? Why/ not?	
Health benefits	Are health benefits a relevant outcome for decision-support in your study? Why/ not?	
Economic valuations	Are economic benefits a **relevant outcome for decision-support** in your study? Why/ not?	
	What **biophysical quantification** of ecosystem services are relevant for economic valuation of ES?	

	At what **scales** (temporal, spatial, beneficiaries) is there a need for economic valuation?	This might be a challenging for spatially explicit valuation due to confidentiality rules.
	How does the study assess **long-term dynamics** in ecosystem capacity, supply and demand in order to measure the **sustainability** of ES use and values?	This aspect might also be challenging due to the EU Common Fishery Policy
	How does the study measure the contribution of ES to **economic development indicators** (e.g. employment, growth)?	This might be a challenging for spatially explicit valuation due to confidentiality rules.

ToR questions useful in some contexts

Diagnostic topic	Draft ToR questions
Spatial and temporal scaling, resolution and uncertainty	How has a **sensitivity analysis** to understand their implications on ecosystem services been considered?
	How has a **sensitivity analysis** of mapping at different **spatial scales** and their implications on ecosystem services been considered?
	Does the study **model risks for beneficiaries (ES benefits x probabilities)**?
Social benefits	How does the study identify or assess disparities in who is affected positively or negatively by changes in ES supply or access to ES benefits?
	What **indicators have** been developed which are specifically **social benefit-relevant** ?
	How does the study consider the **intergenerational aspects of ES** and their implications for future well-being (e.g., impacts of policies or activities)?

Health benefits	What distinct **pathways** between ecosystem structure / function / ecosystem services have been explored or identified for those health aspects?
	How does the study include an assessment of the **stocks and flows** of health relevant ES?
	How does the study identify **disparities in access** to / benefits from health-benefit ES and attempt to understand the **drivers** and consequences of such disparities?
	How does the study assess the current and / or potential future **distributive impacts** of policies or activities on ecosystem management?
	What **indicators** are specifically relevant to **health benefits** ? (were they determined by engagement with stakeholders?)
	How does the study account for **confounding** social, economic, cultural and environmental **factors** which mediate the relationships between ES and health outcomes?
Economic valuation	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)?
	How does the study assess and address **uncertainties** associated with the valuation?

7 Synthesis

7.1 Learning points on iterative and inclusive diagnostic process

The decision to diagnose ES model applications in five groups, each focused on a type of ecosystem services, was made to allow for a strong foundation of expertise and richness of responses for developing the diagnostic method. Each group contained a variety of consortium members with expertise in their specific type of ecosystem service and their specific DP or Test Site. This provided space for constructive discussion and thorough evaluation that led to a constructive review of the diagnostic checklists and the potential for reviewing a large number of ES model application test cases.

To allow for all this expertise to be included in the diagnostic exercise, the process was set up in a decentralised way: after instruction on the goals and the structure of the exercise, each group worked independently on reviewing the diagnostic checklists, selecting best practice cases and consolidating into draft ToR. This led to challenges in funnelling the results from the groups into a coherent whole that allowed for synthesis and generalisation into common findings for broader use. A learning point was to focus as early as possible on the clarity of language used and consistency in understanding of terms. The presentation of draft ToR varies slightly due to the variety in approaches taken across the ES groups, but organising regular common meetings to align ways of thinking and working, a consistent end-result that still allowed for flexibility in approaches for diagnosing different kinds of ES models became possible.

Comparisons of the logic chains – ES model cascade diagrams – for each “best practice” example reveals some cross-cutting challenges. Cases are at different stages of development, with a number still at the conceptual design stage, not having identified the metrics to operationalise ecosystem condition, services and benefits. The diagrammatic presentation of the ES assessment chain in each case is helpful for both communication, and strategic thinking about study design. Some cases have yet to identify ecosystem condition metrics. The majority of cases have only planned for potential outcome metrics on health, social impacts, and economic valuation of ecosystem services. This reveals i.e. that the modelling strengths among SELINA partners is predominantly in biophysical modelling. This cross-cutting characteristics confirms the strategic importance of WP4 in identifying health, social and economic impacts as knowledge gaps that are potential barriers to uptake. Identifying them in ways that are meaningful for stakeholders, and the linkages back to explicit condition variables, is one of the strategic priorities in the continuation of research in SELINA WP4.

7.2 Developing common Terms of Reference

Based on the work presented in this report, Terms of Reference for ES specific methods are to be developed in D4.3 (2024-25) with the aim of increasing likelihood of uptake following a plural valuation approach. This will be done in an iterative process between the ES modellers that here presented draft ToR, and public and private stakeholders engaged in identification of decision-support needs in WP2 through the Communities of Practice.

Questions that the current report has identified, but which can be further addressed in collaboration with stakeholders and other Work Packages towards guidance for decision-support, are:

1. How can sector-specific knowledge needs be addressed most effectively using Terms of Reference for ES model applications?
2. What can guidance on ES model applications best support the creation of common understanding of economic value, social benefits, and justice across stakeholders?
3. How can ES model outputs and the identified links with diagnostic topics explicitly be connected to their implications for past, current and future policies in such a way that they are useful guidance for decision-makers?
4. How can ES model applications be more explicitly linked to private sector decision-making processes? The policy cycle framing is one approach to address decision-support needs that focuses on public decision-making. In future work towards guidance, other frameworks tailored to private decision-making processes should be considered as well. The Natural Capital Protocol, used by private organisations to include natural capital into their decision making, can be supported by the findings from this report, specifically on the Measurement & Valuation (Stage 3) and Apply (Stage 4) parts of the protocol.

The development and use of commonly understood terms and language will also be a key part in this co-creation process. This will lead to ToR that are grounded in both an assessment of what different ES model applications can provide in decision-support, and an assessment of stakeholder needs in different stages of policy and project management cycles. Expanding on **Fig. 3**, the process towards creating final ToR is represented in **Fig. 35.**

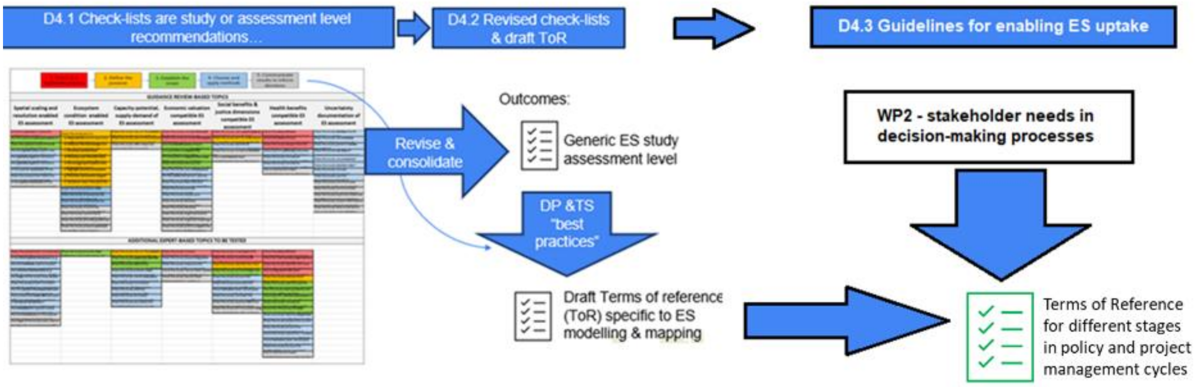


Figure 35: A schematic representation of the process towards common Terms of Reference, from D4.1's grey literature based checklist development, through the diagnostic testing of ES model applications in D4.2, to creating guidance for enabling ES uptake in collaboration with public and private stakeholders in D4.3.

7.3 Knowledge building within SELINA

The work presented in this report forms part of the knowledge base of SELINA on better understanding ecosystems and their services (Strand B). It broadens the scope of assessing ES model applications for improved uptake by taking the current state-of-the-art from the literature-based work presented in Deliverable 4.1, and refining those findings with applying them to real-world applications. This grounds the knowledge on what elements of ES model applications increase their decision-support capabilities in real-world cases.

This work will be presented at SELINA's Workshop 4 – Advancing Solutions II in Trondheim, Norway, taking place in June 2024. Aside from disseminating the findings, this will also allow for first input from stakeholders involved in the Communities of Practice across SELINA in preparation for the development of Deliverable 4.3. The draft ToR presented here will serve as a knowledge basis for creating final ToR for different stages in policy and project management cycles in that deliverable.

The Terms of Reference for ES model application uptake for different types of ecosystem services will also be integrated into the SELINA Database, which will replace the MAES Methods Explorer and underlying ESMERALDA database. Data on best practices for ES modelling applications will be added to the new SELINA Database, allowing for wider dissemination of the diagnostic method for enhanced decision-support.

The large number of SELINA consortium participants in the diagnostic exercise presented in this report also allowed for knowledge and language harmonisation, thereby increasing coherence and efficiency in future co-development of ES modelling for uptake in decision-making. Further engagement with stakeholders through the Communities of Practice in D4.3 will enhance knowledge and language harmonisation with public and private stakeholders.

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9 Annex

Annex 1 - Model descriptions

Some ES groups described more extensive descriptions of the diagnosed ES model applications. These are presented here as a supplement to section 5.2.

9.1.1 Agriculture & forestry provisioning ecosystem services

ESTIMAP, exponential decay function module - used in Test Site 11 for modelling pollination potential in Lower Saxony (Germany)
For mapping pollination potential, a combination of expert estimations, GIS based condition mapping and modelling in ESTIMAP was used.

Biotope classes are used as distinct service providing units, derived from local biotope type data (Hannover Region 2020). In an expert-based approach, the biotope classes are assigned scores with regards to the capacity to provide floral resources and nesting sites for wild bees, all in a best, medium and worst condition scenario.

The approach subsequently applies one spatially explicit condition indicator per aggregated ecosystem type. Management intensity is applied as condition indicator both for agroecosystems and forests (datasets from Rega et al. 2020, Nabuurs et al. 2019). For urban ecosystems, the quantity of urban vegetation is used as indicator ('Greenest Pixel' datasets averaged for the period 2016-2018 from the GEE platform; Chander et al. 2009, Google Earth Engine Data Catalogue 2018). The indicator datasets are classified into good, medium and bad condition and the expert-estimated foraging and nesting capacity scores are assigned to the biotope classes in the respective condition consequently.

An ESTIMAP module is subsequently used to account for the positive effect of semi-natural areas and forest edges on the surrounding areas (Vallecillo et al. 2018). An exponential decay function is applied to these respective areas, expanding the score to the surroundings in the immediate vicinity according to the distance (Hinsch et al. 2024). The decay function considers the visitation rate of a reference wild bee species, which was defined in a hierarchical agglomerative clustering approach based on 250 wild bee species (Theunert 2002, Westrich 2018, Wiesbauer 2020). The described steps are conducted for the foraging and nesting capacity scores separately, which are finally summed and normalised, to derive the potential habitat suitability.

9.1.2 Climate & air quality related ecosystem services

Lavbundsområder 3.1.1 (indicators) (see Gyldenkærne, S. & Greve, M.H. 2020) is currently used in TS 27 Gudenå river catchment, DK.
Lavbundsområder is an open access tool to assist wetland-projects in calculating CO_2 emission. In TS 27, the two key variables in the model are used to identify and map areas with

a high potential for reducing CO_2 emissions by rewetting land. The two variables are: groundwater level below surface and soil C content.
Lavbundsområder is a simple model that can be easily communicated to stakeholders and used primarily for screening and planning. It may be insufficient for project design, where local measurements are needed.
Evidence of uptake: Pilot-project commissioned by 9 municipalities, further work initiated.

The **Urban Multi-Scale Environmental Predicto**r (UMEP) (see link) is one of the models that could potentially be used in DP 03 Trento, Italy.
UMEP is an open-source city-based climate service tool that combines models and tools essential for climate simulations. UMEP has broad utility for applications related to outdoor thermal comfort, wind, urban energy consumption and climate change mitigation. It includes tools to enable users to input atmospheric and surface data from multiple sources, to characterise the urban environment, to prepare meteorological data for use in cities, to undertake simulations and consider scenarios, and to compare and visualise different combinations of climate indicators.
In DP03, the model could be used to assess climate regulation, through two indicators: extreme temperatures and mean radiant temperatures based on evaporation, heat fluxes, impacts of drought, heatwaves, water management and green infrastructure.
The UMEP model provides both guidance and tools that enable the preparation and manipulation of data. It is user-friendly, and technically and economically accessible to users. However, it requires a large number of datasets, and the reference datasets are referred to global or national assessments.
Evidence of uptake: Link

ENVI-met (https://www.envi-met.com/) could potentially be used in DP 03 Trento, Italy.
ENVI-met is an open access, three-dimensional microclimate model designed to simulate the surface-plant-air interactions in urban environments with a typical resolution down to 0.5 m in space and 1- 5 sec in time. It provides detailed insights into the impact of environmental factors on urban design. The model is based on the fundamental laws of fluid dynamics and thermodynamics.
In DP 03, the model could be helpful in assessing microclimate regulation and air pollution reduction.
Envi-met is able to simulate the urban microclimate as an interactive system, like a real environmental system does. However, all variables are calculated in one big model (e.g. an urban quarter) and it is difficult to process such a large amount of data and to upscale the results from the neighbourhood to the city scale.
Evidence of uptake: Link, Link

IPCC Guidelines for National Greenhouse Gas Inventories - Tier 1 stock balance method (see Link) is currently used in DP 14.
It is an open access model that assesses change in carbon stock in different pools (biomass, dead organic matter, soil) due to land use change versus a baseline, using C sequestration as an indicator.
These guidelines enable local adjustments to make the method applicable in specific DP case and are (Tier 1) simple to use – no local data is required beyond knowing the type of land uses

before/after an intervention. However, average data for broad land use classes is used and may not reflect the local conditions.
Evidence of uptake: This is the accepted method for national GHG accounting. Business uptake is less clear.

InVEST Carbon Storage and Sequestration (see link) was initially thought for the TS Azores, Portugal. InVEST is an open access model that estimates the current amount of carbon stored in a landscape and values the amount of sequestered carbon over time. It aggregates the biophysical amount of carbon stored in four carbon pools (aboveground living biomass, belowground living biomass, soil, and dead organic matter) based on land use/land cover (LULC) maps provided by users. Expected change in carbon stocks can also be estimated. This model is widely used and easy to be implemented and can provide estimates and maps of uncertainty. However, the validation of modelling results can be difficult due to lack of reference data. Moreover it relies on simple assumptions that vastly affect the final estimates. Evidence of uptake: https://oneecosystem.pensoft.net/article/69119/

Sets of models linking tree biomass and carbon sequestration (multi steps approach).

This approach has been developed for both the Azores (Portugal) and the Peloponnesus Test Sites (Greece).

For the Peloponnesus Test Site (Greece), carbon sequestration (carbon stock) will be modelled and assessed in terms of accounting, using the following approach. Two carbon stock maps, one for 2021 and another for 2023 will be prepared. The maps will be made with SarVision's biomass mapping software (SarCarbon). This method uses a multistep approach, making use of the following inputs: a land cover map of the area, Sentinel-2 data in the form of a Canopy Density Index (usually using radar backscatter data, but Peoloponnesus mountainous terrain makes optical data a better choice), Lidar vegetation height data, and information on vegetation height and biomass of the area to adjust/develop the allometric equations. The workflow consists in the following steps: (a) land cover mapping of the area using optical and, when needed, radar backscatter data, (b) acquisition of vegetation GEDI height data for each of the land cover types, and definition of probability density functions per land cover type, (c) integration of Canopy Density Index optical data (or of Radar HV backscatter data) with GEDI Lidar vegetation height derived data per vegetation structural type (as defined in the land cover map). The data fusion process involves interpolation techniques and histogram matching. Finally, an assessment of error and uncertainty of the results will be applied via a validation procedure using independent and randomly selected field biomass density estimations.

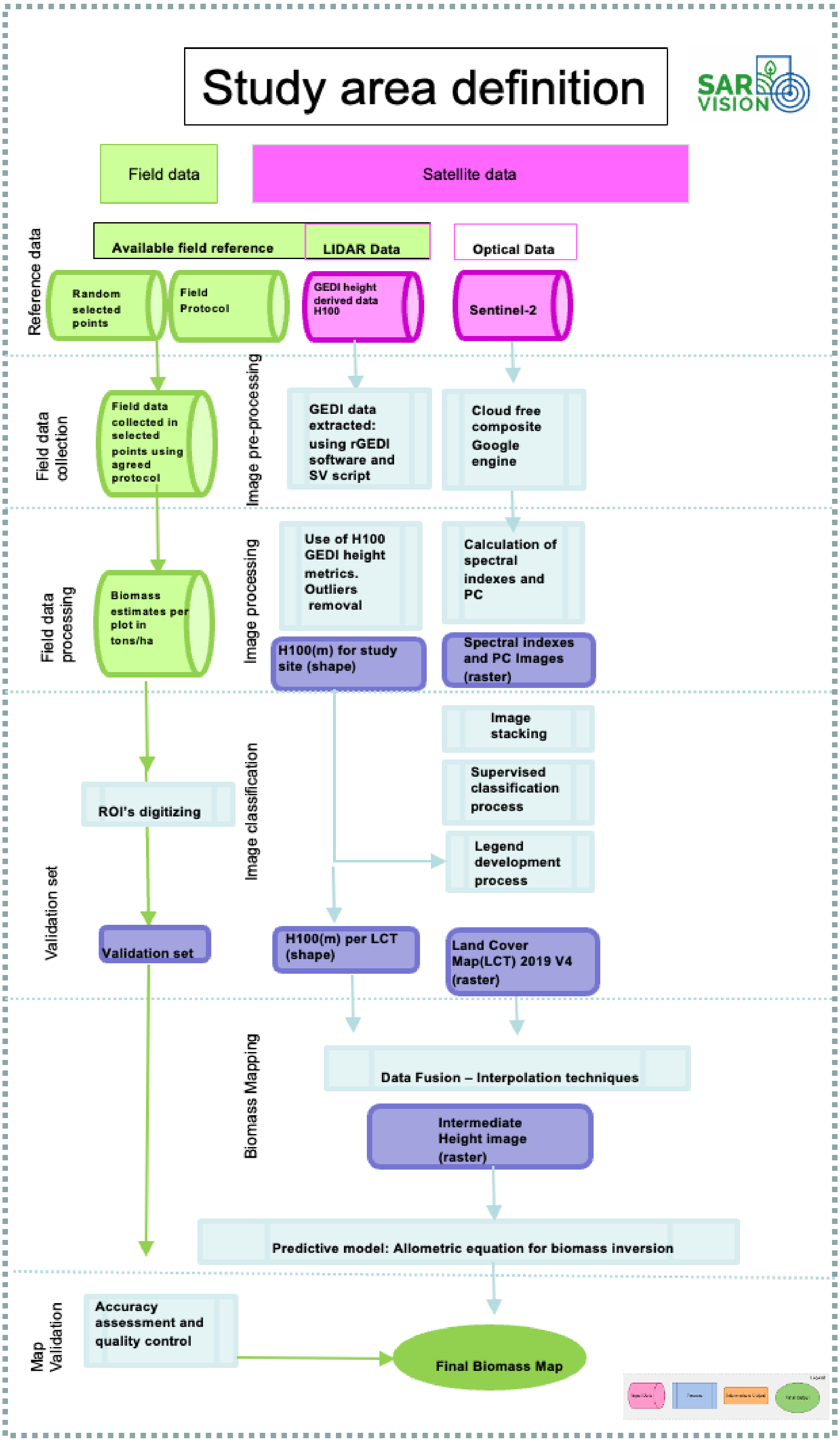


Figure A1: Flowchart for the biomass assessment model, used for the Peloponnesus Test Site.

UrbClim (see link) is currently not used in any volunteer DP or TS but was identified as an interesting model to consider in this task.
The urban boundary layer climate model UrbClim is designed to simulate and study urban heat stress for agglomeration-scale model domains at a high spatial resolution (up to 1m), using the following indicators: UHI, Heat Wave Days, heat-related mortality, lost working days.
UrbClim can simulate long time periods (10-20 years) and climate change impacts for entire urban agglomerations. However, the model does not calculate local advection, clouds, or rainfall (which are taken from a host driving model, e.g. ERA5).
Example of uptake: the model has already been applied in a large number of European research projects, also for Copernicus (https://climate.copernicus.eu/demonstrating-heat-stress-european-cities) and Destination Earth (https://stories.ecmwf.int/destination-earth-use-case/)

9.1.3 Fisheries, aquaculture & marine provisioning ecosystem services

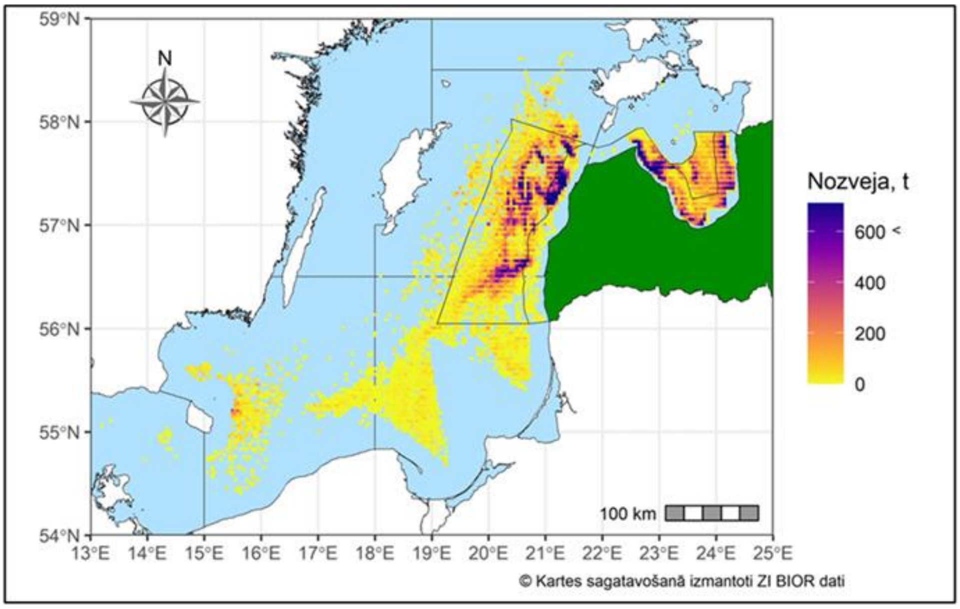
The ES group explored the approach used to integrate information and knowledge on wild fish provisioning ES in maritime spatial planning. The information on wild fish provisioning is provided by research or public institutes that assess fish stock data and can process data on fish landings. In the case of Latvia, this is the Institute of Food Safety, Animal Health and Environment "BIOR." They participated in the fishery ES group discussions on ecosystem 'condition-enabled' ES models for integration into maritime spatial planning.

1.1.6.1 Wild animals (terrestrial and aquatic) used for nutritional purposes (CICES V5.2)

Used indicator - 1.1.6.1 Fish landing (tons/year).

This ES indicator was used already in the MSP (in 2016) and for interim evaluation of MSP. It is important to reflect the spatial distribution for a range of the years as fish are mobile species.

The basemap is based on ICES sub-basins or basins, which are management units for fisheries. The fish landing maps represent annual and longer time periods, spanning at least 10 years, as the spatial fish abundance between years might change due to climatic parameters. The data on fish landing are presented according to single commercial species as well as in total. Fishermen's logbooks are the data source used to produce spatial maps on fish landing. Data were processed with R Statistical Software to estimate the total value of fish landings in a grid cell.



Total commercial fish landing by open sea fishery, 20214-2022 (source: BIOR)

In the process of data visualization, a grid of squares was created on the basemap. The size of one square in the decimal coordinate system was defined as 0.05o length x 0.025o width, which in nature forms a rectangle with approximate side lengths of 2.8 km and 3 km. For each square, the total value was calculated according to the relevant data selection parameters – species, year, catch, etc. The square values on the map were visualized with different color gradation classes. Since the sum values were very high in some quadrats, the maximum value of the gradation classes was determined after excluding 2.5% of the maximum values of the quadrats. These values do not disappear on the map and are included in the maximum gradation class. Such a step allows improving the spatial visualization of the data - displaying a larger number of squares with high values.

Annex 2 - Common template for self-diagnosis and drafting ToR

Draft template testing through a self-audit / self-diagnostic

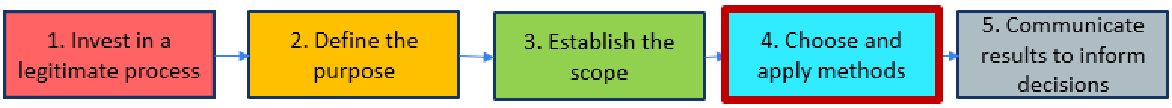
Who?

Demonstration project (DP) and Test Sites (TS) in Ecosystem Service Groups contributing to SELINA D4.2

Purposes of the ToR test

1. Graphical illustration of DP/TS ecosystem service assessment using a logic chain / ecosystem service cascade illustration. Useful for D4.2 visual summaries of this material.

2. Validate and consolidate the selection of checklist questions in each diagnostic topic from D4.1 Supplementary material, focusing on step 4. “choose and apply methods”
    a. Identify irrelevant method questions in the checklists (“false-positives”)
    b. Identify missing key method questions from checklists
    c. Feedback from DPs/TS on wording of checklists from yes/no responses to open / method descriptive questions
    d. Feedback from DPs/TS on logical order of questions



3. (Standardise the description of the DP and TS method selection descriptions using the SELINA Database descriptors (22 descriptors). Systematic DP&TS feedback on method descriptors. OBS: *This is done as part of D4.3 activities*.)

4. (Check consistency of draft ToRs with IPBES VA plural valuation steps (reported in Termansen et al. 2023). *OBS: This is done as part of D4.3 activities.*)

Workflow - instructions

1. Volunteering (“best practice”) **study lead** saves this file to your harddisk to work on for your particular DP/TS.

   Makes a logic chain illustration of your case study [logic chain/ES cascade illustration template](#).

2. Volunteering (“best practice”) **study lead** returns completed templates to ES group lead by <date>

3. **ES group lead** collates the logic chains of studies that participated in testing checklists into Section 5 of D4.2 Report. by <date>

4. **ES group lead** summarises ES group approach and inserts in section 6.x.1 in D4.2 Report. by <date>

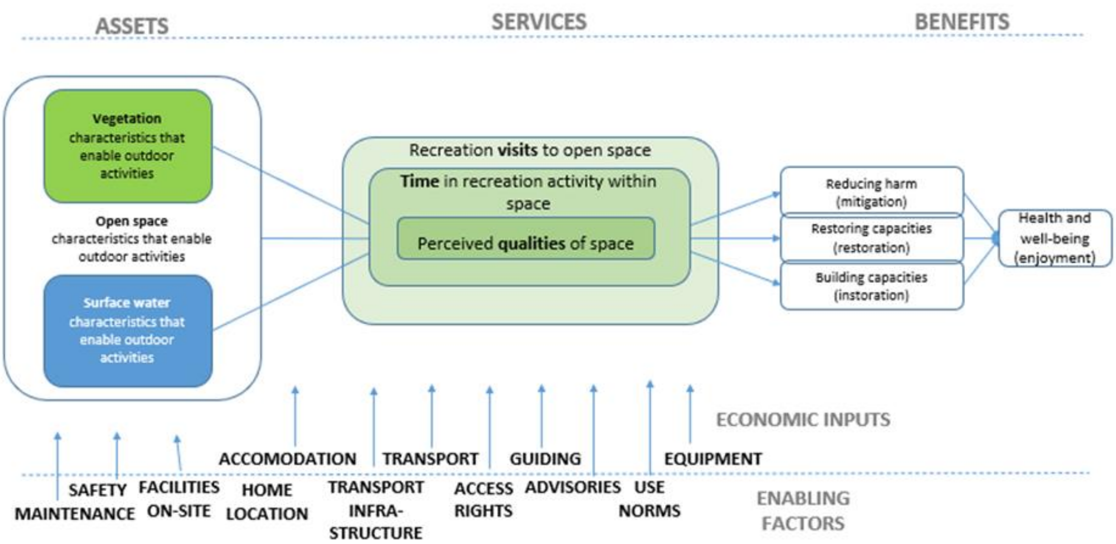
5. Volunteering ("best practice") **study lead** writes up short summary of the case inserted into section 6.x.2 in D4.2 Report. by <date>

6. **ES group lead** consolidates template feedback into one draft ToR proposal by <date>. This is inserted in section 6.x.3 in D4.2 Report. by <date>

Template

1. DP/TS logic chain for ES assessment

<insert image of logic chain illustration from completed template>
<example logic chain/ES cascade for recreation>



2. Validation and consolidation of method-related checklist questions

Instruction: *after inserting responses to questions below*, provide a colour coded evaluation of your perception of the usefulness of this question for a decision-maker hypothetically commissioning your study. This will help to further consolidate a draft ToR

Checklist question /ToR item	**DP& TS response**
<S1-7. Diagnostic topic (from D4.1 supplement)>	
Potential ToR question always useful for the context of my demonstration project or Test Site; It is worded adequately	<insert response>
Potential ToR question useful for the context of my demonstration project or Test Site Could be more useful if reworded <please provide suggestions for rewording>	<insert response>
Potential ToR question never useful for the context of my demonstration project or Test Site	<insert response>
[..]	

Who is hypothetically commissioning your ES assessment?

For the purpose of evaluating the **decision support use case** of your recommendations *please specify the type of decision-maker hypothetically commissioning your study and their decision-support needs* that you will have in mind when answering and reformulating the questions below:	<insert decision-maker type description> governance level; public/private etc. <main assessment purpose / knowledge need of decision-maker> to inform <specify> to design <specify> to decide <specify>

Checklist question /ToR item	DP& TS response
S6 & S7. Spatial scaling, resolution and uncertainty of ES assessments	
What is the **spatial scale of the decision-support needed** from the ES assessment? <by actor commissioning the study>	<insert response>
What year are the **maps** of the study area (landuse, landcover) ? *<Is the mapping data sufficiently up to date relative to the decision-support needs of the decision-maker at the study site?>*	<insert response>
What are the **spatial units** used in the assessment?	<insert response>
Are **metadata** for spatial scales and resolutions included and **following** the **INSPIRE** directive?	<insert response>
What **common frameworks** (e.g. CICES, Essential variables, MAES) are used to defined and communicate ES?	<insert response>
Were the **methods** used to assess **ecosystem services** selected to match the **complexity** of the decision-support needed (e.g. to inform, to decide, to design?)	<insert response>
Which **spatially explicit** indicators used to assess ecosystem **services**?	<insert response>
What **third spatial dimension** (e.g. elevation above sea level, relief, or slope) are considered in the ES assessment?	<insert response>
Does the spatial **resolution** of ecosystem condition indicators **match** the **scale** of the ES assessment?	<insert response; uncertainty related>
How has a **sensitivity analysis** to understand their implications on ecosystem services been considered?	<insert response; uncertainty related>

How has a **sensitivity analysis** of mapping at different **spatial scales** and their implications on ecosystem services been considered?	<insert response; uncertainty related>
How are the **spatial interdependencies** between different ecosystem services within the study area assessed and reported?	<insert response; uncertainty related>>
How does the assessment take into account the **spatiotemporal dynamics** and potential future changes of ES?	<insert response; uncertainty related>>
How does the study consider **multiple models** or model ensembles, and the possibility of a range of ES outcomes?	<insert response; uncertainty related>>
How does the study consider future **scenarios** in study context, and the possibility of a range of ES outcomes? ?	<insert response>
Does the study **model risks for beneficiaries (ES benefits x probabilities)**?	<insert response>
Other questions from D4.1 checklist S6&S7 that are relevant for specifying your study's characteristics for these diagnostic topics?	
<insert question>	<insert response>
<Example:	<insert response>
Any missing questions for a ToR to emphasize the strength of your study in this diagnostic topic?	
<insert question>	<insert response>

Checklist question /ToR item	**DP& TS response to test question relevance**
S1. Ecosystem condition	
What **well-defined methods** for assessing impacts of ecosystem condition on services does your assessment use?	<insert response>
How does your study emphasise the integration of **biodiversity conservation** within the evaluation of ecosystem conditions and services?	<insert response>
How does the study emphasise the integration of **well-being** assessment within the evaluation of ecosystem conditions and services?	<insert response>
Other questions from D4.1 checklist S1 that are relevant for specifying your study's characteristics for this diagnostic topic?	
<insert question>	<insert response>
<Example: Are **spatially explicit** indicators used to assess ecosystem **condition**? (from S6)	<insert response>
Any missing questions for a ToR to emphasize the strength of your study in this diagnostic topic?	
<insert question>	<insert response>

Checklist question /ToR item	DP& TS response to test question relevance
S2. Dimensions of capacity-potential, supply-demand in ES assessment	
What **indicators for ecosystem service (ES) supply-demand** does the study use?	<insert response>
What **indicators for ES capacity-potential** does the study use?	<insert response>
How does the study consider the **relationship** between ES capacity-potential and supply-demand?	<insert response>
What **sustainability thresholds for ES supply-use** are relevant to the study (e.g. minimum safe standards, precautionary policy) ?	<insert response>
How is **uncertainty** in ES supply-demand addressed?	<insert response, uncertainty related>
Other questions from D4.1 checklist S2 that are relevant for specifying your study's characteristics for this diagnostic topic?	
<insert question>	<insert response>
<Example:	<insert response>
Any missing questions for a ToR to emphasize the strength of your study in this diagnostic topic?	
<insert question>	<insert response>
<Example: How are differences between ES potential/capacity and demand assessed?	<insert response>

Checklist question /ToR item	DP& TS response
S5. Economic valuation compatibility of ES assessments	
Are economic benefits a **relevant outcome for decision-support** in your study? Why/ not?	<insert response>
What **biophysical quantification** of ecosystem services are relevant for economic valuation of ES?	<insert response>
At what **scales** (temporal, spatial, beneficiaries) is there a need for economic valuation ?	<insert response>
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)?	<insert response>
How does the study assess and address **uncertainties** associated with the valuation?	<insert response>
How does the study assess **long-term dynamics** in ecosystem capacity, supply and demand in order to measure the **sustainability** of ES use and values?	<insert response>
How does the study measure the contribution of ES to **economic development indicators** (e.g. employment, growth)?	<insert response>
Other questions from D4.1 checklist S5 that are relevant for specifying your study's characteristics for this diagnostic topic?	
<insert question>	<insert response>
<Example:	<insert response>
Any missing questions for a ToR to emphasize the strength of your study in this diagnostic topic?	
<insert question>	<insert response>

Checklist question /ToR item	DP& TS response to test question relevance
S3. Social benefit compatibility of and dimensions of justice in ES assessments	
Are social benefits a **relevant outcome for decision support** in your study? Why/ not?	<insert response>
How does the study identify or assess disparities in who is affected positively or negatively by changes in ES supply or access to ES benefits?	<insert response>
How does the study consider existing social disadvantages (e.g. socio-economic, gender, race/ethnicity/ disabilities etc) that are related to ES inequalities?	<insert response>
How does the study evaluate the potential impacts of different **policy actions** on the distribution of ES benefits among various societal groups?	<insert response>
What **indicators have** been developed which are specifically **social benefit-relevant**?	<insert response>
Have these social benefit indicators been developed or determined by the engagement of stakeholders?	
How does the study consider the **intergenerational aspects of ES** and their implications for future well-being (e.g., impacts of policies or activities)?	<insert response>
Other questions from D4.1 checklist S3 that are relevant for specifying your study's characteristics for this diagnostic topic?	
<insert question>	<insert response>
<Example: What **participatory approaches** are used to ensure that the assessment of ES is rooted in the needs, knowledge and values	<insert response>

of the communities or residents relying on these services? Does the study consider how diverse actors perceive or value ES?	
Any missing questions for a ToR to emphasize the strength of your study in this diagnostic topic?	
<insert question>	<insert response>

Checklist question /ToR item	**DP& TS response**
S4. Health benefit compatibility of ES assessments	
Are health benefits a **relevant outcome for decision-support** in your study? Why/ not?	<insert response>
What distinct **pathways** between ecosystem structure / function / ecosystem services have been explored or identified for those health aspects?	<insert response>
How does the study include an assessment of the **stocks and flows** of health relevant ES?	<insert response>
How does the study include an assessment of the **stocks and flows** of health relevant ES?	<insert response>
How does the study identify **disparities in access** to / benefits from health-benefit ES and attempt to understand the **drivers** and consequences of such disparities?	<insert response>
How does the study assess the current and / or potential future **distributive impacts** of policies or activities on ecosystem management?	<insert response>
How does the study account for existing formal and informal **governance mechanisms** relevant to ES in the study area?	<insert response>
How are the study scenarios / models / inputs / outputs v**alidated against local knowledge** or perspectives?	<insert response>

What **indicators** are specifically relevant to **health benefits** ? (were they determined by engagement with stakeholders?)	<insert response>
How does the study account for **confounding** social, economic, cultural and environmental **factors** which mediate the relationships between ES and health outcomes?	<insert response>
Other questions from D4.1 checklist S4 that are relevant for specifying your study's characteristics for this diagnostic topic?	
<insert question>	<insert response>
<Example: How have the **views of local stakeholders** been incorporated into assessment design?	<insert response>
Any missing questions for a ToR to emphasize the strength of your study in this diagnostic topic?	
<insert question>	<insert response>

*definition of "stocks and flows" of health:

Annex 3 - Overview of consolidated checklists

10.3.1 Hydrology & water quality related ecosystem services

Working group T4.2.1 selected questions matrix assessment. Legend: red (1)—low relevance; yellow (2)—moderate relevance; green (3)—high relevance.

Diagnostic topics, Part, Number	Checklist questions (selected single)	NIGGG-BAS Ogosta river basin	CYI Cyprus, case of livestock feed	denkstatt Coca-Cola	PLUS Salzach river floodplain	UoH Mapping ES in planted forests	CZEG Olešná reservoir watershed	UniTrento/ ComTrento Urban Greening Management Plan of Trento
S1, Main #1c	**Develop standardised condition assessment methods** and accessible, interoperable databases to overcome fragmented data inventory reality faced by policymakers?	green	yellow	red	green	green	green	green
S5, Main #7	Does the study use a **biophysical quantification** of ecosystem services as the basis for the economic valuation?	yellow	green	green	green	green	green	yellow
S5, Main #8	Do the **scales** (temporal, spatial, beneficiaries) of the **biophysical** quantification of ecosystem services **match** the economic valuation ?	yellow	green	green	yellow	green	green	green
S6, Main #3	Does the spatial scale of the ES assessment **align** with the objectives of the **management or policy** decision it aims to inform?	green	green	green	green	green	green	green
S6, Main #8	Does the assessment take into account the **spatiotemporal dynamics** and potential future changes of ES?	green	green	yellow	green	green	yellow	green
S6, Add #12	Are the **methods** used to assess **ecosystem services appropriate** for the **complexity** of the ecosystem services evaluated?	yellow	green	green	green	green	yellow	yellow
S6, Add #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?	yellow	green	yellow	green	green	green	green
S6, Main #2	Are the spatial **scale and extent** of the ecosystem services assessment **explicitly** stated?	green	green	green	yellow	green	yellow	green
S6, Main #5	Are **spatially explicit** indicators used to assess ecosystem **services**?	green	green	yellow	red	green	green	green
S6, Main #6	Are **spatially explicit** indicators used to assess ecosystem **condition**?	green	green	yellow	yellow	yellow	green	green
S6, Main #7	Is the **spatial resolution** of the applied ecosystem condition indicators **appropriate** for the **scale** of the assessment?	yellow	green	green	yellow	green	green	green
S7, Main #1	Does the study **validate** the ES model? (e.g. model intercomparison, external observations, sensitivity analysis)	green	green	green	green	green	green	green
S7, Main #4	Does the study **use data** of appropriate **accuracy** (temporal, spatial resolution)?	green	green	green	green	green	green	green

Diagnostic topics, Part, Number	Checklist questions (selected with consolidation)	NIGGG-BAS Ogosta river basin	CYI Cyprus, case of livestock feed	denkstatt Coca-Cola	PLUS Salzach river floodplain	UoH Mapping ES in planted forests	CZEG Olešná reservoir watershed	UniTrento/ ComTrento Urban Greening Management Plan of Trento
S1, Main #1h	Establish clear indicators for ecosystem condition and services at national, regional, or local levels for monitoring and evaluation in policy development?	yellow	green	red	green	green	green	green
S1, Main #1d	**Develop user-friendly tools**, such as plugins and software, enabling policymakers and practitioners to analyse, visualise, and interpret data on ecosystem condition and services?	green	red	red	yellow	green	green	yellow
S1, Main #2	Does the study present **well-defined methods** for assessing impacts of ecosystem condition on services?	green	green	green	green	yellow	green	green
S1, Main #1d	**Develop user-friendly tools**, such as plugins and software, enabling policymakers and practitioners to analyse, visualise, and interpret data on ecosystem condition and services?	green	red	red	yellow	green	green	yellow
S2, Add #11	Does the study elucidate **uncertainties** associated with each of the assessed dimension(s) (and indicator(s))?	green	green	green	green	yellow	red	green
S7, Main #11	Does the study explicitly state the **simplifying** (model) **assumptions** and underlying uncertainties?	red	green	yellow	green	green	yellow	yellow
S2, Add #8	Does the study clarify **indicators** for each ES and each dimension?	green	green	green	green	green	red	green
S2, Add #7	Does the study present **clear approaches** for assessing each dimension?	yellow	green	green	green	red	red	yellow
S5, Main #12	Does the study develop **recommendations on policy** responses in light of its findings?	green	yellow	yellow	green	yellow	green	green
S6, Main #13	Does the study develop recommendations for **appraisal** of alternative **policy options**?	yellow	red	yellow	yellow	green	green	yellow
S1, Main #1d	**Develop user-friendly tools**, such as plugins and software, enabling policymakers and practitioners to analyse, visualise, and interpret data on ecosystem condition and services?	green	red	red	yellow	green	green	yellow
S5, Main #11	Does the study assess and address **uncertainties** associated with the valuation, providing a clear indication of the confidence level in the results?	yellow	green	green	yellow	green	yellow	green
S7, Main #6	Does the study **monitor risks** ?	yellow	red	red	yellow	yellow	yellow	red
S7, Main #10	Does the study communicate uncertainty in the assessment results by **expressing variation** in the results?	yellow	green	yellow	red	green	yellow	yellow
S6, Add #13	Are **common frameworks** (e.g. CICES, Essential variables, MAES) considered in order to homogenise comparisons?	green	green	green	green	yellow	red	green
S2, Add #6	Does the study define the concept(s) following an **established standard terminology** (e.g., Burkhard et al. 2012; Millennium Ecosystem Assessment; CICES; IPBES)?	yellow	green	yellow	red	yellow	red	red
S6, Add #19	Are **metadata** for spatial scales and resolutions included and **following** the **INSPIRE** directive?	yellow	red	red	green	red	red	yellow
S6, Add #20	Are the **limitations** on the spatial scales and resolutions clearly identified and justified?	green	green	green	green	yellow	yellow	yellow
S6, Main #9	**Is the spatial resolution** of the applied indicators transparently stated?	yellow	green	green	yellow	yellow	red	green
S7, Main #11	Does the study explicitly state the **simplifying** (model) **assumptions** and underlying uncertainties?	red	green	yellow	green	green	yellow	yellow

10.3.2 Amenity & recreation related ecosystem services

Latvia Baltic	Malta	Belgiun Boslan	Poland Poznan	Sloveni Trigliav	Croatia Zagreb	Denmai Guden	Norway Oslo	S1. Ecosystem condition – Tested check-list proposal	Reformulations
								What **methods** for assessing impacts of ecosystem condition on services does your assessment use?	Are condition indicators taken into account in the model/method?
								How does your study emphasise the integration of **biodiversity conservation** within the evaluation of ecosystem conditions and services?	Are biodiversity indicators used in ES models?
								How does the study emphasise the integration of **well-being** assessment within the evaluation of ecosystem conditions and services?	Are well-being metrics linked to condition or service variables in the model?
								Are stakeholders consulted to decide which specific condition indicators (e.g. species, variety, naturalness, management-level, noise level…) are taken into account in the model?	

Latvia Baltic	Malta	Belgium Bosland	Poland Poznan	Slovenia Trigliav N	Croatia Zagreb	Denmark Gudenaa	Norway Oslo	S2. Dimensions of capacity-potential, supply-demand in ES assessment – Tested check-list proposal	Reformulations
								What **indicators for ecosystem service (ES) supply-demand** does the study use?	
								What **indicators for ES capacity-potential** does the study use?	Is carrying capacity for the ES assessed?
								How does the study consider the **relationship** between ES capacity-potential and supply-demand?	
								What **sustainability thresholds for ES supply-use** are relevant to the study (e.g. minimum safe standards,	Is carrying capacity for the ES assessed?
								How is **uncertainty** in ES supply-demand addressed?	
								Are stakeholders involved in the model building?	

Latvia Baltic	Malta	Belgium Bosland	Poland Poznan	Slovenia Triglav	Croatia Zagreb	Denmark Gudena	Norway Oslo		
S3. Social benefit compatibility of and dimensions of justice in ES assessments								**Tested check-list proposal**	**Reformulations**
								Are social benefits a **relevant outcome for decision support** in your study? Why/ not?	
								How does the study identify or assess disparities in who is affected positively or negatively by changes in ES supply or access to ES benefits?	
								How does the study consider existing social disadvantages (e.g. socio-economic, gender, race/ethnicity/ disabilities etc) that are related to ES inequalities?	
								How does the study evaluate the potential impacts of different **policy actions** on the distribution of ES benefits among various societal groups?	
								What **indicators have** been developed which are specifically **social benefit-relevant**? Have these social benefit indicators been developed or determined by the engagement of stakeholders?	Have these social benefit indicators been developed or determined by the engagement of stakeholders?
								How does the study consider the **intergenerational aspects of ES** and their implications for future well-being (e.g., impacts of policies or activities)?	
									What **participatory approaches** are used to ensure that the assessment of ES is rooted in the needs, knowledge and values of the communities or residents relying on these services?

Latvia Baltic	Malta	Belgium Bosland	Poland Poznan	Slovenia Triglav	Croatia Zagreb	Denmark Gudena	Norway Oslo		
S4. Health benefit compatibility of ES assessments								**Tested check-list proposal**	**Reformulations**
								Are health benefits a **relevant outcome for decision-support** in your study? Why/ not?	
								What distinct **pathways** between ecosystem structure / function / ecosystem services have been explored or identified for those health aspects?	
								How does the study include an assessment of the **stocks and flows** of health relevant ES?	Wording: ES is not a stock; redundant covered by the question above
								How does the study identify **disparities in access** to / benefits from health-benefit ES and attempt to understand the **drivers** and consequences of such disparities?	Wording and concepts "health-benefit ES"? Question about drivers as a separate question for policy purposes
								How does the study assess the current and / or potential future **distributive impacts** of policies or activities on ecosystem management?	Generic - not health; this would be covered through the pathways question. Does the ES model/mapping make it possible to assess distributive impacts on
								How does the study account for existing formal and informal **governance mechanisms** relevant to ES in the study area?	Generic - not health related; A question no related to ES modeling; belongs in scoping step
								How are the study scenarios / models / inputs / outputs **validated against local knowledge** or perspectives?	Generic to economic, social, economic
								What **indicators** are specifically relevant to **health benefits** ? (were they determined by engagement with stakeholders?)	
								What **indicators** are specifically relevant to **health benefits** ? (were they determined by engagement with stakeholders?)	Were indicators of health benefits determined by engagement with stakeholders?

Latvia Baltic	Malta	Belgium Bosland	Poland Poznan	Slovenia Trigliav I	Croatia Zagreb	Denmark Gudena	Norway Oslo		
S5. Economic valuation compatibility of ES assessments								Tested check-list proposal	Reformulations
								Are economic benefits a **relevant outcome for decision-support** in your study? Why/ not?	
								What **biophysical quantification** of ecosystem services are relevant for economic valuation of ES?	Redundant question - ES is a biophysical quantification. If ES is correlated with condition so is economic value.
								At what **scales** (temporal, spatial, beneficiaries) is there a need for economic valuation ?	Split into temporal, spatial
								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)? <valuation is only theoretically correct for	
								How does the study assess and address **uncertainties** associated with the valuation?	
								How does the study assess **long-term dynamics** in ecosystem capacity, supply and demand in order to measure the **sustainability** of ES use and values?	Combine with question under condition
								How does the study measure the contribution of ES to **economic development indicators** (e.g. employment, growth)?	
								Are different types of beneficeries/users considered to develop the demand site model?	
								What is the distribution of privately and publically owned land	

Latvia Baltic coast	Malta	Belgium Bosland	Poland Poznan	Slovenia Trigliav N	Croatia Zagreb	Denmark Gudenaa	Norway Oslo		
S6 & S7. Spatial scaling, resolution and uncertainty of ES assessments								Tested check-list proposal	Reformulations
								What is the **spatial scale of the decision-support needed** from the ES assessment?	
								What year are the **maps** of the study area (landuse, landcover) ?	Is the mapping data current relative to the purpose of the analysis?>
								What are the **spatial units** used in the assessment?	
								Are **metadata** for spatial scales and resolutions included and **following** the **INSPIRE** directive?	Are input and output variables publicly Findable, Accessible, Interoperable, Reusable (FAIR?
								What **common frameworks** (e.g. CICES, Essential variables, MAES) are used to defined and communicate ES?	Is a standardised definition of ES used?
								Were the **methods** used to assess **ecosystem services** selected to match the **complexity** of the decision-support needed (e.g. to inform, to decide, to design?)	Is the method choicejjustified for a specific purpose and user? Were the methods for assessment selected to match the need of the decision support?
								Which **spatially explicit** indicators used to assess ecosystem **services**?	Does the spatially explicit data represent the intended service?
								What **third spatial dimension** (e.g. elevation above sea level, relief, or slope) are considered in the ES assessment?	Does the ecosystem service depend on elevation, reilef or slope?
								Does the spatial **resolution** of ecosystem condition indicators **match** the **scale** of the ES assessment?	Does the resolution of condition variables match the resolution needed to assess benefits to ES beneficiaries?
								How has a **sensitivity analysis** to understand their implications on ecosystem services been considered?	Has sensitivity analysis of model or data uncertainties been conducted?>
								How has a **sensitivity analysis** of mapping at different **spatial scales** and their implications on ecosystem services been considered?	Is the highest spatial resolution available used in the ES model? Perhaps include question: "Does the study perform sensitivity analysis - why or why not" first?
								How are the **spatial interdependencies** between different ecosystem services within the study area assessed and reported?	Are trade-offs between ES assessed?>
								How does the assessment take into account the **spatiotemporal dynamics** and potential future changes of ES?	What period of change does the assessment consider?
								How does the study consider **multiple models** or model ensembles, and the possibility of a range of ES outcomes?	Are alternative ES models used to test robustness of recreation estimates?>
								How does the study consider future **scenarios** in study context, and the possibility of a range of ES outcomes? ?	
								Does the study **model risks for beneficiaries (ES benefits x probabilities)**?	Does the study quantify uncertainty in ES outcomes?
								Are maps of the study area used to visualise the assessment results?	
								Are the data and knowledge needs already known & discussed with the potential user of the results?	

10.3.3 Agriculture & forestry provisioning ecosystem services

Spatial scaling and resolution

The diagnostic list includes questions on temporal resolution, so the general diagnostic topic needs to be adapted.

Qnr	Check-list question	Summary of evaluation
4	Are the spatial units used in the assessment clearly defined and justified?	The question considered relevant in most cases. *Remarks*: (i) Q appears to overlap with Qs 1 and 2 (which refer to other steps of the diagnosis).
5	Are spatially explicit indicators used to assess ecosystem services?	The question considered relevant in most cases. *Remarks*: (i) Q appears to overlap with Qs 2 (which refer to other steps of the diagnosis).
6	Are spatially explicit indicators used to assess ecosystem condition?	The question considered relevant in most cases. *Remarks*: (i) Some assessments are not considering EC indicators but regard the question relevant. (ii) Consider overlap with questions in the EC list.
7	Is the spatial resolution of the applied ecosystem condition indicators appropriate for the scale of the assessment?	The question considered relevant in most cases. *Remarks*: (i) Some assessments are not considering EC indicators but regard the question relevant. (ii) Consider overlap with questions in the EC list.
8	Does the assessment take into account the spatiotemporal dynamics and potential future changes of ES?	The question considered relevant in most cases, but these aspects have often not been assessed in the studies. *Remarks*: (i) this Q requires multiple sub-questions that include the specification of timeseries data (sub-daily, daily, averages, climate projects, etc. (ii) Most cases not assessing this dimension.
11	Is the third spatial dimension (e.g. elevation above sea level, relief, or slope) considered in the ES assessment?	The question considered relevant in most cases. *Remarks*: (i) Q may be misleading - it is seldom true 3D assessments are conducted. Requires specification (e.g. landform, canopy volume) and definition of purpose. (ii) Suggest moving this Q to nr 3. (ii) Most cases not assessing this dimension.
12	Are the methods used to assess ecosystem services appropriate for the complexity of the ecosystem services evaluated?	The question considered relevant in all cases.
13	Are common frameworks (e.g. CICES, Essential variables, MAES) considered in order to homogenise comparisons?	The question considered relevant in most cases. *Remarks*: (i) Harmonization needed for upscaling and/or comparisons among regions/countries. (ii) Conceptual & methodological 'legacies' can be relevant for local-level assessments.

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?	The question considered relevant in most cases. *Remarks*: (i) Suggest rephrasing, introduce "reliable map of current land use/cover".
15	Does the assessment include a sensitivity analysis to understand the effects of varying spatial resolutions?	The question considered relevant in most cases.
16	Are the spatial interdependencies between different ecosystem services within the study area assessed and reported?	The question considered relevant in most cases.
17	Have potential trade-offs between different spatial scales and their implications on ecosystem services been considered?	The question considered relevant in most cases.
18	Is temporal variability in ecosystem services addressed and documented in the assessment?	The question considered relevant in most cases.
19	Are metadata for spatial scales and resolutions included and following the INSPIRE directive?	The question considered relevant in most cases.

Ecosystem condition

Qnr	Diagnostic question	Summary evaluation
2	Does the study present well-defined methods for assessing impacts of ecosystem condition on services?	The question considered relevant in most cases. *Remarks*: (i) Q overlaps with questions in Capacity-Potential-Supply-Demand list. (ii) Important, but difficult to assess.
3	Does the study emphasise the integration of biodiversity conservation within the evaluation of ecosystem conditions and services?	The question considered relevant in most cases. *Remarks*: (i) Some assessments do not consider the provision of habitat for native biodiversity as an ES. (ii) There appears to be a need for harmonization/consensus about how EC is integrated in ecosystem and ES assessments
4	Does the study emphasise the integration of wellbeing assessment within the evaluation of ecosystem conditions and services?	The question considered irrelevant in several cases. *Remarks*: (i) Q considered out of scope for this diagnostic topic.

Ecosystem capacity-potential, supply-use of ES

Some general remarks on this list of diagnostic questions refer to the need to specify (when relevant) which of the four dimensions of the ES the questions are addressing.

Qnr	Diagnostic question	Summary evaluation
7	Does the study present clear approaches for assessing each dimension?	The question considered relevant in all cases.
8	Does the study clarify indicators for each ES and each dimension?	The question considered relevant in all cases.
9	Does the study link and/or integrate the ES dimensions considered in it?	The question considered relevant in all cases.
10	Does the study address sustainability aspects of ES dimensions?	The question considered relevant in most cases. *Remarks*: (i) Formulation unclear, "Sustainability of ES dimensions should be defined".
11	Does the study elucidate uncertainties associated with each of the assessed dimension(s) (and indicator(s))?	The question considered relevant in all cases.
12	Does the study elucidate the (spatial) relations between the assessed dimensions?	The question considered relevant in all cases. *Remarks*: (i) Important question.

Uncertainty

Qnr	Diagnostic question	Summary evaluation
1	Does the study validate the ES model? (e.g. model intercomparison, external observations, sensitivity analysis)	The question considered relevant in all cases.
2	Does the study use multiple models leading to a range of outcomes?	The question considered relevant in most cases. *Remarks*: (i)Reformulation needed, relevance depends on the modelling framework and type of modelling.
3	Does the study perform model ensembles?	The question considered relevant in most cases. *Remarks*: (i) Requires reformulation, unclear what model ensemble refers to.
4	Does the study use data of appropriate accuracy (temporal, spatial resolution)?	The question considered relevant in most cases. *Remarks* (i) Revise use of "appropriate accuracy", meaning unclear. (ii) Possible rewording: "Appropriate for the ecosystem process being modelled? Appropriate for communication with stakeholders?

5	Does the study use scenarios?	The question considered relevant in most cases. *Remarks*: (i) Q could be moved to a lower position in the list. (ii) Move here questions more related to uncertainty-related topic.
6	Does the study monitor risks?	The question considered relevant in most cases. *Remarks*: (i) Relevance depending on level of ambition - perhaps too much for stakeholders to reach/consider - but of course interesting from a research perspective and for evidence-based decision-making.
7	Does the study include contingency measures to offset risks of high uncertainty in model outcomes, e.g. risk multipliers.	The question considered relevant in most cases. *Remarks*: (i) Relevance depending on level of ambition - perhaps too much for stakeholders to reach/consider - but of course interesting from a research perspective and for evidence-based decision-making.
8	Does the study use the precautionary principle?	The question considered relevant in most cases. *Remarks*: (i) Would need some reformulation. (ii) Relevance depending on level of ambition - perhaps too much for stakeholders to reach/consider - but of course interesting from a research perspective and for evidence-based decision-making.

Questions related to diagnostic topics of valuation.

General comments: Most of the assessments in the group do not assess explicitly social, economic and cultural aspects or the involvement of communities, and there are also various levels of engagement with local actors.

Dimensions of justice

Qnr	Diagnostic question	Summary evaluation
3	Does the study identify ES beneficiaries and assess disparities in access and distribution of benefits?	The question considered relevant in most cases *Remarks*: (i) would recommend splitting the Q in two, one about beneficiaries and one about access to benefits. (ii) This question is connected to Q2. Maybe they could be merged. (iii) The study may identify ES (provisioning) beneficiaries, but not assess disparities in access and distribution of benefits.
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?	The question considered relevant in most cases. *Remarks:* (i) the Q was considered unclear in some cases.
11	Does the study evaluate the potential impacts of different policy actions on the distribution of ES benefits among various societal groups?	The question considered relevant in most cases.

12	Have indicators been developed which are specifically social benefit-relevant as determined by the engagement with stakeholders?	The question considered relevant in most cases.
13	Does the study consider the intergenerational aspects of ES and their implications for future wellbeing (e.g., impacts of policies or activities)?	The question considered relevant in most cases *Remarks*: (i) Formulation unclear. If we want to understand the future, should climate change issues also be considered?

Health benefits compatibility of ES assessment

These set of questions is marginally related to the assessments in this group, in several cases the link to health benefits is out of the scope of the assessment. There is a sense that questions could be merged.

Qnr	Diagnostic question	Summary evaluation
4	Have distinct pathways between ecosystem structure / function / ecosystem services been explored or identified for those health aspects?	The question considered relevant in some cases.
5	Does the study include an assessment of the stocks and flows of health relevant ES?	The question considered relevant in some cases.
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?	The question considered relevant in some cases.
19	Does the study assess the current and / or potential future distributive impacts of policies or activities on ecosystem management?	The question considered relevant in some cases. *Remarks*: (i) Seems little related to health. (ii) There seems to be repetition in these questions.
20	Does the study account for existing formal and informal governance mechanisms relevant to ES in the study area?	The question considered relevant in some cases. *Remarks*: (i) Seems little related to health. (ii) There seems to be repetition in these questions.
21	Have the study scenarios / models / inputs / outputs been validated against local knowledge or perspectives?	The question considered relevant in some cases. *Remarks*: (i) Seems little related to health. (ii) There seems to be repetition in these questions.
22	Have indicators been developed which are specifically relevant to health benefits, as determined by engagement with stakeholders?	The question considered relevant in some cases.
23	Does the study account for confounding social, economic, cultural and environmental factors which mediate the relationships between ES and health outcomes?	The question considered relevant in some cases.

Economic valuation compatibility of ES assessments

Economic valuation of benefits is beyond the scope of most of the ES assessments in this group.

Qnr	Diagnostic question	Summary evaluation
8	Do the scales (temporal, spatial, beneficiaries) of the biophysical quantification of ecosystem services match the economic valuation?	The question considered relevant in some cases.
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)?	The question considered relevant in some cases.
10	Does the study provide information on equity implications?	The question considered relevant in some cases. *Remarks*: (i) Does the question refer to economic equity?
11	Does the study assess and address uncertainties associated with the valuation, providing a clear indication of the confidence level in the results?	The question considered relevant in some cases.
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.	The question considered relevant in some cases. *Remarks*: (i) More relevant for the ecosystem condition diagnostics.
19	Does the study measure the contribution of ES to economic development indicators (e.g. employment, growth)?	The question considered relevant in some cases.

10.3.4 Fisheries, aquaculture & marine provisioning ecosystem services

The tables below present the exploration of the diagnostic questions for building up the draft ToR to ensure up-take of fish provisioning ES in maritime spatial planning. Maritime spatial planning (MSP) is the tool to manage the use of our seas and oceans coherently and to ensure that human activities take place in an efficient, safe and sustainable way. Maritime spatial planning is mandatory for EU member States to be implemented according to the EU Directive 2014/89/EU.

SELINA Methods Database Descriptor	DP& TS response to test question relevance
S1. Ecosystem condition	

What **methods** for assessing impacts of ecosystem condition on services does your assessment use?	Impacts of ecosystem condition are assessed through ICES methodology on fish stock assessment of single commercial species. The stock assessment is a base to establish scientific advice on Maximum sustainable yield (tons/year). MSFD also develops a national wide assessment on the state of the environment (Descriptor 3) that includes the same indicators as ICES methodology.
How does your study emphasise the integration of **biodiversity conservation** within the evaluation of ecosystem conditions and services?	The study demonstrates the importance of spawning and nursery habitats through mapping essential fish habitats. This map is also used for presenting information on regulating service on fish maintenance.
How does the study emphasise the integration of **well-being** assessment within the evaluation of ecosystem conditions and services?	Not yet, but it could be integrated in the next phase of the implementation of the demonstration project.
Which **spatially explicit** indicators used to assess ecosystem **condition**?	Fish stock assessment is used according to the ICES methodology on stock assessment that covers the following condition indicators: The Fishing Mortality Rate; The Spawning Stock Biomass; The age and size distribution of individuals in the populations of commercially-exploited species; Recruitment. The annual fish stock assessment is carried out for larger ICES units – subbasins of the Baltic sea. Thus, it is not in the same spatial resolution as for fish landing.

SELINA Methods Database Descriptor	**DP& TS response to test question relevance**
S2. Dimensions of capacity-potential, supply-demand in ES assessment	

What **indicators for ecosystem service (ES) supply-demand** does the study use?	Fishery is strictly regulated as the resources are limited due to past overexploitation and environmental impacts (e.g., eutrophication in the Baltic Sea). Therefore, the demand is not fully recognized. The decision making on the annual allowed catch (supply) is difficult to ensure the sustainable fishery. Supply indicator: Fish catch (tons/year) in the Baltic Sea; Fish landing (tons/year) (catch minus discard) is used in MSP as ES supply indicator. This indicator does not include fish import. Latvia imports a significant amount of different fish products, as well as significant exports. Export is higher than import. Demand indicator: Total allowed catch (tons/year) is established based on a scientific advice indicator called "maximum sustainable yield -MSY". This indicator is not used in MSP as the indicator has one total value per stock per sub-basin without further spatial distribution.
What **indicators for ES capacity-potential** does the study use?	Capacity is measured as "Maximum Sustainable Yield" - the largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. This indicator is not used in MSP as the indicator has one total value per stock per sub-basin without further spatial distribution.
How does the study consider the **relationship** between ES capacity-potential and supply-demand?	The MSP needs spatially explicit information; thus it directly considers spatial information on supply of ES through the indicator on fish landing. Demand for fish is limited/regulated due to unfavorable status of fish stock. The catch per unit effort is an indirect measure of the abundance of a target species, thus capacity of the ecosystem to deliver ecosystem services. A decreasing CPUE indicates overexploitation, while an unchanging CPUE indicates sustainable harvesting. CPUE is often considered an index of fish biomass (or abundance).

What **sustainability thresholds for ES supply-use** are relevant to the study (e.g. minimum safe standards, precautionary policy) ?	The decision on fishing opportunities is part of the European Union's approach to adjust the levels of fishing to long-term sustainability targets, called maximum sustainable yield (MSY). The political agreement is made by Agriculture and Fisheries ministers. This agreement sets the total allowable catches (TACs) and quota per member state for each species in the Baltic Sea for the coming year. MSP is not establishing sustainability thresholds on supply-use.
How is **uncertainty** in ES supply-demand addressed?	The uncertainty of scientific assessment of fish stock is 90% which is high rate.

SELINA Methods Database Descriptor	DP& TS response to test question relevance
S3. Social benefit compatibility of and dimensions of justice in ES assessments	
Are social benefits a **relevant outcome for decision support** in your study? Why/ not?	The Latvian MSP has not addressed social benefits. However, for coastal fishermen, fishing is a lifestyle and a cultural heritage topic (another ES), as generations of fishermen have been doing this activity for a hundred years. Traditional fishery practices are at risk, which is also a cultural issue.
How does the study identify or assess disparities in who is affected positively or negatively by changes in ES supply or access to ES benefits?	Not assessed, but could be relevant
How does the study consider existing social disadvantages (e.g. socio-economic, gender, race/ethnicity/ disabilities etc) that are related to ES inequalities?	Not relevant
How does the study evaluate the potential impacts of different **policy actions** on the distribution of ES benefits among various societal groups?	Not relevant
What **indicators have** been developed which are specifically **social benefit-relevant** ?	Employment-related indicators could indeed be valuable for social assessment, but they often lack spatial character due to confidentiality rules.

How does the study consider the **intergenerational aspects of ES** and their implications for future well-being (e.g., impacts of policies or activities)?	Not relevant for MSP, yet it is relevant for fishery policy.

SELINA Methods Database Descriptor	DP& TS response
S4. Health benefit compatibility of ES assessments	
Are health benefits a **relevant outcome for decision-support** in your study? Why/ not?	The nutrition value would be a relevant benefit. However, the current trend is that Latvians are not in favour of regularly eating Baltic Sea fish. Another health benefit could be related to the risk of stress, depression, and anxiety due to decrease in fishing activity, loss of economic income. The Latvia MSP has not analysed health benefits. There have been some studies which could be used in next steps in implementation of DP.
What distinct **pathways** between ecosystem structure / function / ecosystem services have been explored or identified for those health aspects?	The Latvia MSP has not explored health benefits.
How does the study include an assessment of the **stocks and flows** of health relevant ES?	Not implemented
How does the study identify **disparities in access** to / benefits from health-benefit ES and attempt to understand the **drivers** and consequences of such disparities?	Not implemented
How does the study assess the current and / or potential future **distributive impacts** of policies or activities on ecosystem management?	Impacts could be assessed though Strategic Environmental Impact Assessment process of Maritime Spatial Planning
How does the study account for existing formal and informal **governance mechanisms** relevant to ES in the study area?	The question seems not relevant for the context of health benefits from fish products
How are the study scenarios / models / inputs / outputs va**lidated against local knowledge** or perspectives?	The question seems not relevant for the context of health benefits from fish products

What **indicators** are specifically relevant to **health benefits** ? (were they determined by engagement with stakeholders?)	Not implemented, but the nutrition related benefit could be relevant to be addressed also within MSP.
How does the study account for **confounding** social, economic, cultural and environmental **factors** which mediate the relationships between ES and health outcomes?	Not implemented

SELINA Methods Database Descriptor	**DP& TS response**
S5. Economic valuation compatibility of ES assessments	
Are economic benefits a **relevant outcome for decision-support** in your study? Why/ not?	MSP is using different socio-economic indicators on the fishery sector. However, it is not directly linked to ES provisioning.
What **biophysical quantification** of ecosystem services are relevant for economic valuation of ES?	The fish landing (t/y) is relevant for economic valuation. Based on market value of fish (per species) total annual market value can be estimated. The numbers are published by the Central Statistical office.
At what **scales** (temporal, spatial, beneficiaries) is there a need for economic valuation ?	Only national scale estimation is used as price numbers are available at national scale. Due to confidentiality, the number of fish landing is not published per sub-basin at national scale.
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)?	The Latvian MSP does not address the total flow of the ecosystem service and changes in the flow; as spatial planning is strongly interested in spatially explicit data. However, the MSP also integrates national numbers related to fish provisioning.
How does the study assess and address **uncertainties** associated with the valuation?	Not assessed

How does the study assess **long-term dynamics** in ecosystem capacity, supply and demand in order to measure the **sustainability** of ES use and values?	This aspect is not addressed in MSP as the fish landing is strongly regulated based on total allowable catch. However, the long-term good status of fish stocks is dependent also on the condition of spawning and nursery habitats. A link between fish stocks and availability of suitable habitats have been addressed in MSP, but the straightforward links have not been established yet.
How does the study measure the contribution of ES to **economic development indicators** (e.g. employment, growth)?	Economic performance of the fishery sector is calculated and reported annually according to the "Guidelines for the analysis of the balance between fishing capacity and fishing opportunities according to Art 22 of Regulation (EU) No 1380/2013 of the European Parliament and the Council on the Common Fisheries Policy." However, these numbers are not yet integrated in the MSP. Interim assessment of Latvian MSP only illustrated these statistics: number of shipping vessels and number of fishermen companies at national level.

SELINA Methods Database Descriptor	DP& TS response
S6 & S7. Spatial scaling, resolution and uncertainty of ES assessments	
What is the **spatial scale of the decision-support needed** from the ES assessment?	Fish landing (t/km2) data are presented at different scales for different spatial units: 1) Open sea data – t/km2 2) Coastal sea data – per relevant administrative unit
What year are the **maps** of the study area (land use, landcover) ?	The maps shall represent annual and longer time period, at least 10 years

What are the **spatial units** used in the assessment?	The basemap is based on ICES sub basins or basins which are management units for fishery. The units are also divided in open sea and coastal waters, which is up to 20 meters depth.
Are **metadata** for spatial scales and resolutions included and **following** the **INSPIRE** directive?	Yes.
What **common frameworks** (e.g. CICES, Essential variables, MAES) are used to defined and communicate ES?	CICES classification 1.1.6.1 Wild animals (terrestrial and aquatic) used for nutritional purposes (CICES V5.2) 1.1.6.1 Fish landing (tons/year)
Were the **methods** used to assess **ecosystem services** selected to match the **complexity** of the decision-support needed (e.g. to inform, to decide, to design?)	MAES on fish provisioning supports complexity of the MSP as ES assessment is used to inform about important provisioning and regulating areas, thus impacting the design of the plan.
Which **spatially explicit** indicators used to assess ecosystem **services**?	1.1.6.1 Fish landing (tons/year/km2)
What **third spatial dimension** (e.g. elevation above sea level, relief, or slope) are considered in the ES assessment?	ES assessment is based on stocks of the single commercial species according to their habitation
Does the spatial **resolution** of ecosystem condition indicators **match** the **scale** of the ES assessment?	No. Ecosystem condition is assessed based on fish stock assessments, environmental parameters. The assessment is carried out on ICES subbasin scale.
How has a **sensitivity analysis** to understand their implications on ecosystem services been considered?	Not considered. The additional information on the method of sensitivity analyses would be needed.
How has a **sensitivity analysis** of mapping at different **spatial scales** and their implications on ecosystem services been considered?	This has not been analysed in the case, but could potentially be useful in particularly in decision making in case of conflict management or trade-offs.

How are the **spatial interdependencies** between different ecosystem services within the study area assessed and reported?	Fish landing as ES is dependent on essential fish habitats as well as on different environmental parameters. Yet due to the mobile character of species through lifetime, the spatial interdependencies are not straightforward. Therefore, information on essential fish habitats is presented.
How does the assessment take into account the **spatiotemporal dynamics** and potential future changes of ES?	The study includes annual assessment of ES as well as long term trends
How does the study consider **multiple models** or model ensembles, and the possibility of a range of ES outcomes?	For the assessment of the fish provisioning service, the study uptakes the methodology of the International Council for the Exploration of the Sea (ICES). For assessing coastal fishery, a different spatial accounting system is used and could be further elaborated to have a unified approach.
How does the study consider future **scenarios** in study context, and the possibility of a range of ES outcomes? ?	Future scenarios of fish landing are not considered directly in MSP. Through MSP areas limited for fishing activities due to wind park development are discussed with stakeholders, impacts assessed in SEA process.
Does the study **model risks for beneficiaries (ES benefits x probabilities)**?	No, there could be a problem with confidentiality to some extent as economic beneficiaries from open sea fish landing are limited in number.
How was the raw data on fish landing processed?	There can be errors in spatial coordinates entered in the fishermen logbooks for open sea fishery. During the period 2014-2022 it made about 6% of total records or 4.6% of total fish landing. Of open sea fishery.