SELINA
SCIENCE FOR EVIDENCE-BASED AND SUSTAINABLE DECISIONS ABOUT NATURAL CAPITAL

D8.2 Mid-term report on ES evidence generation and uptake in the Demonstration Projects

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Authors: Jarumi Kato-Huerta, Davide Geneletti, Chiara Cortinovis, Paula Rendón, Fátima Arrogante Funes, Fernando Santos-Martín, Paulo Pereira, Luis Pinto, Miguel Inacio, Katarzyna Bogdziewicz, Chiara Parretta, Simone Caridi, Giovanna Ulrici, Francesca Alba, Inge Liekens, An Creemers, Erwann Lagabrielle; Salwa Aabid, Barbara Losen, Marc Reusser, Jonas Schwaab, Adrienne Grêt-Regamey, Ilma Valdmane, Anda Ruskule, Kristina Veidemane

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Preface

The importance of biodiversity, natural capital and healthy ecosystems and the services they supply has increasingly been acknowledged in diverse policy initiatives (e.g., the EU nature restoration and amending Regulation from 2024, EU Biodiversity Strategies 2020 and 2030, Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), UN's Natural Capital and Ecosystem Services Accounting (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 8 (WP8), "Integration of ES-related Evidence into Public Decision-making," is to assess and support the generation and effective mobilisation of evidence on ecosystem services (ES), ecosystem condition (EC), and biodiversity (BD) to inform decisions in public sector contexts. Through a set of seven public Demonstration Projects (DPs), WP8 explores the practical challenges and opportunities of applying scientific knowledge in wide range of public decisions, including those related to spatial planning, environmental regulation, restoration efforts, and sustainability policy, among others

This Deliverable D8.2, *Mid-term Report on ES Evidence Generation and Uptake in the DPs*, provides an interim analysis of progress made within these public Demonstration Projects. It reviews the generation of ES, EC, and BD evidence, assesses the alignment of this evidence with identified decision-making opportunities (decision windows), and examines the conditions that facilitate or constrain uptake. The findings presented here will inform the final stages of the project and feed directly into Deliverable D8.3, which will synthesise lessons learned and provide practical recommendations for sustaining and expanding the use of ecosystem evidence in public governance across Europe.

List of abbreviations

EU	European Union
DPs	Demonstration Project
WP	Work Package
ES	Ecosystem Services
BD	Biodiversity
EC	Ecosystem Condition

1 Introduction

1.1 Objectives and structure

This deliverable serves as an intermediate output of the activities in the public Demonstration Projects (DPs) (Table 1). Specifically, the objective is to report on the progress of generating evidence on the use of ecosystem evidence in public decision-making and its integration into the processes pursued by the different DPs. Furthermore, as a mid-term assessment, this report serves as a key checkpoint, providing an opportunity to evaluate current achievements, identify challenges, and refine strategies to maximise the project's long-term impact.

A key objective of this document is to establish a structured roadmap for ongoing and future data generation efforts while underscoring the role of scientifically robust evidence in informing public decision-making. To achieve this, the deliverable presents the data collection and analysis that each DP conducted to date, offering early insights into emerging trends, patterns, and their potential policy implications. These findings will help to contextualise the current state of ecosystem evidence within SELINA, illustrating its relevance and applicability across various contexts, as well as to drive the activities in the remaining part of the project.

Finally, being embedded in WP8, this Deliverable focuses on public DPs. A similar report is being produced within WP9 for the private sector (Deliverable 9.3, due in month 48). Regarding the three-hybrid public-private DPs, their progress will be addressed in Deliverable 8.5, with a specific focus on enhancing the cost-effectiveness and scalability of ecosystem knowledge generation through collaborative public-private data sharing.

***Table 1**. Overview of the DPs and their decision-making contexts (a detailed description of the DPs' context and objectives can be found in Deliverable 8.1, available at the following link)*

Code	Country	Scientific partner	Public partner	Spatial scale	Decision-making context
DP01	Spain	URJC	MITECO	National	Spanish National Strategy for Green Infrastructure and Ecosystem Restoration
DP02	Lithuania	LRAM	MRU	National	Sustainable Agricultural Practices in the Comprehensive Plan of the Territory of the Republic of Lithuania
DP03	Italy	UniTrento	Com Trento	Local	Urban Greening Management Plan of the City of Trento
DP04	Belgium	VITO	ANB	Local	Bosland National Park
DP05	France (Reunion)	UR	-	Regional	Integration of ES evidence on marine and terrestrial spatial planning
DP06	Switzerland	ETH	-	Regional	Sustainable energy production in mountain regions
DP07	Latvia	BEF	MoERPD	National	Maritime Spatial Plan of Latvia and Thematic Plan of Coastal Infrastructure

This report is structured as follows. Chapter 2 outlines the methods followed to analyse the progress of the DPs in both generating evidence and integrating it into decision-making. To this end, the concept of decision window is introduced, which is used to monitor the progress made so far by each DP within the general decision-making process (e.g., the drawing and approval of a plan or policy). The chapter also describes the timeline of the activities conducted and of the milestones achieved.

Chapter 3-9 presents, DP by DP, the progress made in terms of data collection, analysis, and incorporation into the decision-making processes.

Finally, Chapter 10 presents conclusions and recommendations on refining methodologies and enhancing the impact of ES-informed decision-making. This chapter also outlines the next steps leading to the final Deliverable 8.3, ensuring that future efforts build upon the insights gained from this interim assessment.

2 Methods of analysis of the DPs' progress

2.1 Identification of "decision windows"

Public decision-making typically unfolds through a series of identifiable phases, often described as the policy cycle (explored in Deliverable 8.1). This cycle includes five main stages: agenda setting, policy formulation, adoption, implementation, and evaluation. During each phase different opportunities to introduce new evidence and influence choices arise. These opportunities, or "decision windows", represent specific moments within a policy or planning process when key decisions are being shaped and are open to influence Dalkmann et al., 2004.

This concept draws on research in decision theory and science-policy interfaces (e.g., Cash et al., 2003; Schrefler, 2010; van Stigt et al., 2013), which emphasise that the use of evidence is shaped not only by its credibility, but also by its institutional fit, salience, and timing. Evidence introduced during a decision window may be more likely to influence decisions, provided it aligns with policy priorities and procedural dynamics. Decision windows are typically time-sensitive and highly context-dependent; they can also be influenced by institutional dynamics and other external factors. Consequently, they are not guaranteed, and their success often depends on the ability of decision-makers and researchers to recognise and act on them in real time.

Across the policy cycle, decision windows may appear in many forms (see also Box 1):

- Agenda setting: When an issue is gaining attention within institutions or the public sphere, decision windows allow evidence to shape how the problem is understood and prioritised.

- Policy formulation: As policy options are developed, evidence can inform the comparison of alternatives and highlight trade-offs, supporting more robust decision-making.

- Policy adoption: During formal approval processes, decision windows may provide an opportunity to refine proposals, justify selected approaches, or strengthen the rationale behind choices.

- Implementation: When policies are being operationalised, evidence can guide how actions are carried out, which measures are prioritised, and how resources are allocated.

- Evaluation: In reviewing performance and outcomes, decision windows enable the integration of new evidence to improve future decisions or adapt ongoing strategies.

Identifying decision windows requires a clear understanding of the decision-making framework, institutional context, and policy timelines. It involves mapping key phases and milestones in which decisions are shaped and made, as well as recognising moments when scientific evidence could be meaningfully introduced (Dalkmann et al., 2004). This identification process draws on several interrelated factors:

- Timing and procedural analysis: Examining the timeline of a policy or planning process reveals stages where strategic decisions are anticipated. Decision windows may be scheduled, for instance, alongside regulatory reviews or policy updates, or may emerge in response to shifting political priorities.

- Legal and regulatory frameworks: Understanding institutional requirements, such as Strategic Environmental Assessments (SEA) or other legally mandated processes, helps identify formal points where ecosystem evidence is expected or required.
- Stakeholder engagement: Engaging with actors involved in policy processes is essential for capturing informal knowledge about when and how decisions are made. Policymakers, planners, and practitioners possess critical insights into institutional priorities, routines, and constraints that researchers may overlook on their own.

By strategically leveraging decision windows (Box 1) throughout the policy cycle, policymakers can ensure that ecosystem evidence is introduced not only at the right moments but also continuously refined and adapted.

Box 1: Categories of decision windows

Possible categories of decision windows are hereby described, consistently with the typology of purposes for ES assessments in the public sector, as defined in Deliverable 4.3 (Annex 8.1, pp. 186–194).

Upgrading Scientific Information and Baseline Data: Decision windows open when policymakers acknowledge the need to update, expand, or refine the scientific data that underpins decision-making. In situations where existing data is incomplete or outdated, new BD, EC, and ES assessments present an opportunity to enhance the accuracy and relevance of evidence, thereby reinforcing the foundation for policy interventions.

- Prioritisation of Interventions: As policies and plans shift from defining objectives to selecting concrete actions, opportunities arise for determining which measures to implement. At this stage, BD, EC, and ES information can be assessed alongside other criteria, ensuring that environmental considerations are incorporated into prioritisation frameworks.
- Comparing Alternative Scenarios: Many decision-making processes involve evaluating various policy, planning, or operational alternatives. Decision windows provide opportunities to systematically incorporate BD, EC, and ES assessments into these comparisons, enabling decision-makers to understand the trade-offs and advantages of different options.
- Policy Evaluation and Monitoring: Decision windows arise during the review and assessment of policy outcomes, particularly in post-implementation monitoring. These windows enable the introduction of new BD, EC, and ES indicators, improving monitoring frameworks and influencing how environmental performance is tracked. The insights gained can inform corrective actions and adaptive management strategies, ensuring ongoing policy refinement and improvement.

The concept of decision window was therefore adopted in WP8 to help track the progress of activities in the DPs, since each of them was addressing a different policy or planning process, with very different timeframes and sequences of activities. DPs were encouraged to identify potential decision windows that emerged within the first 36 months of the project, also referring to the categories presented in Box 1. This enabled breaking down the decision process, whenever possible, into smaller elements, which are then individually described in terms of how ES evidence was used and uptaken. (see Chapters 3-9).

2.2 Structure of the Tasks and timeline of the activities

A structured approach was developed to monitor the integration of ecosystem evidence into decision-making and ensure that scientific knowledge is produced and effectively incorporated into various processes. (Figure 2.2). This approach began with Task 8.1, Setting the Decision Contexts (results summarised in Deliverable 8.1), which established the decision contexts within the DPs and provided the foundation for the data and methodological needs explored in Task 8.2, generating evidence on ecosystems and ES in each DP. This evidence then informs Task 8.3, which involves integrating *evidence into decision-making processes*. As shown in Figure 2.1, Tasks 8.2 and 8.3 operate in a dynamic, iterative cycle, where evidence generation continuously informs decision-making, and feedback from policy integration helps refine data collection and analysis.

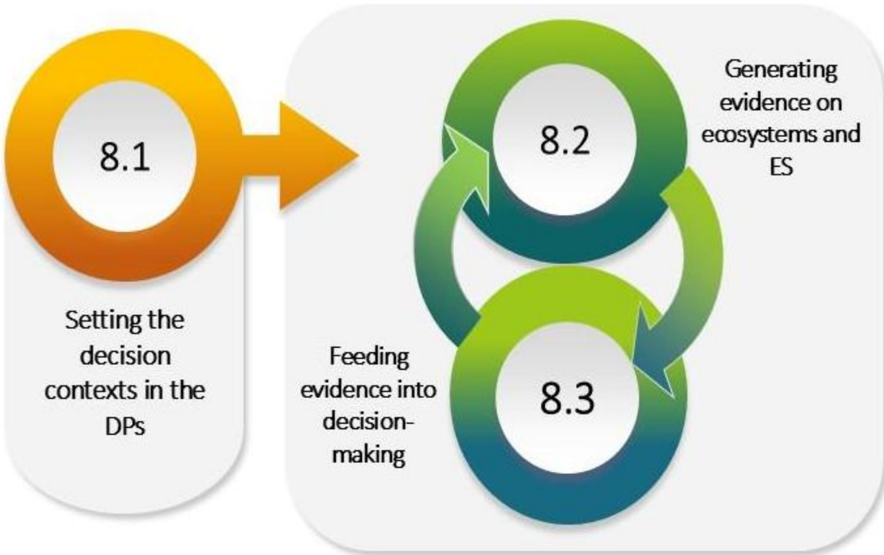


Figure 2.1 *Interaction between Task 8.1, Task 8.2 and Task 8.3 in the ES-related evidence integration Process for public decision-making.*

To implement both Task 8.2 and Task 8.3 within the DPs, different activities were conducted to track the alignment between evidence generation and its integration into decision-making processes. These activities followed a progressive timeline, characterised by ongoing discussions between various WPs to enhance methodological coherence (Figure 2.2). As part of this process, a preliminary evaluation of the Framework for Integrated Ecosystem Assessment (FIEA) was also conducted. This evaluation aims to explore the feasibility and added value of FIEA in guiding the use of ecosystem evidence in public-sector decision-making. Insights from this exploratory testing are presented in Chapter 10 of this document, supporting future refinement and broader applicability of the framework across diverse policy contexts.

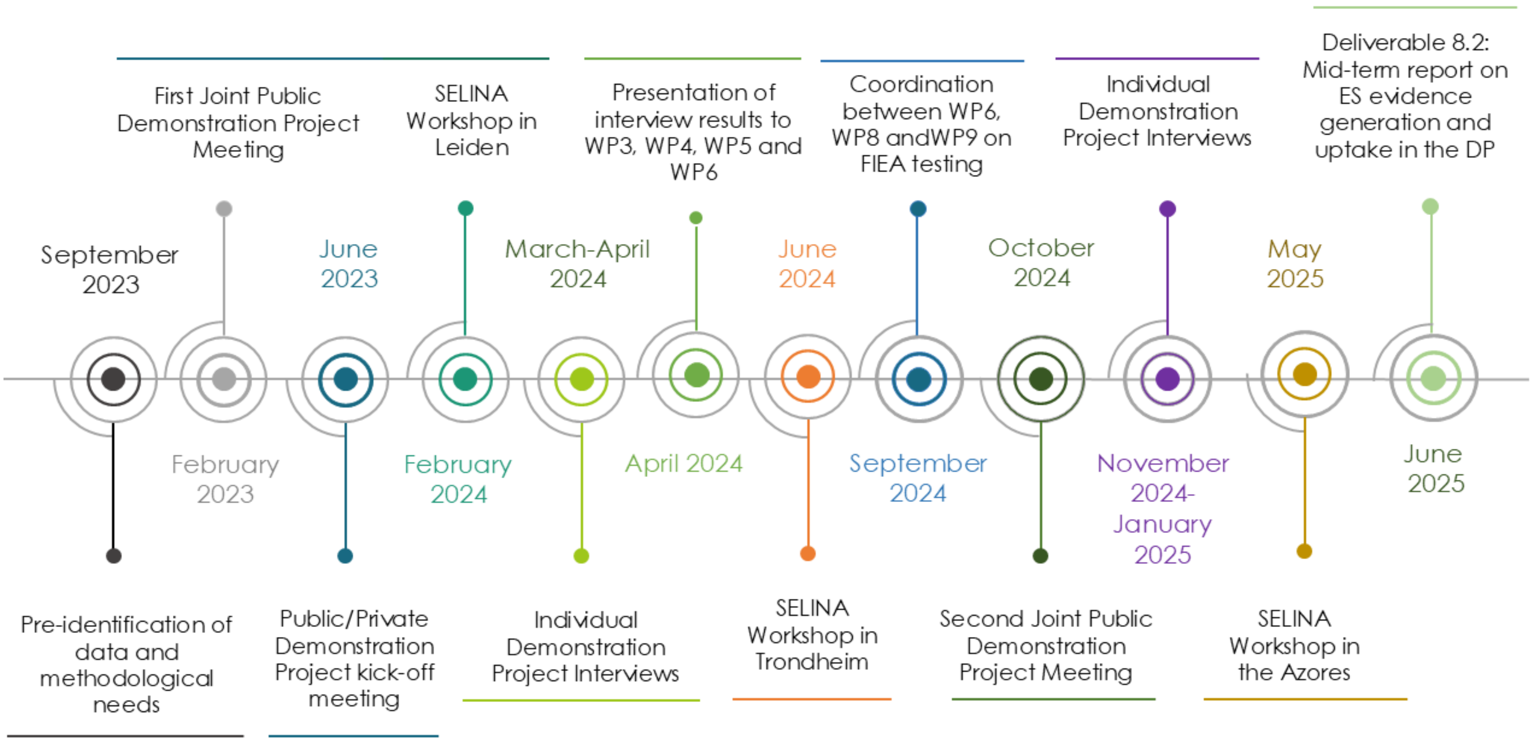


Figure 2.2. *Timeline of the activities developed for both Task 8.2 and Task 8.3*

During the progress of this timeline, several meetings were held with WP9, which focuses on the private sector decision-making. For instance, these gatherings aimed to collaboratively develop the kick-off meeting, coordinate activities across different workshops, formulate a common strategy for testing SELINA's FIEA, and initiate discussions on how to approach Task 8.5, which examines solutions for the joint private-public use of evidence on ecosystems and ES.

The timeline of WP8 activities began in September 2023 with the early identification of data and methodological needs across the public DPs. This initial phase laid the groundwork for aligning evidence generation with policy contexts. In February 2024, the first Joint Public DP meeting created a space to present preliminary findings and to discuss proposed data collection efforts. Shortly afterwards, the joint Public/Private DP kick-off meeting, organised in collaboration with WP9, served to showcase early insights and deepen the understanding of decision-making contexts across both public and private sectors.

Following the SELINA Workshop in Leiden in June 2023, discussions shifted to refining data collection methodologies and enhancing synergies among different WPs. These discussions provided the necessary material to structure seven Public Individual DP interviews conducted between March and April 2024. These interviews served a dual purpose: for Task 8.2, they aimed to analyse progress in data generation, identify methodological gaps, and assess how other WPs could support ES evidence collection. For Task 8.3, the discussions focused on the initial identification of decision windows in each DP, marking a critical step in understanding when and how ecosystem evidence could be most effectively integrated into decision-making.

In April 2024, the interview results were presented to WP3, WP4, WP5, and WP6, promoting cross-WP coordination and ensuring that some of the methodological needs from public DPs could be met. These discussions also laid the groundwork for the SELINA Workshop in Trondheim in June 2024, where methodological needs and strategies for applying ecosystem evidence were further explored. Coordination with WP9 continued during this period to align strategies for incorporating private sector perspectives into these discussions.

By September 2024, coordination efforts intensified, particularly among WP6, WP8, and WP9, to assess the feasibility of testing the FIEA framework within the DPs. These discussions were vital in refining strategies for integrating ecosystem evidence into both public and private policy frameworks, ensuring that a coherent methodology was established across diverse decision-making contexts.

In October 2024, the second Joint Public DP meeting took place, focusing on the practical application of the FIEA framework. The presentations at this meeting aimed to explain how WP8 planned to collect perceptions from the public on the effectiveness of the framework in guiding the use of ecosystem evidence in public decision-making.

Between November 2024 and January 2025, a second round of individual DP interviews was conducted to assess the progress made in the identified decision windows and to further discuss the feasibility of FIEA for public decision-making (interview results further discussed under Chapter 10 of this deliverable). At the same time, a parallel interview process was developed in WP9 to provide insights into integrating ecosystem evidence into business decision-making processes, ensuring that private sector perspectives were considered during the FIEA evaluation phase.

As the project moved into the integration phase of the SELINA project, efforts intensified to turn scientific findings into actionable applications. In May 2025, an integration workshop was held in the Azores, Portugal, to refine strategies for the uptake of ecosystem evidence and to present the main advancements of WP8 for both Task 8.2 and 8.3.

The process of formulating this document will culminate in June 2025 with the submission of Deliverable 8.2, which consolidates the findings on evidence generation and its initial integration into decision-making. This milestone marks a crucial step in assessing the success of Task 8.2 and lays the groundwork for the final phase under Task 8.3. The structured progression of activities demonstrates a methodical approach to achieving the project's objectives, ensuring that ecosystem evidence is generated and meaningfully incorporated into public and private decision-making processes.

All templates and materials used for gathering information on data and methodological needs, as well as for decision window mapping, can be found in **Annex I.** These materials provide a comprehensive record of the methodologies applied throughout the development of WP8, supporting the integration of data collection in relevant decision windows.

3 Spanish National Strategy for Green Infrastructure and Ecosystem Restoration

3.1 Introduction

Introduction Spain faces several significant challenges regarding biodiversity, ecosystems and the services they provide. Such challenges include habitat loss and fragmentation due to urbanisation and agriculture, the impacts of climate change, overexploitation of natural resources, pollution, invasive species, policy and management gaps, and water scarcity. These issues threaten the health and resilience of ecosystems, necessitating integrated management strategies, increased conservation funding, and stronger enforcement of environmental regulations to protect Spain's rich biodiversity and ensure ecosystem sustainability (Lanzas et al., 2024). Therefore, ecosystem services (ES), biodiversity (BD), and ecosystem condition (EC) evidence is fundamental for this Demonstration Project for several reasons.

Firstly, scientific evidence plays a crucial role in ensuring the conservation of ecosystems. Green infrastructure (GI) is conceived as an ecologically coherent and strategically planned network of natural and semi-natural areas. Scientific evidence guarantees that this network is designed and managed appropriately to conserve ecosystems and maintain the services they provide (MITECO, 2022).

Additionally, scientific evidence enables an accurate assessment of the current state of ecosystems and their ecological connectivity. This is essential to identify priority areas and the necessary actions for their restoration and conservation. Without an adequate diagnosis, interventions could be ineffective or even harmful (Valladares et al., 2017).

Another aspect is that it provides clear guidelines for urban and sectoral policy. This ensures that decisions are based on scientific evidence and not on subjective criteria, integrating GI into territorial and urban development policies. In this way, sustainable and environmentally friendly development is promoted (Valladares et al., 2017).

Scientific evidence also helps establish monitoring and evaluation programmes to measure the impact of the implemented actions. This is vital to adjust strategies and ensure their long-term effectiveness. Without proper monitoring, it would be challenging to determine whether the adopted measures are achieving the proposed objectives (Valladares et al., 2017).

Finally, GI plays an important role in climate change mitigation and adaptation. Scientific evidence provides the conceptual framework and diagnosis necessary to understand how ecosystems can contribute to these objectives. This includes the capacity of ecosystems to absorb carbon, regulate the climate, and protect against extreme weather events (Valladares et al., 2017).

Updates to the framing described in D 8.1

Initially, the objective of the DP was to assess all the ES presented in the second version of the

Methodological Guide for the Identification of Green Infrastructure in Spain at different spatial scales. However, after finalising its publication and discussing with representatives from the Ministry for the Ecological Transition and the Demographic Challenge (MITECO), it was decided to focus on four regulating ES described in section 1.2 at the national scale using national data sources. This decision was made because these services were considered a priority for the country and aligned with the reporting requirements from the European regulation on environmental accounts (ENV/EAMESA/WG/2023/18).

Another update is that the ecosystem types initially considered include forests, agroecosystems, heath and grasslands, urban areas, wetlands, rivers, and lakes. However, to gain a better overview of ES provision, the option of assessing them by ecosystem type has been explored, starting with the ES of carbon retention in forests. This approach allows for a more detailed understanding of how different ecosystems contribute to ES provision and helps identify specific areas for conservation and management.

Initially, the DP was more focused on assessing ES rather than EC. However, due to ongoing work and the increasing need to understand the interrelationships between EC and ES, this relationship will be explored for forests and the ES of carbon retention. Understanding how EC influences ES provision is crucial for developing effective conservation strategies and ensuring the sustainability of ES. Despite being included in the methodological guide, biodiversity and functional diversity will not be addressed within the DP, as the focus remains on the selected ES and their assessment.

3.2 Progress in generating evidence

3.2.1 Data identification, collection and processing

As part of the collaboration with MITECO, the DP in Spain focuses on assessing a set of key ES that are essential for environmental sustainability and climate resilience. The services to be addressed include carbon retention, terrestrial carbon sequestration, water cycle regulation and flow control, and erosion control. These services were selected due to their relevance in supporting carbon neutrality, maintaining water security, and preserving soil integrity in the face of increasing environmental pressures.

Carbon Retention

Using spatial and remote sensing data, the assessment applies machine learning (ML) methods to estimate carbon retention across four primary carbon pools — aboveground, belowground, dead wood, and soil organic carbon. We developed four Random Forest (RF) regression models trained on data from 2010 to generate carbon stock predictions for the years 2000 and 2015, offering a Tier 3 level of IPCC-compliant information.

Model Development and Input Data

The RF algorithm was selected after evaluating 18 regression models, demonstrating superior performance for estimating aboveground carbon. Random Forest constructs multiple decision trees from bootstrapped data subsets, minimising overfitting and improving generalisation. Input variables were selected based on availability and relevance in prior literature, combining satellite, climatic, topographic, and ecological datasets.

Table 3.1. *Explanatory variables used in the random forest model for each carbon pool. AG: Aboveground, BG: Belowground, DW: Deadwood, SOC: Soil organic carbon*

Variable	**Acronym**	**Source**	**Model**
Aboveground carbon	agb	Duncanson et al., 2019	BG
Actual evapotranspiration	aet	Running et al., 2019	AG, BG
Aspect	aspect	Jarvis et al., 2008	AG, BG, DW
Bulk density	bulk	Hengl et al., 2017	SOC
Climate water deficit	def_water	Abatzoglou et al., 2018	SOC
Digital terrestrial model	mds	Jarvis et al., 2008	AG, BG, SOC
NDVI	ndvi	Meneses-Tovar, 2011	AG, BG, SOC
NDWI	ndwi	Gao, 1996	DW
Annual mean temperature	temp	Wan et al., 2015	AG, BG, SOC
Tree canopy	per_tree	Carroll et al., 2010	AG, BG, DW
Tree species	Species_t	MITERD, 2023	DW
Vegetation canopy (non-tree)	per_notree	Carroll et al., 2010	AG, BG, SOC
Palmer Drought Severity Index	pdsi	Abatzoglou et al., 2018	AG, BG, SOC
Profile curvature	pro_cur	Jarvis et al., 2008	SOC
Annual mean precipitation	prec	Abatzoglou et al., 2018	AG, BG, SOC, DW

Variable	Acronym	Source	Model
Downward surface shortwave radiation	srad	Abatzoglou et al., 2018	AG, BG, SOC
Slope	slope	Jarvis et al., 2008	AG, BG, SOC, DW
Soil moisture	soil_mes	Abatzoglou et al., 2018	SOC
Net primary productivity	npp	Running et al., 2015	AG, BG

Model Validation

To assess accuracy, we compared RF-derived carbon estimates with the Spanish National Forest Inventory (NFI4), applying regression analysis on average values from both sources. This comparison accounts for temporal differences: NFI4 includes data from 2008 onward, whereas the model outputs are for 2015.

Other ES

In addition to estimating **carbon retention**, the DP aims to assess other key ES that play a crucial role in environmental sustainability and climate regulation. These include: (1) **terrestrial carbon sequestration**, which quantifies the net absorption and storage of atmospheric CO_2 by ecosystems; (2) **water cycle regulation and flow control**, evaluating how natural landscapes manage water availability, reduce flood risks, and protect coastal zones; (3) **erosion control**, which focuses on the capacity of vegetation to stabilise soils and reduce sediment loss; and (4) **pollination,** which focuses on the contribution of wild pollinators in the fertilisation of crops and benefiting the abundance and diversity of other species. Each of these services is estimated through scientifically robust methodologies that integrate satellite data, spatial modelling, and ecosystem process analysis.

Terrestrial Carbon Sequestration

This service evaluates how ecosystems capture and store atmospheric CO_2 through photosynthesis, storing it in vegetation and soils. The estimation follows a spatially explicit approach using satellite data and remote sensing. The Net Ecosystem Carbon Balance (NECB) is calculated using the following equations:

- **NECB = NEP – CL**, where:
    - **NEP (Net Ecosystem Production)** = NPP – SR
      (NPP: Net Primary Production; SR: Soil Respiration)
    - **NPP = GPP – PR**
      (GPP: Gross Primary Production; PR: Plant Respiration)

- **CL** accounts for carbon losses resulting from disturbances such as land clearing, harvesting, and fires.

This methodology enables the quantification of carbon sequestration over time and space, accounting for both inputs and outputs of carbon in ecosystems.

- **Variables** for estimating terrestrial carbon sequestration are in Table 3.2:

Table 3.2. *Variable descriptions and sources for estimating terrestrial carbon sequestration.*

Variable/Indicator	**Description**	**Source**
GPP (Gross Primary Production)	Total carbon fixed by vegetation through photosynthesis.	MOD17A2H V6 MODIS
NPP (Net Primary Production)	Difference between GPP and PR. Represents carbon available for biomass accumulation.	MODIS / Literature
Soil Respiration (SR)	Carbon released from the soil due to microbial and root activity.	Literature (Zhao et al., 2020)
Carbon Loss (CL)	Carbon losses from disturbances (harvests, fires, land use changes).	Global Forest Watch / National data
NECB (Net Ecosystem Carbon Balance)	Net carbon sequestration by the ecosystem.	Own elaboration based on the above

Water Cycle Regulation and Flow Control (including flood and coastal protection) This service analyses how ecosystems such as forests and wetlands regulate water flows, improve water availability, reduce flood risks, and protect coastal areas. The assessment is conducted through hydrological balance modelling, particularly using the SWAT (Soil and Water Assessment Tool) model.

The water balance is estimated using the following equation:

- **$Wt = SW_0 + \sum (P^d - SURQ - E - wseep - GQW)$**
  where:
    - **Wt**: Final soil water content (mm)
    - **SW_0**: Initial soil water content (mm)
    - **P^d**: Precipitation (mm)
    - **SURQ**: Surface runoff (mm)
    - **E**: Evapotranspiration (mm)

- **wseep**: Water percolating to deeper soil layers (mm)
- **GQW**: Groundwater flow (mm)

The model operates in two phases: **the land phase** (how water interacts with soil and vegetation) and **the routing phase** (how water moves through river networks), allowing for precise estimation of water availability and flow regulation.

- **Variables** for estimating water cycle regulation and flow control are in Table 3.3:

Table 3.3. *Variables, descriptions, and sources for estimating water cycle regulation and flow control.*

Variable/Indicator	Description	Source
Precipitation (P)	Total rainfall in the area.	ERA5-Land Climate Reanalysis
Evapotranspiration (ET)	Total water loss due to evaporation and plant transpiration.	MOD16A2 V6 MODIS
Surface Runoff (SURQ)	Water not infiltrated, flowing over the surface.	SWAT Model
Water Percolation (wseep)	Water that infiltrates into deeper soil layers.	SWAT Model
Groundwater Flow (GQW)	Water that flows into or from the groundwater reservoir.	SWAT Model

Erosion Control
This service measures how vegetation prevents soil loss and sediment transport. The methodology includes two main components:

- **Avoided Erosion**: Calculates the reduction in soil erosion due to vegetation cover using:
  - **RKLS**: Potential erosion without vegetation (based on rainfall, soil type, slope
  - **USLE**: Actual erosion considering land cover and management practices
    → **Avoided Erosion = RKLS – USLE**
- **Avoided Sediment Export**: Estimates how much sediment is retained by vegetation and prevented from reaching water bodies. It is calculated as:
  - **Avoided Export = (RKLS – USLE) × SDR + T**, where:
    - **SDR**: Sediment Delivery Rati
    - **T**: Sediment retained from upper slopes

These estimates are made pixel-by-pixel using GIS and remote sensing data, enabling fine-scale spatial assessments of erosion control services.

- **Variables** for estimating erosion control are in Table 3.4:

Table 3.4. *Variable, description and source for estimating erosion control*

Variable/Indicator	**Description**	**Source**
RKLS	Potential soil loss without vegetation cover or conservation practices.	Derived from RUSLE model
USLE	Actual soil loss considering land cover and conservation practices.	Derived from RUSLE model
SDR (Sediment Delivery Ratio)	Proportion of eroded sediment that reaches water bodies.	Literature / SWAT Model
Retained Sediment (T)	Sediment trapped in upper slopes due to vegetation.	Based on terrain and vegetation data
Avoided Erosion / Export	Difference between potential and actual erosion, adjusted by SDR and T.	Own elaboration based on model outputs

Pollination

Pollination services refer to the contribution of wild pollinators to crop fertilisation, enhancing both crop yields and the abundance and diversity of other plant species. This ES plays a crucial role in enhancing agricultural productivity and conserving biodiversity.

The primary focus of this study is on crop production. The approach is adapted from the InVEST model at a continental scale, called ESTIMAP. The methodology includes modelling floral availability and nesting suitability, considering crop types and pollinator activity. It accounts for landscape barriers that limit pollinator presence and combines land-use data to estimate floral resources and foraging areas. The model generates relative abundance maps adjusted for temperature and excludes unsuitable nesting zones to estimate relative pollination potential. Additionally, it supports species-specific mapping using data on flight ranges and activity periods. GIS software such as ArcGIS, GRASS, QGIS, or R is used in the modelling process. Variables for estimating pollination service are in Table 3.5:

Table 3.5. *Variable, description and source for estimating pollination service.*

Variable/Indicator	Description	Source
Floral resources	Areas with sufficient flowers for foraging	Corine Land Cover
Nesting habitat suitability	Presence of suitable nesting areas for wild pollinators	Corine Land Cover + expert input
Barriers to movement	Landscape elements that hinder pollinator movement	Corine Land Cover + literature
Relative abundance of pollinators	Estimation of spatial abundance of pollinators based on habitat, temperature, and land use	Adapted InVEST
Relative pollination potential	Spatial estimate of pollination service, excluding unsuitable areas for nesting	Adapted InVEST

3.2.2 Key findings and expected future activities

Carbon Retention

The original objective of this study was to incorporate high-precision, carbon-specific variables derived from national field inventories provided by MITECO. Due to their detailed ground-truth information, these plot-level datasets were expected to play a central role in model training and carbon estimation.

However, access to the exact coordinates of these national inventory plots has proven challenging, and their availability was not guaranteed within the timeframe required for model development. As a result, in this study, the national forest inventory data have only been used for model validation at the ecosystem level. Due to the lack of precise geolocation, these data could not be used directly as training input for the machine learning models.

Efforts to obtain these spatially explicit inventory datasets are ongoing. Collaboration with MITECO remains active, and both parties are working together to enable the secure transfer of inventory data with geographic coordinates. Until such data become available, their use in carbon modelling remains limited to validation purposes only.

Other ES

The preliminary analysis of the ecosystem services considered in the Spanish DP—carbon retention, terrestrial carbon sequestration, water cycle regulation and flow control, erosion control, and pollination services—has provided valuable insights into potential spatial patterns and modelling approaches for service quantification across the landscape.

Key findings include:

- Satellite-based assessments allowed for spatially explicit estimations using carbon balance equations for terrestrial carbon sequestration. However, initial results highlight considerable uncertainty in areas with intensive land-use change due to the limited availability of ground-truthing data.
- For hydrological regulation, model simulations using the SWAT framework outlined the critical role of vegetated ecosystems in maintaining water availability and mitigating flood risks. Still, accurate calibration is hampered by the lack of detailed sub-basin hydrological measurements.
- In erosion control, initial estimates using USLE and RKLS demonstrate the protective function of vegetative cover. However, refined data on vegetation structure and management practices is essential to improve precision.
- For pollination services, relative pollinator abundance maps derived from the adapted InVEST model point to areas of high service potential. Nevertheless, the lack of species-specific pollinator activity data and nesting information limits the model's accuracy at a local scale.

Foreseen data generation: The current limitation across all services stems from the lack of access to high-resolution, high-quality data, particularly those managed or committed by the MITECO. These datasets—such as national-scale LIDAR, soil carbon monitoring networks, precise land management records, or biodiversity inventories—are subject to strict access protocols and prolonged approval procedures, which have delayed integration into the project.

By the end of the project, it is foreseen that access to the following data will significantly enhance analysis:

- High-resolution spatial layers on carbon stock and soil organic matter from national forest and agricultural inventories.
- Detailed hydrological and meteorological time-series at sub-catchment levels to better calibrate flow and evapotranspiration models.
- Updated erosion monitoring data linked to land cover dynamics and field management intensity.
- Pollinator species data, including habitat requirements and seasonal patterns, to refine the model of pollination potential.

Collaboration with MITECO will remain central to obtaining and processing these sensitive datasets, and efforts will be made to streamline the data-sharing and permitting procedures within the remaining project timeline.

3.3 Progress in integrating evidence in decision-making

3.3.1 Decision Windows identified to date

For DP01 (Spain), the most significant decision window was the approval of regional Green Infrastructure Strategies by 14 July 2024, as required by the Spanish National Strategy for Green Infrastructure, Connectivity, and Ecological Restoration. This window offered an opportunity to incorporate evidence of ES evidence into strategic planning at the regional level, ensuring that infrastructure projects align with national objectives whilst addressing region-specific needs.

The second relevant decision window is the process of defining and classifying Green Infrastructure elements, which represents another opportunity to integrate scientific evidence into national and regional planning. While there is no fixed timeline for this process, it is essential to establish a standardised approach to Green Infrastructure mapping, ensuring consistency across different administrative levels.

Outside of these two decision windows, identifying areas for ecological restoration becomes important within the context of the EU Nature Restoration Regulation. Spain intends to formulate a National Restoration Plan, where ES assessments can significantly guide the process.

These decision windows provide key moments in the policy cycle where scientific data on ES can influence policy formulation, adoption, and implementation. By strategically aligning evidence with these decision points, decision-makers can enhance the effectiveness, coherence, and long-term impact of Green Infrastructure and ecological restoration planning in Spain. The following Table (3.6) presents a detailed comparison of these decision windows.

Table 3.6: *Main elements of the decision windows identified by DP01*

	DW1: Integration of ES in Regional Green Infrastructure Strategies	**DW2: Identification and Classification of Green Infrastructure Elements**	**DW3: Integration of ES in the Identification of Priority Restoration Areas**
Policy Context	Linked to the approval of regional Green Infrastructure Strategies, as mandated by the Spanish National Strategy for Green Infrastructure, Connectivity, and Ecological Restoration.	Related to identifying and classifying Green Infrastructure elements within national and regional planning processes.	Linked to the EU Nature Restoration Regulation and Spain's forthcoming National Restoration Strategy, which will identify priority areas for restoration.
Decision Window Timing	Regional strategies must be approved by July 14, 2024.	Ongoing process: There is no clear deadline, but it should align with regional GI mapping efforts.	Dependent on EU regulation: Spain must develop a National Restoration Plan. Otherwise, restoration planning will continue under a national strategy with undefined deadlines.

	DW1: Integration of ES in Regional Green Infrastructure Strategies	DW2: Identification and Classification of Green Infrastructure Elements	DW3: Integration of ES in the Identification of Priority Restoration Areas
Primary Objective	To assist in developing and approving regional GI strategies, ensuring they incorporate scientific ES evidence on priority services	To define and standardise what constitutes Green Infrastructure at the national and regional levels by integrating ES evidence.	To identify and prioritise areas for ecological restoration
Role of ES Evidence	Used to prioritise intervention areas, define conservation goals, and guide spatial planning within Green Infrastructure Strategies	Used to help public administrations determine which elements qualify as Green Infrastructure and to compare different mapping methodologies	Used to prioritise areas needing ecological restoration
Stakeholder Engagement	Primarily, regional authorities are responsible for approving the GI strategies before the deadline.	Focuses on national and regional authorities working on GI mapping	Involves national policymakers, scientific experts, and regional governments
Challenges	-Need to ensure alignment with national objectives while addressing regional priorities. -Variation in data availability and decentralised data repositories	Variation in data availability and decentralised data repositories	Competing interests and political agendas, and issues related to the scale of projects and fragmented knowledge that affect Spain's national restoration planning

The evidence described in section 1.2 is still under development. Consequently, the following sections address the potential applications of ES evidence in informing policy and planning. They also explore the potential for transdisciplinary collaboration and stakeholder engagement activities, as well as the challenges in bridging scientific evidence with policy needs. Additionally, examples of the integration of this evidence and activities are provided for each identified decision window.

3.3.2 Integration of ES in Regional Green Infrastructure Strategies

Integration of evidence

In March 2024, a survey was conducted to gather information supporting the implementation of Green Infrastructure (GI) in Spain (MITECO and URJC, 2024). This survey targeted the Green Infrastructure Working Group (GIWG) of the Committee of Protected Natural Spaces, which included technicians from the General State Administration (AGE, from the Spanish Administración General del Estado), autonomous communities and cities, and the Spanish Federation of Municipalities and Provinces (FEMP) responsible for GI within their jurisdictions.

The results provided valuable insights into ongoing initiatives in the autonomous communities for evaluating and mapping ES. Most GIWG members had undertaken initiatives to evaluate and map ES in their territories, with variations in approaches and stages of development. Some regions had integrated these efforts into the development of their GI Strategy, while others had initiated independent projects with similar objectives.

Regarding the ES evaluated and mapped, provisioning, regulating, maintenance, and cultural services were included. Evaluating these services has been crucial for the sustainable management of natural resources. In terms of methodologies and models used, there is a diversity of approaches, with certain methods, such as total carbon content and foliar biomass, being more common than others. However, differences in the adoption of specific tools were identified, highlighting the need to share best practices and promote standardisation in this field. Finally, the responses from GIWG members regarding future plans and ongoing initiatives indicate a continuous commitment to evaluating and mapping ES.

The potential uses of integrating ES into regional GI strategies are numerous. ES can inform climate change adaptation strategies by identifying areas that act as carbon sinks or provide climate regulation services. For example, in the Valencian Community, reforestation and coastal ecosystem restoration projects have been implemented to increase climate resilience (Fundación Global Nature, n.d. and Oceanogràfic Foundation, n.d). Another example is rural development and sustainable agriculture. ES evidence can support the development of sustainable agricultural practices that improve soil health and biodiversity. In the Murcia region, for instance, regenerative agriculture practices have been promoted to enhance soil fertility and water retention (European CAP Network, 2024).

Role of different actors, and their interaction

The development of regional GI strategies varies across the different autonomous communities in Spain, leading to diverse interactions among experts, stakeholders, and decision-makers. However, within the framework of these strategies, transdisciplinary collaboration has facilitated knowledge exchange and has been crucial for the adoption of existing evidence.

In Catalonia, for instance, the participation of experts, stakeholders, and decision-makers has facilitated the creation of urban green spaces based on ES maps (De Luca et al., 2021; Ajuntament de Barcelona, 2020). In the Community of Madrid, various initiatives and workshops have been conducted to promote urban sustainability and innovation, focusing on integrating green spaces and sustainable urban planning (Future Hubs, 2024).

Another recent example of interaction is the case of Murcia. The regional government of Murcia is advancing its 'Green Infrastructure and Ecological Connectivity and Restoration Strategy' to develop a network of natural and semi-natural elements essential for biodiversity and ecological balance. An informative session was held on 14 February 2025 to promote the strategy's implementation in local planning, emphasising the need to prevent the isolation and biological impoverishment of protected areas by ensuring ecological connectivity and promoting nature-based solutions for climate change adaptation (CARM, 2025).

The strategy aims to integrate innovative tools into urban and environmental policies, involving various stakeholders, and establish an ecologically coherent network of natural and semi-natural areas through a participatory approach. Objectives include defining ecological corridors, integrating high-value agricultural spaces, and improving connectivity between protected natural areas. The session also opened a communication channel with municipalities to collect technical data for planning and evaluating the strategy, featuring national experts and fostering collaboration among municipalities and other key actors (CARM, 2025).

Challenges

The integration of scientific knowledge into GI strategies faces several barriers. Insufficient institutional support from political leaders and institutions hampers the prioritisation and implementation of GI initiatives. Additionally, the lack of effective coordination between national, regional, and local governments creates challenges in harmonising policies and strategies.

Furthermore, decision-makers frequently lack the necessary technical knowledge and training to effectively incorporate scientific findings into policy making. Public awareness and engagement are also critical issues, with gaps in public understanding and support for GI leading to resistance or a lack of engagement in these initiatives. Lastly, the availability of high-quality, relevant data is often limited, and the decentralisation of data repositories further complicates the ability to base decisions on solid scientific evidence (MITECO, 2024b).

3.3.3 Identification and classification of Green Infrastructure Elements

Integration of evidence

Previous studies and data have been used to identify elements that could form part of the GI in the marine environment. This includes independent mapping and characterisation for each demarcation managed by the AGE in coordination with other responsible administrations. Potential GI elements in natural areas managed by the Ministry of Defence have also been identified. Most actions related to evaluating GI elements in the marine domain, such as conservation status, connectivity contribution, ES provision, and restoration needs, have been completed through monitoring programmes of Marine Strategies and the marine Natura 2000 network under AGE's jurisdiction.

The MITECO website maintains an updated cartographic viewer and information repository on GI. Additionally, scientific knowledge for identifying GI elements has been enhanced through various calls promoted by the Biodiversity Foundation, which are mostly still in progress (biological corridors and GI strengthening, connectivity, and ecological restoration). As stipulated in the strategy, the final selection and formal declaration of GI elements under AGE's responsibility remain pending (MITECO, 2024b).

Role of different actors, and their interactions

The National Strategy for GI and Ecological Connectivity and Restoration (MITECO, 2021) sets guidelines for identifying and conserving GI elements in Spain's terrestrial and marine environments. Public administrations are responsible for identifying these elements within their competencies based on the National Strategy's criteria. To standardize the selection processes across different geographic scales and administrations, MITECO has created a methodological guide in 2021. This guide, updated in 2023, provides practical methodologies for identifying and mapping GI elements, ensuring coherence and avoiding environmental or spatial inconsistencies.

The guide is dynamic, allowing for periodic updates as knowledge and information improve. Contributions from specialists have enriched successive editions, enhancing methodologies for evaluating ES and ecological connectivity. The guide aims to integrate areas with high ecosystem service provision, biodiversity conservation, and connectivity into a cohesive GI network, classified for conservation or restoration purposes. The development and update of the guide brought together experts from various fields, including ecology, urban planning, and social sciences, to work collaboratively towards common goals. The integration of diverse perspectives and expertise facilitated the exchange of knowledge and the co-creation of innovative solutions (MITECO, 2024a).

Challenges

The integration of ES into the identification and classification of GI elements faces several barriers. These include a polarised approach to territorial planning, which results in social conflicts between conservation authorities and resource users, negatively impacting biodiversity and ES. Natural areas under strict conservation programmes are embedded in a broader matrix of intensively managed land uses, primarily for food production. There is a need for further integration of industrial and nature conservation policies, as well as the incorporation of biodiversity into economic sectors like tourism to promote multifunctional GI areas (European Environment Agency, 2023).

Sustainable agriculture and a network of protected areas should be integrated within broader production landscapes to develop multifunctional GI areas. Additionally, the GI approach should be further embedded into landscape and urban planning processes, with a promotion of commitment in regions where it is currently low. Incorporating conclusions and recommendations from MAES into decision-making and further developing sub-regional plans, which are still lacking in some regions, are also crucial steps (European Environment Agency, 2023).

3.3.4 Identification of priority restoration areas

Integration of evidence

Evidence on ES has the potential to inform the identification of priority restoration areas. Some examples of similar evidence being applied for these purposes include urban planning and land use, where the incorporation of ES can help identify areas that should be protected or restored due to their ecological benefits, such as climate regulation and water purification. An existing case is Barcelona, where ES maps have been used to identify priority areas for creating urban green spaces (Ajuntament de Barcelona, 2023).

In water management, ES evidence can be used to improve watershed management. For example, in the Duero River basin, measures have already been implemented to improve water quality and reduce flood risk through the restoration of wetlands and the reforestation of riparian areas (Life IP-RBMP Duero, 2023). In terms of biodiversity conservation, the integration of ES into conservation policies can help identify and protect critical habitats. In Andalusia, for instance, conservation plans have been developed that prioritise the protection of areas providing essential services such as pollination and pest control (Junta de Andalucía, n.d).

Role of different actors, and their interactions

Transdisciplinary collaboration has been crucial for knowledge exchange and stakeholder engagement in integrating ES to identify priority restoration areas. This approach has enabled a comprehensive understanding of ES and ensured that restoration strategies are inclusive and reflect the needs of all stakeholders involved. Additionally, it has facilitated the identification of priority areas based on an integrated assessment of ecological, social, and economic factors (MITECO, 2022).

One specific example is the National River Restoration Strategy 2022-2030, which aims to restore and reconnect 3,000 km of Spanish rivers by 2030. This strategy focuses on improving the ecological status of water bodies, minimising flood risks, and enhancing biodiversity through integrated sediment management and public participation. Public participation is a key component of this strategy, involving local communities, government agencies, NGOs, and private sector entities in the planning and implementation processes to ensure transparency, equity, and the success of restoration efforts (MITECO, 2022).

Challenges

The approval of the EU Nature Restoration Regulation (European Parliament and Council, 2024) has a significant impact on Spain's national restoration planning, as it sets clear restoration targets for degraded ecosystems, ensures adequate funding and resources, and emphasises public participation. Spain must develop comprehensive plans to meet these goals, establish robust monitoring systems, and integrate climate change considerations.

However, several challenges hinder the integration of ES knowledge in identifying priority restoration areas and fulfilling the restoration targets. These challenges include competing interests and political agendas, which can impede consensus and collaboration among stakeholders. Additionally, issues related to the scale of restoration projects and the fragmentation of knowledge across disciplines further complicate efforts.

4 Supporting sustainable agricultural practices in the Comprehensive Plan of Lithuania

4.1 Introduction

The Comprehensive Plan of the Republic of Lithuania establishes a strategic framework for sustainable land-use planning and environmental management across the national territory. Within this framework, assessing ecosystem condition—defined as the structural integrity, functional performance, and capacity to provide ecosystem services—is fundamental for informed decision-making. While national assessments have traditionally prioritised forest, wetland, and protected natural habitats, there is a growing recognition that agricultural ecosystems (i.e., arable lands, permanent grasslands, and agroforestry areas) require dedicated evaluation. This focus aligns with European Union policies (e.g., the Common Agricultural Policy's "Green Deal" objectives, or the EU Biodiversity Strategy 2030) and domestic commitments to climate resilience, biodiversity conservation, and rural development.

Agricultural ecosystems in Lithuania cover approximately 54 % of the country's land area, making them the predominant land cover type. Unlike relatively stable natural forests or wetlands, agricultural landscapes are intensively managed and subject to rapid land-use changes (crop rotation, intensification, abandonment). Consequently, their ecological condition can fluctuate widely over short temporal scales. Assessing these systems is essential for several reasons:

Ecosystem Services Provision: Agricultural lands deliver critical services—food and fiber production, carbon sequestration in soils, pollination support, water regulation, and cultural values. Quantifying condition (e.g., soil organic carbon content, biodiversity indices of field margins, hydrological stability) reveals trade-offs between provisioning services and regulating/supporting services.

Biodiversity and Landscape Connectivity: Semi-natural features within farmland (hedgerows, grass margins, small wetlands) serve as stepping stones for many species. Condition assessments identify habitat quality, connectivity metrics, and pressures (e.g., monoculture expansion), which differ markedly from pressures in forested or wetland ecosystems.

Climate Change Mitigation and Adaptation: Agricultural soils represent a significant carbon pool; land management practices (no-till, cover cropping, crop diversification) directly influence greenhouse gas fluxes. Evaluating soil health and carbon sequestration potential in agricultural plots is therefore critical to meet Lithuania's nationally determined contributions (NDCs) under the Paris Agreement.

Socioeconomic Implications: Rural livelihoods in Lithuania remain heavily dependent on agriculture. Assessing condition informs not only ecological status but also socioeconomic resilience—identifying areas at risk of land degradation, declining productivity, or abandonment, which in turn affects rural demographics and cultural heritage.

4.2 Progress in generating evidence

4.2.1 Data identification, collection and processing

The assessment of ecosystem condition (EC) for the agricultural areas of Lithuania followed the protocol established under the SELINA project. The methodology framework is shown in Figure 4.1.

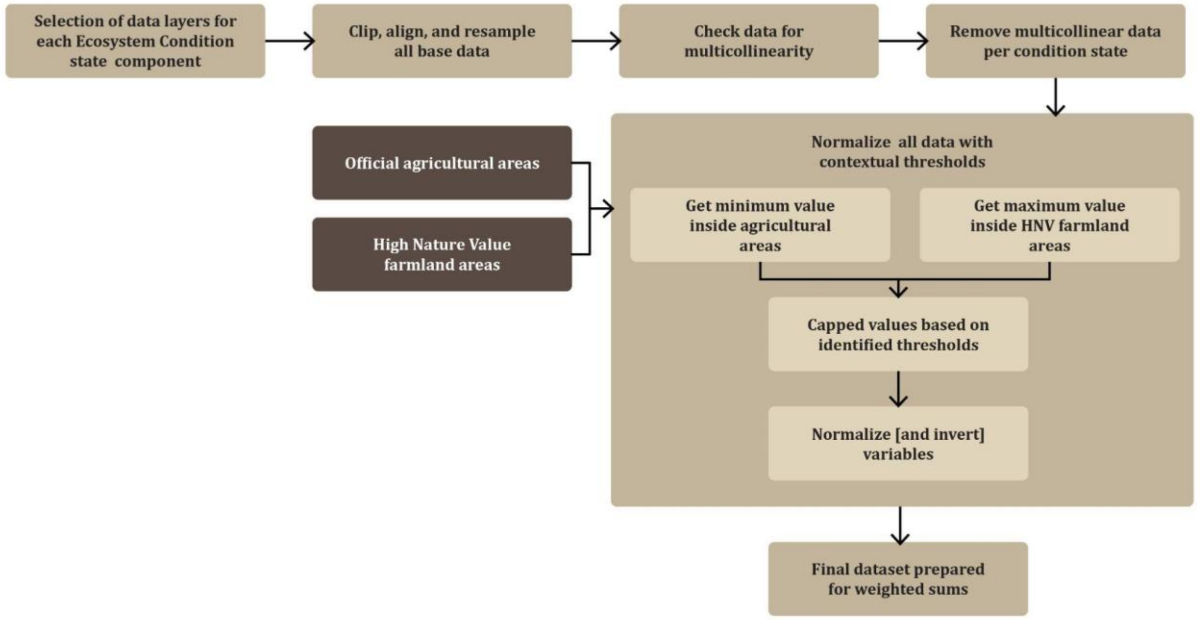


***Figure 4.1**. Methodological framework for the assessment of ecosystem conditions in the Lithuanian DP*

For this assessment, six ecosystem states were considered, with specific variables selected for each state (Table 4.1), including a set of remote sensing indices (formulas in Table 4.2), calculated from median images for the 2016-2023 time interval, prepared in Google Earth Engine (GEE) with the Sentinel2 dataset.

After collecting all data, the full dataset was assessed for multicollinearity via a Spearman correlation analysis. Variables were considered multicollinear whenever Spearman's Rho ≥0.8. Due to the size of the DP area and data resolution, a 500m point grid was used to sample the values from all variables. The sampling grid point was restricted to the official Lithuanian dataset 2024 for agricultural areas (obtained from geoportal.lt). The resulting file was then exported to a CSV file, which was analysed in JASP (v.0.19.1 Apple Silicon). Multicollinear variables are identified in Table 4.1. The Bare Soil Index (BSI) and Green Chlorophyll Vegetation Index (GCI) were found to be multicollinear (R = 0.886). Nevertheless, since they are used for different ecosystem states, they are retained in the dataset. Leaf area index (LAI) and Wide Dynamic Range Vegetation Index (WDRVI), initially considered for the Structural state, were also found to be multicollinear (R=0.952). As such, the option was made to keep LAI.

Table 4.1. *Ecosystem states and associated variables*

Ecosystem state	Variables considered and assessed	Resolution	Year	Source	Notes
Physical state	(1) Slope	30m	2014	EU-DEM	1
	(2) Bare soil index (BSI)*	30m	2016-2023	GEE [i]	1,2
	(3) Bulk density	100m	2018	ESDAC	1
	(4) Modified normalised difference water index (MNDWI)	30m	2016-2023	GEE [i]	2
Chemical state	(1) Soil organic carbon (SOC)	500m	2018	ESDAC	-
	(2) Cation exchange capacity	500m	2009	ESDAC	-
	(3) Heavy metals in soils:	-	-	-	-
	(3.1) Cadmium	100m-	2009	ESDAC	1
	(3.2) Mercury	250m	2009	ESDAC	1
	(3.3) Zinc	250m	2009	ESDAC	1
	(4) Soil nitrogen content	100m	2018	ESDAC	-
Compositional state	(1) Soil microbial biomass and respiration	-	-	-	-
	(1.1) Soil microbial basal respiration	1000m	2018	ESDAC	-
	(1.2) Soil microbial biomass	1000m	2018	ESDAC	-
	(2) Soil biodiversity	-	2016	ESDAC	-
	(3) Species diversity	10km	2013-2018	EEA	-
Structural state	(1) Leaf Area Index (LAI)**	30m	2016-2023	GEE [i]	2
	(2) Structural Intensive Pigment Vegetation Index (SIPVI)	30m	2016-2023	GEE [i]	2
	(3) Wide Dynamic Range Vegetation Index (WDRVI)**[a]	30m	2016-2023	GEE [i]	2
Functional state	(1) Green Chlorophyll Vegetation Index (GCI)*	30m	2016-2023	GEE [i]	2
	(2) Visible and Shortwave Infrared Drought Index (VSDI)	30m	2016-2023	GEE [i]	1,2
	(3) Ground ozone level	1113.2m	2018-2023	GEE data	1,2
	(4) Albedo	500m	2016-2023	GEE data	1,3
Landscape state	(1) Crop diversity	1000m	2018	JRC-EU	-
	(2) Connectivity index	100m	2014	EU-DEM [ii]	1,4
	(3) Landscape fragmentation index	100m	2016	EEA	-

Multicollinear results:

* BSI and GCI were found to be multicollinear (R=0.886),

** LAI and WDRVI were found to be multicollinear (R=0.952),

[a] Variable not used due to multicollinearity.

Source:

[i] Remote sensing index calculated in Google Earth Engine.

[ii] Based on EU-DEM and calculated with the SedInConnect software.

Notes:

1. Inverted values (applied to variables where the maximum value corresponds to a lower ecosystem condition),
2. Calculated based on the median image for the period 2016-2023,
3. Calculated based on the median image for the period 2018-2023 (2018 corresponds to the first available data),
4. Calculated with the SedInConnect software (Crema and Cavalli, 2018).

Table 4.2. Remote sensing indices.

Remote sensing indices	Indices formulas	Reference
Bare soil index (BSI)	BSI = ((S1 + r) - (N + b)) / ((S1 + r) + (N + b))	Rikimaru et al., (2002)
Modified normalised difference water index (MNDWI)	MNDWI = (g – S1) / (g + S1)	Xu (2006)
Leaf Area Index (LAI)	LAI = (3.618 * (2.5 * (N - r) / (N + 6 * r - 7.5 * b + 1) - 0.118)	Boegh et al. (2006)
Structural Intensive Pigment Vegetation Index (SIPVI)	SIPVI = (N - b) / (N - r)	Penuelas et al. (1995)
Wide Dynamic Range Vegetation Index (WDRVI)	WDRVI = (0.2 * N - r) / (0.2 * N + r)	Gitelson (2004)
Green Chlorophyll Vegetation Index (GCI)	GCI = (N / g) - 1	Gitelson et al. (2003)
Visible and Shortwave Infrared Drought Index (VSDI)	VSDI = 1 - ((S2 - b) / (r - b))	Zhang et al. (2013)
r – red; g – green; b – blue; N – Near Infrared (NIR); S1 – Short Wave Infrared 1 (SWIR1); S2 – Short Wave Infrared 2 (SWIR2)		

After the multicollinearity assessment, all rasters were spatially aligned with the 'Align Rasters' tool in QGIS. Grid size was set to 100m. The Lithuanian country limits were selected as the clipping extent. Variables with lower original resolution (≥250m) were resampled using the Cubic B-spline option. Each variable was then normalised. Before normalisation, each variable was revised based on minimum and maximum values. Minimum values were calculated inside 2024 agricultural areas (Lithuanian official data, obtained from geoportal.lt). Maximum values were calculated inside high nature value (HNV) farmland areas (obtained from the European Environmental Agency Datahub). All values above the maximum value obtained inside HNV farmland areas were reclassified to the maximum value. All values below the minimum value assessed in agricultural areas were reclassified to the minimum value. Variables were then normalised on a 0 to 1 scale. Variables positively affecting the assessed EC were normalised with (1), while variables with a negative effect were normalised and inverted with (2).

$$x_{norm} = (x_i - x_{min}) / (x_{max} - x_{min}) \quad (1)$$

$$x_{norm.inv} = 1 - ((x_i - x_{min}) / (x_{max} - x_{min})) \quad (2)$$

Where:

X_{min} = minimum value.

X_{max} = maximum value.

With all variables normalised, weighted sums are applied for each ecosystem condition state. Table 4.3 shows the weights attributed, according to the weighting level.

Table 4.3. *Weights attributed to each variable.*

Ecosystem state	Variables considered and assessed	Weight level 3	Weight level 2	Weight level 1	For data repository
Physical state	(1) Slope		0.25	0.16(7)	LT_EC_PhysSt
	(2) BSI		0.25		
	(3) Bulk density		0.25		
	(4) MNDWI		0.25		
Chemical state	(1) SOC		0.25	0.16(7)	LT_EC_ChemSt
	(2) Cation exchange capacity		0.25		
	(3) Heavy metals in soils:		0.25		
	(3.1) Cadmium	0.33(3)			
	(3.2) Mercury	0.33(3)			
	(3.3) Zinc	0.33(3)			
	(4) Soil nitrogen content		0.25		
Compositional state	(1) Soil microbial biomass and respiration		0.33(3)	0.16(7)	LT_EC_CompSt
	(1.1) Soil microbial basal respiration	0.5			
	(1.2) Soil microbial biomass	0.5			
	(2) Soil biodiversity		0.33(3)		
	(3) Species diversity		0.33(3)		
Structural state	(1) LAI		0.5	0.16(7)	LT_EC_StrucSt
	(2) SIPVI		0.5		
Functional state	(1) GCI		0.25	0.16(7)	LT_EC_PhysSt
	(2) VSDI		0.25		
	(3) Ground ozone level		0.25		
	(4) Albedo		0.25		
Landscape state	(1) Crop diversity		0.33(3)	0.16(7)	LT_EC_LandscSt
	(2) Connectivity index		0.33(3)		
	(3) Landscape fragmentation index		0.33(3)		
Global Ecosystem condition					LT_EC_glohal_DP

After the weighted sum of each sublevel, the respective results are normalised again for the next weighted sum (e.g., the result of the weighted sum for heavy metals, including variables Cadmium, Mercury, and Zinc, was normalised before being used in the weighted sum corresponding to the chemical state). The last column identifies the final layers to be uploaded to the data repository.

4.2.2 Key findings and expected future activities

After an initial test calculating the global ecosystem condition based on standard minimum and maximum values at the national level, we are currently reviewing the variables and preparing the normalised versions based on minimum and maximum values extracted from agricultural areas and HNV farmland areas, respectively, to proceed with the final calculations.

4.3 Progress in integrating evidence in decision-making

4.3.1 Decision Windows identified to date

The Lithuania DP02 incorporates ES-related evidence into the Comprehensive Plan of the Republic of Lithuania, with a particular emphasis on sustainable agricultural practices and rural development. The decision windows identified through this DP (Table 4.4) provide valuable opportunities to align scientific knowledge with policy implementation.

Two primary decision windows have been identified:

- **Public Consultation of the Rural Development Plan:** This phase presents a crucial opportunity to integrate ES-related evidence into public discussions on rural land-use planning and agricultural strategy. It enables stakeholders to review, debate, and refine policy directions before adoption, helping to ensure that ES considerations are embedded in the framework for sustainable rural development.
- **Evaluation of the Rural Development Plan:** This decision window focuses on assessing the effectiveness of existing rural policies in integrating ES-related considerations. It serves as a critical moment for evaluating progress and making evidence-informed adjustments.

Political transitions in Lithuania, particularly the formation of a new government in December 2024, are likely to influence both decision windows. Discussions around a potential new Rural Development Plan have been postponed indefinitely. Although the previous plan (2014–2020) remains technically in effect, it no longer provides active policy guidance, making the uptake of new knowledge particularly challenging.

Nonetheless, the Comprehensive Plan for Lithuania 2030 remains the principal guiding document for DP02. Despite recent political and policy uncertainties, it continues to set priorities that require consideration of evidence related to ES, underscoring their enduring relevance in national planning.

__Table 4.4.__ Main elements of the decision windows identified by DP02

	DW1: Public Consultation of the Rural Development Plan	**DW2: Evaluation of the Rural Development Plan**
Policy Context	Linked to Lithuania's Comprehensive Plan for Rural Development, which ensures sustainability in land-use planning and agricultural policies. Public consultations are necessary before finalising national rural strategies.	Focuses on evaluating the effectiveness of Lithuania's Rural Development Plan
Decision Window Timing	Expected in early to mid-2025, depending on government priorities	Political transitions may delay evaluations; the process could extend beyond 2025, depending on policy shifts.
Primary Objective	To engage stakeholders in shaping sustainable rural development policies, ensuring that ES evidence informs agricultural strategies.	To assess the impact of the plan
Role of ES Evidence	- Supports policy implementation by offering evidence-based guidance for rural development initiatives. - Scenario mapping aids in visualising ES integration within land-use planning. - Ecosystem accounts will be used to organise land-use planning decisions,	- Used for policy evaluation in determining if rural development strategies successfully incorporate ES-related evidence -- Ecosystem accounts will be used to monitor changes in rural landscapes and evaluate the effectiveness of implemented policies.
Stakeholder Engagement	- State data agencies are expected to provide official datasets to support ES assessments.	- Farmers, policymakers, and scientific experts collaborate to evaluate the effectiveness of policies. - The Ministry of Agriculture leads policy evaluations, seeking input from research institutions.
Challenges	- Political uncertainty: The new government (from Dec 2024) may alter rural policy priorities, which could impact the outcomes of public consultations. -- There is limited clarity regarding how ES integration will be prioritised during the policy transition. - There is inadequate tracking of ES adoption in actual policies, hindering evidence uptake measures.	- Political transition may delay long-term sustainability evaluations.

4.3.2 Public consultation of the Rural Development Plan

Integration of evidence

As previously mentioned, there are currently no indications that the government intends to initiate work on a new Rural Development Plan. The previous plan, which covered the period from 2014 to 2020, is being extended; however, this extension does not influence policymaking, and the future of the document remains uncertain. For example, it remains unclear whether an evaluation of its implementation will be conducted.

Despite the government's clear stance that no new initiatives related to the Rural Development Plan will be introduced, the *Comprehensive Plan of the Republic of Lithuania* explicitly underscores the importance of ES and the need to protect ecosystems and their functions. As a result, ES knowledge will need to be incorporated into other territorial planning documents to ensure that environmental considerations continue to inform national policies.

It is also noteworthy that the Ministry of Environment has commissioned a national initiative aimed at integrating the valuation of ecosystems and their services into decision-making across public administration and various economic sectors in Lithuania. According to the Ministry, this initiative aims to demonstrate the benefits of incorporating ecosystem services into public policy. Its objective is to enhance the efficiency, cost-effectiveness, and sustainability of decisions in diverse policy areas, while simultaneously improving the condition of ecosystems and the services they provide. Ultimately, this approach aims to promote societal well-being and foster broader support among public institutions and other stakeholders for incorporating ecosystem services (ES) into governance processes.

A key finding from this assessment is the identification of agriculture as a priority sector where ES-related knowledge can be meaningfully applied. This highlights the potential for ecosystem-based approaches to be integrated into agricultural policy and practice, supporting more sustainable and resilient land management strategies.

An English summary of the findings is available here:
https://am.lrv.lt/uploads/am/documents/files/EP%20III%20etapo%20SANTRAUKA%202023%2009%2014%20ANGLU%20K.pdf.

The Lithuanian DP has developed a comprehensive assessment of **EC across agricultural areas**, using a combination of remote sensing indices, soil data, biodiversity metrics, and landscape structure indicators. These variables were carefully selected to represent six distinct ecosystem states (physical, chemical, compositional, structural, functional, and landscape) and were normalised and weighted to produce harmonised EC scores.

This integrated evidence base provides multiple pathways for informing rural policy and planning, which will be explored throughout the project's duration.

Role of different actors, and their interactions

Both the Ministry of Environment and the Ministry of Agriculture recognize the importance and value of collaborating with various stakeholders. For example, the Ministry of Agriculture actively supports research and experimental development projects aimed at promoting sustainable and innovative agricultural practices. Recently, the Ministry has financed projects related to crop production, agri-environmental practices, and organic farming. To foster dialogue and gather insights, the Ministry has also hosted meetings where farmers, social partners, and representatives from various institutions come together to discuss projects' results, critical issues affecting the agricultural sector, such as soil health improvement, sustainable farming techniques, livestock innovation, and the challenges posed by climate change.

Similarly, the Ministry of Environment has engaged a wide range of stakeholders in discussions concerning the results of the National Study on Integrating the Valuation of Ecosystems and their Services into Decision-Making Processes within Public Administration and Economic Sectors in Lithuania. According to Ministry representatives, stakeholders—particularly those from the scientific community—provided valuable feedback on how to enhance the Study, offering critical insights and recommendations.

Challenges

The authorities demonstrate a willingness to listen to the academic community and create opportunities for them to contribute to various initiatives. However, it is essential to acknowledge that these initiatives are often influenced by the prevailing political agenda, which may not always align with the latest scientific research and knowledge.

4.3.3 Evaluation of the Rural Development Plan

Despite the political uncertainty surrounding the future of the Rural Development Plan, the Ministry of Environment's new initiative to mainstream ecosystem valuation across sectors may serve as an alternative institutional entry point for evidence uptake. The EC assessment developed in DP02 is directly aligned with such cross-sectoral needs.

Integration of evidence

To date, the evaluation of the previous Rural Development Plan (2014–2020) has not progressed, and there are no formal indications that such a process will be initiated soon. As noted, discussions around a potential new Rural Development Plan have been postponed indefinitely following political transitions in late 2024, and the former plan no longer serves as an active policy reference. In the absence of an ongoing evaluation process, direct institutional interaction related specifically to this decision window has been limited.

Role of different actors, and their interactions

As there is currently no formal process to evaluate the previous Rural Development Plan, interactions specifically focused on this decision window have not occurred. However, the Ministry of Environment has engaged stakeholders through its national initiative on integrating ES valuation into public decision-making. While not directly related to the Rural Development Plan, this initiative reflects a broader institutional openness to using scientific evidence in policy processes and may offer future opportunities for uptake.

Challenges

The absence of a current or planned evaluation process for the previous Rural Development Plan presents a fundamental obstacle to integrating scientific evidence. Although relevant EC assessments have been developed, there is no operational framework in place for their uptake. Nevertheless, the EC dataset represents a valuable, policy-aligned resource that could be used in future evaluations, should political or institutional circumstances allow the decision window to re-open.

5 Urban Greening Plan for the city of Trento

5.1 Introduction

The Trento Demonstration Project (DP03) is centred on the development and implementation of the city's Urban Greening Plan (UGP). The importance of the UGP lies in its ability to address multiple urban challenges in a coordinated manner. This stems from the fact that the city of Trento faces increasing environmental pressures, including heat stress, flood risk, and ecological fragmentation, alongside social concerns such as uneven access to green spaces and the need for more public environments that promote well-being and inclusion.

Within this context, ES evidence has been crucial in addressing the identified challenges and is a key element in drafting the UGP. The methods employed in mapping priority ecosystem services have enabled the Municipality of Trento to identify areas where to target greening actions, ensuring they offer the most significant benefits. Moreover, the ES modelling outputs have facilitated internal coordination, political communication, and public engagement, making the UGP scientifically grounded and institutionally reinforced. In this sense, compared to the DP framing presented in D8.1, which primarily positioned ES evidence as conceptual support for decision-making, the Trento DP has progressed towards a more advanced operational stage.

5.2 Progress in generating evidence

5.2.1 Data identification, collection and processing

Trento's UGP was developed through a comprehensive data-driven approach, guided by the identification, processing, and integration of multiple environmental, spatial, and social datasets. While the contribution of EC information was acknowledged as relevant for the DP, its primary focus has been on generating and applying ES evidence, especially since the Municipality of Trento already had a solid foundation on the topic. Consequently, the ES approach supported the formulation of priorities and informed key planning decisions, technical choices, and stakeholder dialogue.

The data identified for DP03 fell into several thematic areas that were considered priorities for the city, including:

- **Climatic and microclimatic conditions for mapping urban heat islands (UHI) and identifying thermally vulnerable zones.**

The mapping of UHI (Table 5.1) was conducted to identify municipal properties located within areas impacted by this issue. Currently, the focus is on designing targeted interventions to locally reduce temperature and enhance thermal comfort for residents in the most affected areas, including streets, squares, car parks, and school grounds.

***Table 5.1**. Input/Output Data Summary for UHI assessment*

Data input		
Data	Description	Source
T_average_nighttime_2023-08-23	Temperature mapping is based on the nighttime average of August 23, 2023. This analysis, with a resolution of 100 meters, detected temperatures ranging between 20 and 28 °C. The air temperature was derived using a numerical model and refers to the average temperature within the streets at a height of 2 meters above ground level.	University of Trento
Municipal property	Areas that are municipally owned (parking lots, roads, public green spaces, squares, etc.)	Municipality of Trento
Green areas in municipal management	Green areas managed by the municipality, categorised by type (large urban parks, neighbourhood gardens, school gardens, sports areas, etc.), surface area, and the presence of children's playgrounds. Data is collected every five years and used for annual ISTAT analyses.	Municipality of Trento
Tree census	Tree census with information about species, trunk diameter, crown diameter and height	Municipality of Trento
Data output		
Data	Description	Source
Identified areas of possible interventions	Areas identified as those most affected by the phenomenon, obtained by overlapping temperatures and municipal assets, are those where NbS interventions should be considered.	Municipality of Trento

- **Hydrogeological data, including runoff modelling and drainage capacity, relevant to stormwater management and flooding risk.**

DP03 used the Stormwater Management Model (SWMM) (Table 5.2) as a well-recognised tool for addressing stormwater management. Developed by the U.S. Environmental Protection Agency, SWMM integrates hydrologic and hydraulic components to assess runoff production and its downstream impacts on the underground drainage network for both single events and long-term precipitation data. Thanks to its detailed output data, the model enables the identification of flood-prone areas and the assessment of the benefits of greening interventions upstream.

In DP03, the model simulated the impact of an extreme rainfall event on the municipality's valley floor. Results were analysed regarding runoff volume per sub-basin and the degree of pipeline filling in the drainage network, considering an overload threshold of 80% (G = 0.8). To refine intervention strategies, the mapping obtained with SWMM was then overlaid with municipal assets to identify areas where NbS or depaving interventions can be prioritised in public spaces.

Table 5.2: Input/Output Data Summary for Hydrological Assessment

Data input		
Data	Description	Source
Runoff volume and pipeline capacity of the underground drainage network	Map of runoff volumes and degree of pipeline filling based on a simulation of a pluvial event of 15 minutes and a 100-year return period	University of Trento
Municipal property	Areas that are municipally owned (parking lots, roads, public green spaces, squares, etc)	Municipality of Trento
Green areas in municipal management	Green areas managed by the municipality, categorised by type (large urban parks, neighbourhood gardens, school gardens, sports areas, etc.), surface area, and the presence of children's playgrounds. Data is collected every five years and used for annual ISTAT analyses.	Municipality of Trento
Tree census	Tree census with information about species, trunk diameter, crown diameter and height	Municipality of Trento
Data output		
Data	Description	Source
Identified areas of possible interventions	Areas identified as those most affected by the phenomenon, obtained by overlapping temperatures and municipal assets, are those where NbS should be considered. (theoretical scale)	Municipality of Trento

- **Accessibility and recreation for assessing per capita green space availability and spatial equity.**

The UGP includes detailed data categorised by recreational typologies (e.g. large urban parks, neighbourhood gardens, school gardens, sports areas, etc.), surface area, and the presence of children's playgrounds. This data, collected every five years (Table 5.3), enables the analysis of the amount of public green space per capita, the use of recreational spaces, and the distribution of green areas within a five- or ten-minute walking distance.

To further explore accessibility and recreational aspects, three types of analysis were conducted:

1. Usable Urban Green Space per Citizen

This analysis is crucial, as Italian regulations require municipalities to provide at least 9 m^2 of publicly accessible green space per inhabitant. In Trento, the study was conducted on both the entire municipal territory and in each district individually. This detailed approach helped identify areas where public green spaces are most needed while keeping in mind that the analysis only includes urban green spaces and excludes surrounding forests.

2. Accessibility of Urban Green Areas within 5 and 10 Minutes on Foot

The accessibility assessment evaluates how many residents can access nearby green spaces within 5 or 10 minutes on foot. This analysis is fundamental for enhancing urban quality of life and ensuring an efficient distribution of green spaces. Within the UGP, the study considered real pathways, rather than simple linear distances, for greater accuracy. It accounts for streets, pedestrian paths, crossings, and park entrances, reflecting the actual accessibility for residents, including physical obstacles and urban layout.

3. Inclusivity of Public Green Areas

The analysis of inclusivity in parks and public gardens was based on existing regulations, including the PEBA (Plan for the Elimination of Architectural and Sensory Barriers in Trento), the Agenda 2030, Law 104/1992, and DPR 503/1996. Additionally, urban management models from other Italian cities were reviewed to identify relevant indicators for assessing the inclusivity of municipal parks.

The following indicators were established to evaluate inclusivity:

- Presence of disabled parking spaces and accessible bus stops
- Number of accessible entrances (out of the total)
- Accessible pathways and appropriate pavement
- Rest areas (inclusive, adaptable, or non-inclusive)
- Number of inclusive playgrounds
- Adequate lighting
- Vegetation placement to facilitate movement
- Accessible fountains
- Sensory stimulation paths (for therapies related to mental and degenerative diseases)
- Sufficient shading in inclusive areas
- Inclusive sports facilities
- Guided paths for visually impaired individuals

Table 5.3. *Input/Output Data Summary for accessibility and recreational assessment*

Data input		
Data	Description	Source
Green areas in municipal management	Green areas managed by the municipality, categorised by type (large urban parks, neighbourhood gardens, school gardens, sports areas, etc.), surface area, and the presence of children's playgrounds. Data is collected every five years and used for annual ISTAT analyses.	Municipality of Trento
Access to parks	Access points to public parks and gardens were identified through cartographic analysis and validated through field surveys	Municipality of Trento
Road graph	Pedestrians can use roads in the municipal territory of Trento. Therefore, bypasses and motorways were excluded. All others were included because they have pavements, cycle or pedestrian paths or because they are tertiary roads with low vehicle flow	/Municipality of Trento
Buildings	Residential buildings in the municipal territory of Trento	Municipality of Trento
Resident Population	Average resident population for the reference years 2021-2022, for each house number and aggregated by district	Municipality of Trento
Tree census	Tree census with information about species, trunk diameter, crown diameter and height	Municipality of Trento
Furniture	Equipment in public parks and gardens, including benches, table groups, fountains, sports equipment, playground equipment, etc.	Municipality of Trento
Data output		
Data	Description	Source
Mapping of districts classified based on m^2/inhabitant	Classification of districts based on the square meter of green space per inhabitant. The mapping analysed the individual districts to pinpoint areas most in need, focusing exclusively on urban green spaces	Municipality of Trento
Mapping the city within a 5 and 10-minute walk	Assessment of residents' accessibility to green spaces within a 5- or 10-minute walk, considering real pathways rather than linear distances. Two thresholds were defined based on green space size: 300 meters for areas under 1 hectare and 600 meters for larger areas, assuming a walking speed of 3.6 km/h for greater accuracy.	Municipality of Trento
Mapping of green areas classified on the level of inclusiveness	Mapping obtained from field surveys, where municipal parks and gardens were classified into three levels of inclusivity: non-inclusive, partially inclusive, with accessible and well-lit paths and adaptable rest areas, and fully inclusive, featuring fully accessible rest areas, fountains, playgrounds, sports facilities, and sensory stimulation paths.	Municipality of Trento

- **Carbon storage and sequestration**

A combined approach using i-Tree Eco software (Table 5.4) and digital twin technology was implemented to scientifically assess and monitor the environmental value of the city's urban trees. In August 2023, a sample of 711 municipal trees was digitally scanned to create high-resolution digital replicas, reproducing each tree's physical form, spatial location, and visible health traits. These digital twins, enhanced with AI for diagnostic purposes, were used alongside i-Tree Eco, a modelling tool developed by the U.S. Forest Service, to calculate the trees' contributions to carbon storage, oxygen production, stormwater interception, and air pollutant removal.

The analysis extended beyond the scanned sample to include 16,014 trees from the city's inventory. Key data inputs for the model comprised species, diameter at breast height (DBH), total height, and crown diameter, all of which are essential for estimating ecosystem functions in iTree.

Species-specific outputs enabled the city to identify key contributors to ecosystem performance—for example, *Platanus x acerifolia* alone was responsible for over 187,000 kg of stored carbon. The integration of AI-enabled digital twins further enhanced precision by facilitating ongoing health assessments and vulnerability detection.

Table 5.4. *Input/Output Data Summary for Carbon Sequestration Assessment*

Data input		
Data	**Description**	**Source**
Tree census	Tree census with information about species, trunk diameter, crown diameter and height	Municipality of Trento
Data output		
Data	**Description**	**Source**
Report of results	Report explaining the results obtained regarding the carbon sequestered and stored, as well as the pollution removed.	iTree Eco
Report of results	Report explaining the results obtained regarding the carbon sequestered and stored, as well as the pollution removed.	R3gis

Challenges encountered in data generation

Several obstacles emerged during the identification, collection, and processing of data, which affected both the scope and granularity of the analyses.

One major limitation was the lack of grey infrastructure data, particularly regarding the underground drainage system. The absence of accurate and comprehensive information on the location of pipes and nodes limited the accuracy of the SWMM model. Data harmonisation and integration also presented notable challenges, as spatial datasets often differed in scale, resolution, and classification schemes. This was especially evident when aligning administrative land-use data with ecological or biophysical layers, requiring extensive preprocessing to ensure consistency and comparability across analyses.

5.2.2 Key findings and expected future activities

During the early stages of SELINA, DP03 focused on generating and analysing spatial and environmental data to support ES assessments in the city of Trento.

A component of the assessment involved the use of the i-Tree Eco model, which was applied to an inventory of 16,014 urban trees. The model estimated that the urban forest in Trento stores approximately 14,300 tons of CO_2, representing a sequestration value of around €715,000. Annually, the tree population captures 450 tons of CO_2, with an additional value of €22,500. Trees also contributed to removing 23 tons of air pollutants per year, including ozone, nitrogen dioxide, and PM2.5, resulting in public health and environmental benefits valued at €226,000 annually. Furthermore, urban trees reduce surface runoff by an estimated 3,000 cubic meters per year, corresponding to a monetary value of approximately €4,500.

Regarding the climatic analyses, the DP identified urban heat accumulation hotspots, particularly in densely built-up areas, where surface temperature differences of up to 6°C were observed between vegetated and impervious zones during summer extremes. Urban green areas with canopy cover exceeding 40% were found to reduce local air temperatures by 1.5–3°C, confirming the role of urban vegetation in microclimate regulation and guiding priority areas for tree planting and depaving.

Additionally, the hydrogeological analysis, based on rainfall-runoff simulations and drainage network capacity, identified significant flood risk in parts of the urban area, particularly in the southern and industrial sectors. During high-intensity rainfall events (with a return period of up to 50 years), more than 30% of the modelled runoff volumes exceeded the system's capacity.

These findings have been instrumental in shaping the UGP under decision window 1, as the spatially explicit evidence on ES delivery informed the identification of priority zones to allocate greening interventions, which will be further tested under decision window 2 (Chapter 5.3)

Although the current information allowed the identification of priority areas for intervention, several areas of data development remain necessary to support future planning and evaluation.

Building on the existing knowledge base, the next step will involve proposing concrete NbS and their spatial distribution, guided by more detailed modelling tools capable of simulating local-scale effects. For example, a key element of future work will be the development of alternative NbS scenarios in areas with the highest ES demand and the greatest potential for improving social and environmental benefits, particularly in terms of temperature and stormwater regulation. In particular, the SWMM results already highlight zones where stormwater management interventions could be prioritised. This type of analysis will be expanded and refined to support the identification of intervention sites on both public and private properties and combined with feasibility assessments to evaluate implementation potential. These outputs are expected to inform planning tools that also recognise the role of private green areas in mitigating flood risks.

Similarly, the results of UHI mapping demonstrate the role of urban vegetation, particularly parks, corridors, and residential green spaces, in enhancing thermal comfort and reducing nighttime temperatures. For this purpose, more local-scale specific models, such as the Urban Multi-scale Environmental Predictor (UMEP) is currently being used to simulate indicators like mean radiant temperature and thermal comfort conditions. Results from this analysis will inform microclimate-sensitive planning strategies and guide the precise use of NbS to maximise both environmental and social benefits for microclimate regulation.

5.3 Progress in integrating evidence in decision-making

5.3.1 Decision windows identified to date

Within the workflow of DP03, two key decision windows (Table 5.5) were identified to structure the integration of ES evidence into Trento's urban planning and governance processes.

Before the start of SELINA, the Municipality of Trento already had a solid foundation in ES assessment, supported by detailed spatial datasets, models, and prior planning experience. Thus, rather than starting from scratch, the city was well-positioned to shift from assessing ES to embedding this information into practical planning tools and policy decisions.

In this context, Decision Window 1 represented a pivotal moment in this transition. Although the development of a UGP was not legally mandated, the municipality seized the opportunity to voluntarily formalise its ES knowledge into a structured, citywide planning instrument. As such, the UGP became both the primary output of this phase and the key mechanism through which scientific evidence related to ES was deepened and operationalised in municipal governance. This process encompassed the whole planning cycle, from data analysis and spatial prioritisation to interdepartmental coordination, stakeholder consultation, and political endorsement.

Table 5.5. *Main elements of the decision windows identified by DP03*

	DW1: Development of the Urban Greening Plan of the city of Trento	**DW2(A): Location, selection and design of NbS for stormwater management**	**DW2(B): Location, selection and design of NbS for addressing UHI**
Policy Context	Strategic planning document developed by the Municipality of Trento with support from LAND Italia and the University of Trento.	Operational phase focused on enhancing stormwater infiltration and reducing runoff risk using NbS	Operational phase aimed at mitigating urban heat through shading and vegetation-based cooling.
Decision Window Timing	The decision window closed, having been achieved through planning and formal approval by the City Council.	Ongoing: selection of areas of intervention for NbS, prioritised based on evidence generated in DW1 and on SWMM outputs	Ongoing: Selection and design of NbS interventions for thermally stressed zones based on UHI mapping.
Primary Objective	To establish a citywide, evidence-informed greening strategy promoting climate resilience, inclusion, and ecological connectivity.	To assess and plan NbS that enhance drainage and reduce hydrological risk in priority areas.	To implement targeted NbS that reduce surface temperatures and improve thermal comfort in high-risk areas.

	DW1: Development of the Urban Greening Plan of the city of Trento	DW2(A): Location, selection and design of NbS for stormwater management	DW2(B): Location, selection and design of NbS for addressing UHI
Role of ES Evidence	Used to identify priorities based on information related to temperature, runoff, accessibility, biodiversity, and citizen needs. This informed plan structure and rationale.	Used to identify runoff-prone areas and to inform modelling of catchment-level benefits and infiltration potential	Supported identification of 100 municipal sites suitable for heat mitigation interventions based on UHI intensity and land availability.
Stakeholder Engagement	Co-development process involving municipal planning offices, scientific partners and residents via surveys and workshops.	Ongoing technical dialogue with infrastructure and environment departments; future public involvement planned.	Coordination with planning offices; stakeholder engagement
Challenges	Need to translate complex spatial data into actionable planning tools and align scientific outputs with institutional workflows.	Incomplete infrastructure data, difficulty delineating drainage basins, and adapting model outputs to site-level feasibility.	Need to reconcile modelling outputs with operational constraints; no public engagement has yet been initiated

The approval of the UGP under Decision Window 1 lays the groundwork for the next phase as defined in Decision Window 2. With priority areas for intervention identified and supported by robust ES evidence, the focus now shifts toward the potential strategic implementation of NbS. Hence, Decision Window 2 builds directly on the outputs of the UGP by translating its spatial priorities into concrete NbS design options. Thus, this next step will depend on more detailed modelling tools to simulate local-scale impacts, enabling the city to assess and optimise NbS deployment in terms of expected performance.

Given the city's priorities and the structure of available evidence, two distinct but interrelated sub-decision windows have been identified under Decision Window 2:

- Sub-window 2A: NbS for Stormwater Management
- Sub-window 2B: NbS for Urban Heat Mitigation

Each sub-window corresponds to a thematic focus within the broader implementation phase. While both aim to enhance the capacity of NbS to address specific challenges within the urban context, they differ in their technical requirements, evidence inputs, and current state of development. The subdivision reflects the practical realities of implementation, where strategies are being developed and refined in parallel but under separate workflows and with different operational challenges.

5.3.2 Development of the Urban Greening Plan

Integration of evidence

This decision window represents a strategic phase in Trento's urban policy process during which the Municipality, supported by the SELINA project, chose to consolidate and formalise its use of ES evidence into a comprehensive planning instrument. This means that the UGP represents a distinct moment in which political will, scientific capacity, and institutional opportunity aligned, allowing for the formulation of the plan as a vehicle for integrating ES knowledge into urban governance. Furthermore, this decision window has opened due to several enabling conditions, including a robust internal foundation of knowledge regarding environmental data and ES assessments developed in previous projects, SELINA's methodological support, and the policy momentum generated by national and EU strategies that advocate for urban greening and climate adaptation within broader national and international frameworks, such as Italian Law 10/2013, the National Strategy for Urban Greening (2018), the National Adaptation Plan to Climate Change (PNACC, 2023), the EU Biodiversity Strategy, and the UN 2030 Agenda.

The planning process began with collaborative problem framing and ES prioritisation. Scientific partners, including the University of Trento, provided spatial analyses and modelling to identify vulnerabilities and high-impact intervention areas. This evidence enabled the municipality to structure the UGP around measurable priorities and to define 24 operational strategies distributed across four distinct landscape contexts: urban, fluvial, peri-urban, and forested. Concerning its structure, the UGP comprises two main documents: a strategic plan outlining overarching goals and priorities, and a catalogue of actions detailing location-based interventions.

Throughout this process, decision-makers, experts, and stakeholders collaborated through workshops, public consultations, and technical meetings. Particular attention was given to making scientific outputs operationally meaningful. For example, the UGP is formally included in the Municipality of Trento's 2024–2026 *Documento Unico di Programmazione* (DUP), which secures its integration within the city's broader strategic and budgetary planning. The plan also features a precise monitoring and evaluation schedule, including a biennial review of progress and a full revision every five years, allowing for continuous adaptation in line with local needs and priorities. These efforts culminated in the UGP's formal adoption by the City Council in December 2024.

In this sense, DW1 marks a critical moment when the city transitioned from understanding ES to implementing available evidence through a structured and politically endorsed planning instrument. It served as a foundational phase, not only for the UGP itself but for the upcoming implementation phase addressed under Decision Window 2.

Role of different actors, and their interactions

The UGP results from a dialogue involving citizens and thematic in-depth discussions. Between the end of 2023 and the first half of 2024, regular public presentations were organised to share parts of the ongoing work, with a specific focus on participatory processes. Around 400 questionnaires were distributed to citizens regarding urban green spaces, and numerous Collaboration Pacts were reported as part of the Regulation for Common Goods, which governs citizen participation in the care of municipal assets.

A key milestone in this process was a multi-departmental technical workshop, organised to define the parameters for monitoring the future implementation of the plan. The workshop brought together staff from several municipal departments and provided an opportunity for an in-depth review of the

ES analyses generated. Moreover, it served as a platform for cross-departmental discussion and led to the co-development of monitoring indicators that could be incorporated into the city's long-term evaluation framework.

Further collaboration was also established with the European BioValue project, which focuses on biodiversity and ecosystem connectivity. This partnership led to the joint development of strategies to reinforce green and blue infrastructure, particularly along a stream corridor identified as a shared area of interest.

Taken together, these interactions represent the participatory process of Decision Window 1, shaping not only the content but also the legitimacy and institutional ownership of the UGP. By creating space for expert review, public dialogue, and interdepartmental coordination, this window enabled the Municipality of Trento to co-develop the plan based on ES evidence and public priorities.

Challenges

In developing the UGP, no significant barriers were encountered when integrating scientific evidence into policy. The collaboration among technical experts, municipal planners, and scientific partners was constructive, facilitating the effective use of ES data throughout the process. More importantly, no significant discrepancies emerged between the scientific findings generated and the city's political priorities or planning objectives. The alignment between the evidence base and the policy framework was supported by ongoing dialogue and a mutual interest in enhancing the city's resilience through greening strategies.

Nonetheless, a key consideration that emerged during the process was the need to translate scientific outputs, particularly spatial mapping, into formats that are directly applicable to planning tools and regulatory instruments. While the analyses provided clear spatial and thematic insights, their operationalisation required interpretation, simplification, and alignment with existing administrative processes. For this reason, ensuring that evidence is actionable within urban planning practice remains a critical aspect of effective integration in public policymaking.

5.3.3 Location, selection and design of priority NbS

Integration of evidence

Decision Window 2 represents the initial phase of the UGP following its approval in December 2024. While Decision Window 1 concentrated on using ES-related information to support several elements of the plan, this window directly builds upon that foundation by applying ES evidence to evaluate the feasibility of NbS based on the identified priorities.

This phase operationalises two core analyses initiated during DW1:

- UHI mapping, which identified zones most affected by thermal stress.
- Hydrological modelling using the SWMM model, which estimated surface runoff patterns and highlighted areas vulnerable to flooding.

The temperature analysis integrated cadastral data with UHI maps to identify approximately 100 publicly owned sites, such as schoolyards, paved squares, and parking areas, where cooling-focused NbS may be technically feasible. These candidate sites have undergone preliminary review by municipal departments and are now informing early prioritisation and design assessments.

In parallel, SWMM-based modelling provided a spatially explicit assessment of stormwater vulnerability across the urban drainage system. The resulting criticality indicators are now being systematically combined with feasibility data for NbS, including green roofs, rain gardens, and permeable pavements. For each subcatchment, the proportion of technically suitable area for NbS implementation is calculated and disaggregated by land ownership (public vs. private).

This integrated approach enables the identification of priority zones where high hydrologic-hydraulic vulnerability overlaps with feasible areas for intervention, highlighting the respective roles that public and private spaces can play in supporting urban stormwater management. This methodology will inform the development of targeted intervention scenarios and support municipal planning by identifying technically feasible and ownership-based strategies for enhancing stormwater resilience.

To further enhance the decision-making framework, the University of Trento is refining this approach to incorporate additional spatial layers of vulnerability (e.g., exposure to urban heat) and to produce maps that offer a robust tool to guide the spatial prioritization of NBS in complex urban environments.

Role of different actors, and their interactions

The ongoing interactions primarily involve the University of Trento and municipal departments responsible for infrastructure, green space management, and environmental planning. Meetings have focused on refining priority areas and adapting modelling outputs to specific urban constraints.

At this stage, community engagement activities have not yet been initiated. These activities are scheduled for later phases, once preliminary designs and site selections have been formalised. Future engagement will incorporate user feedback and address potential social, functional, and contextual considerations in the final design and implementation of potential NbS.

Challenges

A key challenge lies in scaling down scientific evidence to a level of detail that can support site-specific action. While the ES information used in Decision Window 1 enabled the Municipality of Trento to identify broad strategic priorities and define areas of high vulnerability, the shift towards Decision Window 2 demands tools and models that can guide precise decisions about where and what types of NbS to implement, based on the potential benefits they can deliver in specific local contexts.

In other words, the primary difficulty lies in transitioning from general spatial analyses that support strategic planning to high-resolution, localised modelling that captures the real-world complexity of individual sites. This involves simulating how NbS interventions perform while considering variables such as land availability, ownership, slope, soil type, surrounding buildings, and existing infrastructure.

To overcome this challenge, the DP is now working to refine and integrate modelling tools capable of delivering locally tailored, benefit-focused guidance. These tools are being designed not only to estimate the effectiveness of interventions, but also to help prioritise where different types of NbS are likely to provide the greatest benefit, especially within the strategic zones already identified under the UGP.

6 Bosland National Park (Belgium)

6.1 Introduction

The National Park Bosland (NP Bosland) has broad objectives outlined in its Masterplan, aiming to maintain and enhance biodiversity while developing an attractive area for nature experiences. These goals are pursued with attention to the area's cultural heritage and the interests of diverse stakeholder groups.

Scientific evidence gathered through SELINA supports the development of evaluation programmes to assess the impact of the implemented actions. This is essential for refining strategies and ensuring their long-term effectiveness. Without such evaluation, it would be difficult to determine whether the measures taken are meeting their intended objectives.

NP Bosland is required to report on its progress toward these objectives every six years to the National Park Bureau. While the exact indicators are still being defined, many relate to biodiversity, ES, and broader societal benefits. The planned ecosystem assessment could provide key information to support this reporting.

Scientific findings will also be integrated into NP Bosland's governance structure to strengthen the rationale for implementing certain measures by the park’s steering committee. This ensures that conservation actions are grounded in evidence and that ecosystem knowledge informs policy decisions effectively.

In addition, the assessment contributes to understanding how ecosystems support climate mitigation and adaptation. This includes their capacity to absorb carbon, regulate local climates, and mitigate the effects of extreme weather events.

The DP04 had initially intended to focus solely on ES assessment. However, in response to ongoing research in WP3 and by VITO, the scope was expanded to include assessments of forest conditions as well. The integration of these two aspects is still under consideration, with recommendations expected from SELINA WP3 and WP6.

The DP focuses on the following ecosystem services:

- Wood production
- Agricultural production
- Carbon sequestration
- Water infiltration and (rain)water retention
- Water quality through nutrient removal
- Air quality via the capture of fine particles

- Recreation
- Physical and mental health benefits from contact with nature

In addition to these, the DP also considers other relevant values such as sense of place, cultural heritage, and similar intangible benefits.

6.2 Progress in generating evidence

6.2.1 Data identification, collection and processing

The ecosystem assessment conducted for DP04 within the activities of SELINA will comprise several components:

- Extent: Habitat mapping
- Forest Condition Indicator
- Ecosystem Services Assessment
- Social Parameters: Including contentment, sense of place, connectedness, and cultural heritage

Flanders benefits from a highly detailed 10x10 m land use map, which provides a strong foundation for spatial analysis.

Forest Condition Indicator

VITO, through the PEOPLE-EA project, developed a methodology to assess forest condition using multiple variables, including remote sensing data. This model is operational at the European scale. For NP Bosland, the model will be fine-tuned to reflect local forest classifications and reference conditions relevant to the area.

A tiered approach will be applied:

- Tier 1: Use of the European-scale model without modifications. Available variables in this tier include:
    - Normalized Difference Water Index (NDWI)
    - Soil organic carbon
    - Diversity of threatened forest bird species
    - Above-ground biomass
    - Leaf Area Index (LAI)
    - Net Primary Production (NPP)
    - Fraction of Green Vegetation Cover (FCOVER) (Terrascope Sentinel-2)
    - Canopy cover (%)
    - Normalized Difference Vegetation Index (NDVI)
    - Forest connectivity

    - Landscape naturalness (%)
    - Forest fragmentation

- **Tier 2**: Adaptation of forest classifications and reference situations specifically for NP Bosland.
- **Tier 3**: Further adaptation or inclusion of additional variables based on site-specific data, such as the presence of pests or local stress factors.

This approach builds on the methodology previously applied in WP5 for the Azores.

Ecosystem Services Assessment

The assessment is based on a variety of spatial input maps, which are used within the statistical functions of the *Nature Value Explorer* tool. These maps include, among others:

- Habitat map
- Soil maps
- Concentration maps for pollutants (e.g., PM10, PM2.5 in air; nitrogen in water)
- Path density maps
- Population density maps
- Biological water quality maps

Most of these datasets are available via official geographic information platforms managed by the Flemish and Walloon governments.

At this stage, only summary tables (as shown in Figure 6.1) will be generated. A decision has yet to be made on whether the underlying datasets will be uploaded to the Zenodo repository. If resources allow, ecosystem services maps will also be developed.

The *Nature Value Explorer* tool simplifies complex ecosystem service models, offering accessible and policy-relevant insights. Although it does not generate precise numerical outputs, it provides a reliable indication of how changes in land use and soil parameters influence the supply and use of ecosystem services.

In addition to the quantifiable ecosystem services, the assessment also includes qualitative mapping of other values, based on survey results from local residents, recreational users, and vulnerable groups in the area. These insights help capture the broader social and cultural dimensions of ecosystem value.

Qualitative value | Quantitative value | Monetary value

Quantitative valuation	Unit	Present		Future		Difference	
		Low	High	Low	High	Low	High
Food production	€ Added value production / year	30070.8	35552.8	30056.6	35532.1	-14.2	-20.7
Wood	m³ harvested / year	223.1	223.1	161.4	161.4	-61.7	-61.7
Air quality - filtration of fine particles	kg PM10 / year	1684.4	1684.4	1678.5	1678.5	-5.9	-5.9
Increased infiltration	m³ / year	249023.3	249023.3	249023.3	249023.3	0.0	0.0
Mass stabilisation and control of erosion rates	tonnes avoided erosion / year	-1363.4	-1819.6	-1362.4	-1817.5	1.0	2.1
Global climate regulation - Carbon sequestration in soils	tonnes C / year	582.7	582.7	587.4	587.4	4.7	4.7
Global climate regulation - Carbon sequestration in biomass	tonnes C / year	42.5	42.5	33.6	33.6	-8.9	-8.9
Water conditions - denitrification	kg N / year	-	-	-	-	-	-
Pollination and seed dispersal		-	-	-	-	-	-
Physical and experiential interactions - recreation and tourism	Number of visits / year	114672.1	114672.1	125080.4	125080.4	10408.3	10408.3
Extra value houses in the neighbourhood	% increase in housing value	7.1	7.1	7.1	7.1	0.0	0.0
Alternative method to compute the cultural services							
Total cultural services with stated preferences	Number of households	224834.0	718604.0	224677.0	717897.0	-157.0	-707.0
Physical and experiential interactions - Health effects from contact with nature	DALY/year	25.0	25.0	25.0	25.0	0.0	0.0

Figure 6.1. Example of summary Table created for the DP

6.2.2 Key findings and expected future activities

Much of the information and data collected for Bosland is highly case-specific and was not initially intended for ecosystem service assessment. As a result, it is not always scalable or directly comparable to other regions. Nevertheless, these data remain valuable for validating the outputs of the assessment tool.

The ecosystem assessment process is still underway. While no results have been produced yet, the project is currently in the data consolidation phase, focused on gathering and preparing relevant sources for analysis.

6.3 Progress in integrating evidence in decision-making

6.3.1 Decision windows identified to date

A key milestone in the DP04 was the official recognition of NP Bosland, reinforcing the need for evidence-based policy decisions. To support this, three major decision windows have been identified (Table 6.1)

- Upgrading ES-related scientific information: This decision window focuses on consolidating and improving scientific data for ecosystem service assessments. Efforts include structuring scattered datasets, refining methodologies, and enhancing scientific collaboration. These upgrades will be crucial in shaping future conservation policies and land-use planning.

- Implementing the National Park Action Plan: This decision window ensures that governance structures, conservation actions, and stakeholder engagement efforts align with the national park's overarching sustainability objectives. The Action Plan offers a flexible framework for integrating ES assessments into management strategies, striking a balance between biodiversity conservation and socioeconomic considerations.
- First-year evaluation: This window focuses on monitoring and evaluating Bosland National Park's progress. It responds to policy requirements mandating annual reporting to the National Park Bureau, with a more detailed report due every six years (next in 2030). The primary objective is to assess progress towards the park's Master Plan goals and inform the next Operational Plan. Ecosystem services (ES) assessments are central to this process, providing evidence to measure impacts and inform future actions.

Table 6.1. *Main elements of the decision windows identified by DP04*

	DW1: Upgrade of ES-related scientific information	**DW2: Implementation of the National Park Action Plan**	**DW3: First-year evaluation of the National Park**
Policy Context	The context for this decision window revolves around improving scientific assessments to support conservation planning in Bosland.	Following the official recognition of Bosland as a National Park, the focus shifted to executing the Action Plan. This includes hiring personnel, engaging with stakeholders, and creating an operational roadmap. The plan seeks to integrate ES assessments into some sections, ensuring that conservation efforts align with both environmental and socio-economic priorities.	The National Park Bosland is required to report its progress to the National Park Bureau annually. Every 6 years (2030), it needs to report more thoroughly on a comprehensive list of indicators to demonstrate progress and secure additional financial resources for the next Operational Plan.
Decision Window Timing	Scientific information has been upgraded. The process included gathering and structuring ecosystem service data, refining methodologies, and consolidating scientific knowledge.	The execution of the National Park Action Plan is expected to span approximately 6 years. The timeline enables adaptive management approaches, allowing adjustments to be made based on stakeholder feedback, scientific findings, and evolving policy priorities. The process is designed to ensure long-term sustainability and effective conservation planning.	Within the next 6 years, a limited report on the progress must be submitted. In 2030, a more elaborate reporting is due.

	DW1: Upgrade of ES-related scientific information	DW2: Implementation of the National Park Action Plan	DW3: First-year evaluation of the National Park
Primary Objective	The primary objective of this decision window is to improve the quality, consistency, and availability of scientific data for ecosystem assessments. Consolidating scattered data and refining assessment methodologies will enhance evidence-based decision-making, providing stronger scientific support for conservation policies.	The main goal of this decision window is to successfully implement the National Park Action Plan, ensuring that conservation efforts are effectively managed and guided by ecosystem (service) assessments.	The ES assessment can support the reporting and help develop the next Operational Plan in 2030.
Role of ES Evidence	ES data is crucial in shaping the scientific assessments under this decision window. ES evidence is being gathered and structured to support policy processes, and the refined data will play a key role in developing a systematic assessment framework.	Ecosystem (service) assessments will guide key planning actions within the National Park Action Plan. ES evidence will help align conservation efforts with governance structures and stakeholder priorities, ensuring that scientific data informs policy decisions.	The Ecosystem assessments will evaluate the progress towards the goals of the Masterplan. The evidence will help develop recommendations for the next Operational Plan.
Stakeholder Engagement	Scientific boards are being established to ensure expert consultation and broad stakeholder involvement. These boards will bring together experts from various fields, enabling collaborative discussions and enhanced data interpretation.	Local politicians, national and regional policymakers, scientific experts, and civil society organisations are actively engaged in executing the National Park Action Plan. The involvement of a diverse range of stakeholders ensures that conservation planning is well-rounded. However, maintaining strong engagement from all stakeholders remains a key challenge.	Local politicians, national and regional policymakers, scientific experts, and civil society organisations are actively engaged in executing the National Park Action Plan. The involvement of a diverse range of stakeholders ensures that conservation planning is well-rounded. However, maintaining strong engagement from all stakeholders remains a key challenge.

	DW1: Upgrade of ES-related scientific information	DW2: Implementation of the National Park Action Plan	DW3: First-year evaluation of the National Park
Challenges	One of the main challenges is that scientific data remains fragmented across different sources, making it difficult to create a unified assessment framework. Furthermore, different scientific disciplines employ varying terminologies and methodologies, complicating consensus-building efforts.	The successful implementation of the Action Plan depends on effective coordination among multiple stakeholders. Engaging local politicians and steering committees requires continuous effort, as different stakeholders may have varying priorities.	Scale the available data to the scale of the whole NP. Translate the results of the broad assessment to specific actions in the Operational Plan.

6.3.2 Upgrade of ES-related scientific information

Integration of evidence

During this decision window, all available data and research related to ecosystem services in Bosland from the past decade were systematically reviewed. This included:

- A comprehensive inventory of existing information and ongoing or completed studies relevant to Bosland
- The identification and listing of potential indicators compiled by VITO to support a robust ecosystem assessment

This preparatory phase laid the groundwork for informed decision-making. It culminated in the organisation of a dedicated scientific workshop, where experts reviewed the findings and discussed the feasibility and added value of a formal assessment. Based on the outcomes of this workshop, it was decided to proceed with a comprehensive ecosystem (services) assessment for Bosland.

Role of different actors, and their interactions

In November 2024, a scientific workshop was organised, bringing together professors from all Flemish and Brussels universities who work on topics related to biodiversity, ecosystem services, and health. The agenda focused on three key discussion points: the goals of NP Bosland; the variables required for conducting a comprehensive ecosystem assessment, such as those related to biodiversity, ecosystem condition, and ecosystem services; and the practical measures needed to facilitate scientific research in the area. The discussion also explored how to establish long-term collaborations with universities to ensure that research becomes more actionable and aligned with real-world challenges.

Challenges

Scientific research in Bosland is often conducted in an ad hoc manner, frequently as part of PhD or master's thesis. While valuable, these studies rarely have a sustained impact on policy processes, and their findings are not always easily translated into operational plans or concrete management actions.

Additionally, the fragmentation of knowledge across disciplines poses another challenge. Insights from different fields—such as ecology, social science, and spatial planning—are not always well-integrated, making it more difficult to develop cohesive, evidence-based strategies.

Despite these challenges, some long-term collaborations have been established to address the need for consistent data collection and knowledge continuity. A notable example is the FORBIO project, which aims to build long-term datasets and foster ongoing scientific engagement to inform forest management and policy over extended timeframes.

6.3.3 Implementation and evaluation of the National Park

Integration of evidence

At this stage, the ecosystem assessment process is still in its start-up phase. As such, it is too early to confirm the integration of ES information generated through SELINA into the current decision windows. However, the effort to compile all available information and research from recent years, combined with the organisation of a scientific workshop involving key academic stakeholders, has already yielded important outcomes.

Notably, this process led to the establishment of a Scientific Advisory Board for NP Bosland, as well as the initiation of several long-term collaborations between policy and science. These developments mark a significant step toward strengthening the science-policy interface within the governance of the National Park.

Once available, the results of the ecosystem assessment will provide valuable input to both the steering committee and the Flemish National Park Bureau, offering insights into the state of habitats, forest condition, and the provision of ecosystem services. This evidence will support more informed decision-making and may lead to the refinement of management actions outlined in the Operational Plan.

Role of different actors, and their interactions

Local politicians, national and regional policymakers, scientific experts, and civil society organisations are actively involved in the execution of the National Park Action Plan through participation in the steering committee. The inclusion of this broad range of stakeholders ensures that conservation planning is comprehensive and benefits from a wide alliance of perspectives.

Regular monthly meetings take place between ANB and VITO to coordinate efforts and align on technical and strategic developments.

Additionally, a scientific advisory board is being established to guide future management decisions. This structure will strengthen the integration of scientific expertise into decision-making processes and enhance the overall effectiveness of park governance.

Challenges

One of the ongoing challenges in the process is the presence of language barriers, both between different scientific disciplines and among the various stakeholder groups involved. These differences can hinder mutual understanding and slow down collaboration. Additionally, there is a need to balance two distinct approaches: on the one hand, a broad ecosystem assessment is essential for reporting and strategic planning; on the other hand, highly detailed monitoring of specific ecosystem functions and the effects of particular management actions is necessary for effective implementation. The differing scales and purposes of these processes can complicate their integration. While working groups have been set up to help bridge these gaps, they operate outside the SELINA framework. Furthermore, competing interests and political agendas can create additional friction, making it difficult to reach consensus and maintain cohesive collaboration among stakeholders.

7 Integration of ES information on marine and terrestrial spatial planning in La Rèunion

7.1 Introduction

The Réunion Island Demonstration Project (DP05) focuses on integrating ecosystem services ES, EC and BD evidence into both terrestrial and marine spatial planning processes. Situated in a complex socio-ecological context within a French overseas territory, the project addresses two realms of governance: regional terrestrial planning and national-level marine strategies. This duality presents both opportunities and challenges for implementing science-based decision support tools.

DP05's primary objective is to enhance the uptake of ES evidence in strategic decision windows, particularly in the context of spatial planning and sectoral policy domains. This includes informing revisions of the Schéma d'Aménagement Régional – Schéma de Mise en Valeur de la Mer (SAR-SMVM), contributing to the future update of the South Indian Ocean Maritime Basin Strategic Document (DSBM), and supporting the implementation of thematic conservation measures such as shark risk mitigation and Papangue (Circus maillardi) conservation.

The project adopts a transdisciplinary approach, combining spatial analysis, participatory methods, and scenario modelling. Tools such as InVEST, STRAVA, and the SeaSketch platform have been employed to generate, validate, and communicate ES data. A strong emphasis has been placed on co-producing knowledge with stakeholders from civil society, academia, and governance bodies to ensure the relevance and legitimacy of the outputs.

7.2 Progress in generating evidence

7.2.1 Data identification, collection and processing

A wide range of data types and sources have been mobilised as part of the Réunion Island DP (Table 7.1). Biophysical data encompassed land-use layers, urban and agricultural transformation metrics, and detailed mapping of invasive species, distinguishing between canopy and understory levels. These datasets were primarily extracted from existing GIS databases and enhanced with outputs from earlier initiatives such as the MOVE-ON project. In terms of biodiversity, spatial layers representing different habitat types were compiled to support regional conservation planning objectives, particularly those embedded in the terrestrial (SAR) and coastal (SMVM) spatial planning frameworks that emphasise the preservation of landscapes and local biodiversity.

Ecosystem condition data focused on assessing degradation processes, notably those driven by erosion and invasive species, to better understand the pressures on ecological integrity. Socio-economic and stakeholder engagement data were collected through twelve dedicated meetings involving planners, civil society organisations, and marine authorities. These interactions resulted in the creation of stakeholder maps that separately addressed marine and terrestrial domains, enhancing the representativity and relevance of stakeholder input. Policy and governance data were sourced from strategic planning documents, most notably the SAR-SMVM and the South Indian Ocean Maritime Basin Strategic Document (DSBM), as well as from thematic plans addressing shark risk and the conservation of the Papangue (Circus maillardi).

To produce and validate ES evidence, the project employed a mixed-methods approach. This included GIS-based spatial analysis, scenario modelling covering both retrospective (from 1950) and prospective (up to 2025) timeframes, and participatory approaches facilitated through digital platforms like SeaSketch. Analytical tools such as InVEST and STRAVA were instrumental in assessing regulating services, often in conjunction with field-collected data and historical maps. Furthermore, multi-criteria assessments were conducted to support the prioritisation of ecosystem service disservice (ESD) management zones under various planning scenarios, ensuring that data-driven insights could inform spatial and strategic decision-making processes.

Table 7.1. *Data sets and sources*

Dataset/Layer	Source	Status
Land-use change (1950–2050)	MOVE-ON	In progress
Invasive species canopy/understory mapping	GIS datasets, field inputs	Ongoing
Stakeholder maps	DP workshops	Completed
Planning documents (SAR-SMVM, DSBM)	Regional/National authorities	Available
Cultural ES	Survey data	In progress

Despite the substantial progress made, several limitations continue to constrain the full integration of ecosystem services evidence within the Réunion Island Demonstration Project. A key challenge lies in the non-spatialised nature of the South Indian Ocean Maritime Basin Strategic Document (DSBM), which limits the direct incorporation of spatial data and hinders its use in marine planning processes.

Marine datasets also present significant issues in terms of consistency and completeness when compared to terrestrial data, making cross-realm analysis and integration particularly difficult. In addition, stakeholder engagement has been uneven, with limited participation from private sector actors and coastal communities, which affects the inclusiveness and applicability of the findings.

The project also faced technical difficulties stemming from legacy data, which often varied widely in format, resolution, and quality. This necessitated a time-consuming process of data harmonisation to ensure compatibility across sources. Although access to key regional planning documents was generally good, the legal enforceability of incorporating scientific evidence, especially in the context of the SAR-SMVM planning process, remained weak. Without formal mandates or regulatory requirements, the uptake of ES evidence continues to rely heavily on voluntary adoption by planners and institutions.

7.2.2 Key findings and expected activities

Analyses of land-use change have highlighted a marked urban expansion on Réunion Island, with developed areas increasing from 59 km² in 1980 to over 300 km² by 2023. This rapid growth has placed considerable pressure on the island's natural ecosystems and the services they provide. Mapping efforts have identified key biodiversity areas that are increasingly threatened by invasive alien species (IAS) and landscape fragmentation, particularly in lowland regions and agricultural frontiers.

Stakeholder mapping has revealed distinct knowledge systems and policy priorities between marine and terrestrial domains. In response, the Demonstration Project adopted a dual-domain engagement strategy, enabling more effective communication with institutions and the development of ES evidence tailored to each governance context.

Significant progress has also been made through sector-specific policy frameworks, notably in shark-risk management and the conservation plan for the Réunion harrier (Papangue). These entry points have provided practical opportunities to apply ecosystem disservice (ESD) and condition data, demonstrating how science-based evidence can help reframe debates that are often politically sensitive or emotionally charged.

Looking ahead, the project plans to deliver a full suite of ES maps for the island, integrating both marine and terrestrial data layers. Additional outputs will include compatibility models linking ES-sensitive areas with prospective marine wind farm sites, as well as cultural ES datasets grounded in landscape appreciation and recreational use. An updated scenario analysis is also under development and will be aligned with the SAR-SMVM consultation timeline to maximise policy relevance and visibility.

7.3 Progress in integrating evidence in decision-making

7.3.1 Decision windows identified to date

The Réunion Island DP engages with three key decision windows (Table 7.2), which reflect both the dual terrestrial-marine planning landscape of the island and its sector-specific policy priorities. These windows serve as strategic entry points for embedding ecosystem services (ES) evidence into planning and decision-making processes:

- DW1 focuses on revising the SAR-SMVM, the regional terrestrial and coastal spatial development plan. This presents a significant policy opportunity to integrate ES evidence into long-term land-use planning and biodiversity conservation frameworks.
- DW2 concerns the Strategic Document of the South Indian Ocean Maritime Basin (DSBM), which guides marine spatial planning within Réunion's Exclusive Economic Zone (ZEE). Although the DSBM remains in its early stages of spatial implementation, it provides a valuable platform for incorporating marine ES data into future planning cycles.
- DW3 targets specific sectoral policies, including shark risk management and the national conservation plan for the Papangue (Harrier – *Circus maillardi*). These thematic domains

enable the operational application of ES and ecosystem disservices (ESDs) data, supporting adaptive, evidence-informed responses to biodiversity loss and socio-environmental conflicts.

Table 7.2. *Main elements of the decision windows identified by DP05*

	DW1: Revision of the SAR-SMVM plan	**DW2: Strategic guidance for marine use planning**	**D23: Sectoral entry points**
Policy Context	Revision of the SAR-SMVM plan (regional spatial development)	Strategic guidance for marine use planning in the South Indian Ocean Basin	Specific thematic public policies: shark risk management and species conservation (Papangue)
Decision Window Timing	2023-2026 : assessment, formulation, consultation and adoption	2024–2027: next DSBM update cycle anticipated	Ongoing implementation under respective action plans (CSR, SEOR), feeding into regional strategies (e.g. SAR)
Primary Objective	Integrated ES evidence into land-use decisions and biodiversity protection	Inform zoning strategies and resolve sea-use issues (e.g. wing energy, marine conservation)	Enhance legitimacy and effectiveness of targeted public policies through ESD/BD data integration
Role of ES Evidence	Mapping ES, Invasive species, land transformation and cultural services	Support spatial scenario discussions	ES disservices mapping (shark risk), habitat condition data (Papangue), prioritisation of sensitive zones
Stakeholder Engagement	Regional Council (SAR-SMVM unit), DEAL, elected officials, SEOR, NEXA, University of La Réunion	DMSOI, CSR, Blue Economy Unit, SPL Horizon, University of Brest, Blue Institute	CSR, SEOR, site managers, field technicians, and local NGOs
Challenges	Optional ES integration; fragmented mandates; lack of standardised ES indicators for planners	No legal ES integration requirement; lack of spatial explicitness; fragmented marine governance; data gaps	Emotionally charged debate (shark); land-use competition (Papangue); weak enforcement of conservation measures

7.3.2 Revision of the SAR-SMVM (Terrestrial-Coastal Regional Plan)

Integration of evidence

The revision of the SAR-SMVM (*Schéma d'Aménagement Régional – Schéma de Mise en Valeur de la Mer*) represents a significant opportunity to integrate ES-related evidence into land-use and coastal planning at the regional scale. Since 2022, the DP has aligned its analytical work with the SAR-SMVM timeline, currently in its assessment and policy formulation phases (2023–2024).

Concrete integration actions included sharing maps of land transformation and invasive alien species (IAS) spread (canopy and understory) with the SAR-SMVM technical team and NEXA. ES data were used to inform discussions on zoning decisions, particularly identifying zones of high ecological value or degradation. A prospective modelling exercise (2050) simulating urban growth and biodiversity impacts under various planning scenarios was also presented.

While full uptake in official SAR outputs is still pending, the inclusion of these data in regional consultations marks a first step toward operational use. The DP aims to synchronise its final ES deliverables (maps, trade-off analysis) with the public consultation phase in 2025, increasing policy visibility.

Role of different actors, and their interactions

Stakeholder engagement was designed as a progressive, structured process combining formal consultation and targeted technical dialogue. Between late 2022 and the end of 2023, the DP team facilitated a series of twelve in-person meetings and one online session involving a broad range of stakeholders connected to the SAR-SMVM planning process. Core participants included the technical team from the Regional Council, members of the *Direction de l'Environnement, de l'Aménagement et du Logement* (DEAL), elected officials, and representatives from civil society organisations such as SEOR (*Société d'Études Ornithologiques de La Réunion*).

Each meeting was framed around a specific objective, ranging from presenting spatial diagnostics and ES mapping drafts to gathering stakeholder input on priority zones, perceived ecosystem pressures, and management trade-offs. In many sessions, the DP team used visual tools such as thematic maps and scenario boards to stimulate discussion and clarify the implications of ES-based planning.

The Seasketch platform played a key role in facilitating remote and asynchronous engagement. Stakeholders were invited to explore spatial data online, add comments, and rank thematic priorities, which proved particularly useful in reaching actors unable to attend in person. The platform also served as a repository for working maps, indicator definitions, and feedback history.

Recognising the distinct governance and knowledge ecosystems across land and sea domains, the DP implemented a dual engagement strategy, organising separate workshops and working groups for terrestrial (e.g., land-use and biodiversity planners) and marine (e.g., coastal risk, fisheries, and MSP) stakeholders. This allowed for more targeted discussions, adapted to the responsibilities, language, and planning cycles of each group.

Throughout the process, technical exchanges focused on aligning ES concepts with existing planning tools rather than introducing new frameworks. This pragmatic approach helped overcome initial scepticism among planners who feared the addition of new, non-standard criteria. By linking ES indicators to already established SAR-SMVM objectives (e.g., natural heritage, land take control), the DP was able to position ecosystem evidence as a complementary support layer, increasing its potential for integration.

Challenges

Despite constructive engagement with key institutions and the expressed interest of planners, the integration of ES evidence into the SAR-SMVM remains non-mandatory. Unlike environmental impact assessments or biodiversity inventories, which are formally embedded in planning procedures, there is no legal requirement in French spatial planning law to incorporate ES metrics or ecosystem condition data into zoning or strategic development decisions. Consequently, the adoption of such evidence largely depends on the willingness and internal capacity of planning teams to interpret and apply scientific outputs voluntarily.

One of the main structural barriers encountered was institutional fragmentation. The SAR-SMVM covers both terrestrial and marine zones, but responsibilities are divided across different departments and governance scales, with limited coordination mechanisms. Terrestrial planning is primarily led by regional institutions (e.g., Région Réunion), while coastal and marine competencies fall under state services (e.g., DEAL, DMSOI), making it challenging to apply a unified analytical framework for ES across domains. This siloed approach has led to inconsistent feedback loops and separate policy logics, which hinders the operationalisation of integrated ecosystem assessments.

Another recurrent issue raised during technical discussions was the perceived lack of usability of ES outputs. Some planners expressed that while the maps and models produced were scientifically sound, they lacked direct translation into actionable planning instruments such as zoning regulations, urbanism codes, or policy benchmarks. The terminology and structure of the ES indicators were seen as misaligned with the official categories and indicators used in the SAR-SMVM framework. For instance, while the DP applied the Burkhard matrix and scenario-based modelling, planners requested clearer equivalencies with existing land-use typologies and legally defined spatial functions (e.g., remarkable natural areas and protected agricultural zones).

7.3.3 Strategic guidance for marine use planning

Integration of evidence

The South Indian Ocean Maritime Basin Strategic Document (DSBM) provides a broad planning framework for marine activities in Réunion's Exclusive Economic Zone (EEZ). Although the 2020–2026 version lacks spatial zoning, the anticipated 2027 update creates a key policy window for incorporating marine ES data.

So far, the DP's contribution has been exploratory but promising. ES evidence from shark risk management (e.g., risk mapping, user conflict data) and future marine wind energy compatibility layers has been discussed with the Directorate of the Southern Indian Ocean Sea (DMSOI) and other stakeholders. These data provide insights into ecosystem pressures and potential spatial conflicts—core concerns of the DSBM.

The DP intends to deliver an integrative ES analysis tailored to marine planning needs, including a preliminary zoning exercise and spatial trade-off scenarios, in time for the next DSBM review cycle.

Role of different actors, and their interactions

Key institutional actors engaged in this decision window included the *Direction de la mer Sud Océan Indien* (DMSOI), the *Centre de Sécurité Requin* (CSR), and the Blue Economy Unit of the Regional Council. These stakeholders were strategically selected for their involvement in maritime planning, public safety, and marine resource management.

In 2023, several targeted meetings were organised with the support of NEXA (the regional innovation and development agency) and academic collaborators, including experts from the University of Brest. These engagements aimed to align the scientific evidence generated by the DP with the policy objectives of the upcoming revision of the DSBM (Document Stratégique de Bassin Maritime). During these interactions, the DP team presented early-stage ES data relevant to maritime spatial planning (MSP), such as spatial conflict layers, marine biodiversity sensitivity zones, and compatibility indicators for offshore wind energy development.

Stakeholder feedback was constructive and highlighted a strong interest in using ES-based tools to support MSP, particularly in zones where multiple interests overlap, such as nearshore waters used for both tourism and conservation, or proposed areas for renewable energy infrastructure. The concept of mapping ecosystem services to anticipate and reduce user conflicts was viewed as particularly promising by both technical staff and policy officers.

Additionally, the Blue Institute, a regional research and innovation hub, and SPL Horizon, a semi-public company managing maritime infrastructure and projects, were identified as valuable partners to foster dialogue between the public and private sectors. Their involvement is expected to support the validation and transfer of ES tools into operational contexts, including marine concession planning and stakeholder negotiation processes.

Challenges

The DSBM of the South Indian Ocean does not currently have a legal obligation to integrate ES evidence, particularly in overseas territories like Réunion. Unlike the mainland, where EU directives, including the Marine Spatial Planning Directive and the Marine Strategy Framework Directive, apply directly, overseas regions are not bound by these frameworks. As a result, the DSBM functions primarily as a strategic orientation document rather than a spatially prescriptive planning tool, which limits the enforceability of scientific inputs and their translation into decision-making.

One of the key limitations identified by the DP is the lack of spatial explicitness in the current 2020–2026 version of the DSBM. The strategy outlines general thematic priorities—such as sustainable fisheries, coastal tourism, and marine biodiversity—but does not include maps, zonings, or overlays that could directly accommodate or be enhanced by ES outputs. This absence of georeferenced content makes it challenging to overlay ES maps or condition indicators in a way that supports regulatory or operational planning processes.

Moreover, the availability and quality of marine data is substantially lower than for terrestrial systems. The DP noted significant gaps in spatial coverage, time series continuity, and indicator harmonisation across marine datasets. Some relevant data are either not publicly available, highly fragmented across institutions (e.g., DEAL, Ifremer, universities), or lack the resolution required for local-scale planning.

The issue is compounded by fragmented governance of maritime sectors. Marine planning in Réunion involves a complex array of actors, including DMSOI, CSR, port authorities, tourism operators, and environmental agencies, with no unified mechanism for data integration or shared spatial decision-making. This dispersion makes the coordination of ES evidence uptake more difficult, particularly in contexts where institutional mandates and planning horizons differ.

7.3.4 ES evidence in sectoral entry points

Integration of evidence

Two thematic policies provide concrete application grounds for ES evidence: the shark risk mitigation strategy and the national action plan for *Circus Maillardi* (Papangue). In the shark risk context, the DP provided spatial datasets and narrative framing using ESD (ecosystem disservices) logic to support the CSR's efforts to balance safety, conservation, and public acceptance. By integrating scientific risk maps and user conflict zones into the planning discourse, the DP aimed to move from media-driven reactions to science-informed strategies. For the Papangue, the DP supported the integration of habitat requirements into SAR-SMVM priorities (actions 6.1 and 6.2 of the national action plan), leveraging existing BD and EC data to guide zoning and mitigation measures.

Role of different actors, and their interactions

The DP collaborated directly with staff from the CSR and the SEOR at various local management sites. These collaborations were not incidental but formed part of a deliberate strategy to engage with organisations operating at the interface of ecological monitoring and public policy.

In the case of CSR, engagement focused on integrating ecosystem disservice (ESD) concepts into shark risk mitigation strategies. Through multiple on-site meetings and data-sharing sessions, the DP team worked with CSR to identify high-risk zones based on previous incidents and user data. This included the use of spatial layers representing ocean use intensity, public access points, and existing monitoring infrastructure. Mapping exercises were co-developed to visualise overlaps between risk-prone zones and ecological priority areas, such as coral reefs or marine biodiversity corridors. These maps served both as internal planning tools and as visual aids for policy discussions with elected officials and coastal user groups.

For SEOR, collaboration focused on the conservation of the *Papangue* (Réunion harrier). The DP supported efforts to spatialise the species' critical habitats based on known nesting areas, movement corridors, and historical records. Through shared field observations, joint interpretation of satellite imagery, and consultations on indicator frameworks, SEOR experts contributed to refining EC and BD assessments in upland and lowland zones. This reciprocal process ensured that the proposed indicators (e.g., nesting density, proximity to disturbance sources) were both ecologically valid and practically measurable using available data.

Challenges

Shark risk management in Réunion remains a deeply polarised societal issue, where public perception, political pressure, and media narratives often override scientific reasoning. The so-called "shark crisis" has generated intense emotional responses following a series of fatal incidents, particularly affecting surfers and coastal users. As a result, the debate has been largely framed by safety concerns and fear, rather than ecosystem balance or marine conservation logic. Although the DP and partners, such as the CSR, have made progress in producing spatially explicit shark risk maps and data on human-wildlife interactions, these outputs are frequently contested in public discourse and subject to misinterpretation or political manipulation.

This emotionally charged context poses a barrier to the objective uptake of ESD evidence. Public demand for rapid, visible solutions (e.g., shark nets, culling) often clashes with the precautionary and evidence-based approaches promoted by conservation actors. Consequently, attempts to integrate shark risk into marine spatial planning (e.g., through exclusion zones, risk mitigation corridors) must navigate a landscape of conflicting interests, with limited space for consensus-building.

In parallel, conservation efforts for the Papangue (*Circus maillardi)*—Réunion's only endemic raptor—face more structural but equally constraining challenges. Although the species benefits from a national conservation action plan and is emblematic of the island's biodiversity, its habitat is increasingly threatened by land-use competition, especially in lowland agricultural zones and peri-urban areas. Nesting and foraging zones often overlap with sugarcane plantations, pasturelands, or development corridors, which lack protective zoning under current regional plans.

Despite the availability of high-quality data on Papangue distribution, nesting ecology, and population trends (much of it produced or mobilised by SEOR and the DP), there is no binding mechanism to ensure the incorporation of this knowledge into planning decisions. Spatial planning instruments such as the SAR-SMVM may refer to biodiversity values, but enforcement remains weak, and conservation considerations are often subordinate to economic or infrastructural priorities.

In both cases—shark risk and Papangue conservation—the gap between evidence and implementation illustrates the broader challenge of bridging science and policy under conditions of emotional, political, or land-use tension. The DP's strategy has been to work through trusted intermediaries (e.g., NGOs, technical committees) and to translate ecological evidence into policy-relevant, spatially grounded formats that can incrementally influence decision-making despite the absence of legal mandates.

8 Sustainable energy production in mountain regions of Switzerland

8.1 Introduction

Switzerland faces a critical challenge in balancing the rapid expansion of renewable energy infrastructure (REI) with the protection of biodiversity, ecosystem services, and the preservation of its iconic cultural landscapes, particularly in mountain regions. Incorporating ES-related evidence into DP06 is essential for several interconnected policy reasons.

Switzerland has committed to a comprehensive Swiss Biodiversity Strategy (SBS 2030) aimed at halting the loss of biodiversity and habitat degradation (FOEN, 2022). As part of this commitment, Switzerland aims to establish coherent networks of protected areas and ecological corridors to ensure habitat connectivity and species migration. The goal is to designate 30% of the country's area for biodiversity by 2030 - a significant increase from the current 13.4% (FOEN, 2021).

Simultaneously, the Swiss Energy Strategy 2050 mandates a nuclear phase-out and rapid expansion of renewable energy capacity (SFOE, 2018). This transition has been accelerated by the "Solar Express" initiative, introduced through amendments to the Energy Act (EnG) in 2022. The initiative streamlines approval procedures and subsidises large-scale Photovoltaic (PV) projects if they connect at least 10% of their total planned capacity to the grid by the end of 2025 (DETEC, 2023). This pressing deadline has catalysed cantonal authorities to accelerate their spatial planning processes (Richtplanung) for solar energy, specifically identifying suitable zones for large-scale PV installations.

Adding complexity to this policy landscape is Switzerland's strong commitment to preserving its unique natural and cultural landscapes, particularly in Alpine regions. These landscapes provide crucial cultural ecosystem services, including recreation, tourism, cultural heritage, spiritual connections, and aesthetic value. Switzerland recognises these values through the Federal Landscape Concept (Landschaftskonzept Schweiz, LKS), updated in 2020, which provides a binding framework for federal authorities regarding landscape development (FOEN, 2020).

For governmental and cantonal planning authorities, the challenge lies in harmonising these multiple objectives: ensuring energy security, meeting climate goals through REI expansion, and preserving biodiversity while maintaining the cultural and aesthetic integrity of Swiss landscapes. This challenge is formalised in Switzerland's Spatial Planning Act (Raumplanungsgesetz, RPG), which stipulates that spatial development must balance economic needs with ecological resilience and social wellbeing (Swiss Federal Council, 2019).

The timing of evidence-based decision support is particularly pressing as Swiss cantons are currently developing their spatial plans for solar energy deployment in response to the 2025 deadline for the 10% standalone PV capacity requirement. Decision-support tools that integrate multiple perspectives and objectives can help identify areas that maximise renewable energy potential while minimising impacts on biodiversity, ecosystem services, and landscape aesthetics.

Within this context, several advances have occurred since the initial framing in D8.1:

Enhanced Cultural Ecosystem Services Assessment: Initially, the demonstration project team intended to incorporate the ENERGYSCAPE study and the perceived landscape quality map into the demonstration project's tool to assess cultural ecosystem services potentially affected by REIs. However, both datasets were excluded due to their coarse resolution, often at the municipality level or larger, which does not align with the 100 m-resolution approach of the DP's tool. Through the demonstration project's parallel involvement in the Speed2Zero project, the demonstration project team were able to access and incorporate a newly developed layer that combines data from ENERGYSCAPE as well as landscape quality metrics with multiple additional geospatial data. This novel layer models and predicts the social acceptance of REIs in the landscape from a broader societal (non-local) perspective, offering a more state-of-the-art approach to cultural ecosystem service assessment. Importantly, it aligns with the 100m resolution of the other datasets in the demonstration project's tool. While the demonstration project team are currently using preliminary results, researchers from the Speed2Zero project are finalising a publication on this methodology.

Improved Ecosystem Condition Assessment: The DP's initial assessment of land use intensity and infrastructure relied primarily on the wilderness study by Radford et al. (2019). The demonstration project team have now supplemented this with a recently published map of "Open Spaces in Mountain Regions" by Riva et al. (2024). This study was conducted in collaboration with the Swiss Alpine Club (SAC), Mountain Wilderness Switzerland, and the Swiss Foundation for Landscape Conservation. The study combined expert consensus from a Delphi survey with machine learning models to map open spaces in Swiss mountain regions, taking into account both physical characteristics and perceived landscape values. After careful consideration of potential limitations and concerns that it might be used as a standalone reference for REI planning, the demonstration project team reached consensus to incorporate it into the demonstration project's decision-support tool. Complementing the wilderness map, these studies provide robust information on ecosystem conditions in alpine areas, particularly regarding the degree of land-use intensity—a key indicator of ecosystem health (Felipe-Lucia et al., 2020).

Refined Biodiversity Impact Framework: The demonstration project's approach to biodiversity assessment remains largely consistent with D8.1, reflecting the limited empirical research on direct impacts of REI on biodiversity and ecosystem services in Switzerland. The demonstration project's focus remains on comprehensive biodiversity mapping. Working with approximately 12 biodiversity scientists also involved in the Speed2Zero project, three independent biodiversity metrics were identified that must be considered simultaneously: connectivity, complementarity, and extinction risk. Furthermore, the demonstration project team have completely excluded protected areas from potential REI development analysis, recognising Switzerland's commitment to expand protected areas and acknowledging the current protection deficit (13.4% versus the 30% target).

8.2 Progress in generating evidence

8.2.1 Data identification, collection and processing

Since the official launch of the Swiss SolarWind Explorer on January 28th, 2025, substantial progress has been made in generating and integrating evidence relevant to ecosystem services ES, BD and EC into the tool. The structure and content of the tool are the result of an iterative and participatory process led by the Swiss Academy of Sciences (SCNAT), in which approximately 100 stakeholders—ranging from public authorities and researchers to NGOs and industry representatives—co-developed a set of criteria to guide spatial planning for renewable energy infrastructure (REI) in Switzerland.

These criteria were refined through expert consultations and cross-checked for geodata availability, resulting in the current version of the tool. The criteria are grouped into four thematic categories in line with the published SCNAT criteria catalog from this process.

- General (technical feasibility, legal restrictions),
- Energy (annual and winter production potential, grid distance),
- Biodiversity (protected areas, ecological connectivity, complementarity, ERI contribution), and
- Landscape (protected areas, land use intensity via wilderness and open space mapping, acceptance of REIs).

While the terminology used in the tool prioritises intuitive understanding and accessibility for policymakers and practitioners, many of the integrated spatial datasets correspond directly to scientific concepts of ES, BD, and EC. For instance, connectivity, complementarity and extinction risk map biodiversity, while layers such as the wilderness map (Radford et al., 2019) and open spaces map (Riva et al., 2024) reflect land use intensity and human modification, key indicators of ecosystem condition (Felipe-Lucia et al., 2020). Similarly, landscape protection areas and social acceptance of REI in the landscape can contribute to cultural ES.

A detailed overview of all spatial layers, including a brief description and the corresponding Zenodo folder and file name, is provided in Table 8.1. This table also includes a dedicated column that classifies each criterion according to whether it reflects biodiversity (BD), ecosystem condition (EC), ecosystem services (ES), or none (-).

Table 8.1. Summary of data used in the decision support tool Swiss SolarWind Explorer

Category	Criteria Name	Brief Description	ES/ BD / EC	Zenodo Folder
General	Forest	Combined forest types from SwissTLM 3D	ES	1. forest
	Agricultural Land	Agricultural land use categories	ES	1. LN
	Slope	Terrain slope gradients	-	1. slope
	Exclusion Areas	Unsuitable areas for large-sclae PV development (Buildi ng zones, glaciers, rivers)	-	1. exclusion_pv
Energy	Annual Energy Production	Annual solar energy production potential	-	2. yearly_energy
	Winter Energy Production	Winter solar energy production potential	-	2. winter_energy
	Grid Distance	Distance to electrical grid network	-	2. distance_grid
	Road Distance	Distance to road infrastructure	-	2. distance_street
Biodiversity	Strictly Protected Areas	Comprehensive protection biodiversity areas	BD	3. strictly_protected_biodiversity
	Partially Protected Areas	Areas with partial biodiversity protection	BD	3. partially_protected_biodiversity
	Complementarity	Biodiversity richness contribution	BD	3. complementarity
	Extinction Risk	Species extinction vulnerability	BD	3. extinction_risk
	Connectivity	Ecological connectivity importance	BD	-
Landscape	Protected Landscapes	Cultural and natural landscapes and UNESCO areas	ES	4. protected_landscapes
	Land Use Intensity (Wilderness)	Wilderness based on remoteness from infrastructure and settlements.	EC	4. landuse_intensity_wilderness
	Land Use Intensity (open spaces mountains areas)	Expert-validated map of mountain areas with minimal infrastructure.	EC	4. landuse_intensity_openspaces
	Social Acceptance	Modeled societal acceptance of REI	ES	-

Note: Not all datasets are available in the Zenodo repository, as some have not been published yet or are subject to copyright constraints.

Throughout the data collection and development process of the decision support tool, the DP encountered several challenges:

Limited empirical research on REI impacts: A significant knowledge gap exists regarding the direct impacts of REI on biodiversity. The approach focused on mapping current biodiversity patterns, assuming that REI development would negatively impact biodiversity through construction processes, road building, and maintenance activities. The lack of impact-specific data represents an important limitation.

Challenges in Criteria Selection and Data Integration: While the criteria incorporated into the Swiss SolarWind Explorer are largely based on the SCNAT catalogue, which received broad support through the involvement of many stakeholders, some criteria were later removed due to mismatches with anticipated outcomes following expert consultations or simply due to missing geodata. For instance, the distance to end-user criterion was initially included based on stakeholder input, but energy experts pointed out that it is not a key factor for large-scale PV installations. Similarly, the habitat regeneration criterion was removed after discussions with biodiversity experts, who clarified that habitats with longer regeneration times are not necessarily more important for biodiversity or threatened species, especially given the lack of reliable data above the treeline. More broadly, translating the SCNAT catalogue into usable geospatial layers posed challenges, requiring careful navigation between expert insights and the integrity of the bottom-up participatory process.

Limitations in Ecosystem Condition Assessment: While the approach to ecosystem condition assessment via human influence indicators (wilderness map and open spaces map) provides valuable information, it does not capture all relevant dimensions of ecosystem condition, particularly those related to ecosystem functioning, integrity, and health. The DP lacks comprehensive data on ecosystem processes and functions that might be impacted by REI development.

Limitations in Ecosystem Services Assessment: While the approach used captures cultural ecosystem services relatively well, particularly through indicators related to protected landscapes and social acceptance of renewable energy infrastructure, many other categories of ecosystem services remain unrepresented. In particular, there is a lack of spatially explicit data on provisioning, regulating, and supporting services that may be affected by REI development.

Data accessibility and complexity barriers: The three-biodiversity metrics developed for this project are methodologically sophisticated and can be challenging for non-experts to interpret. To address this barrier, the descriptions for public communication were simplified while preserving the scientific integrity of the underlying data. Detailed methodological documentation will be made available following the academic publication of these maps.

Data ownership and use permissions: Obtaining agreements to incorporate existing datasets into the tool presented significant challenges. Data owners often expressed concerns about potential misuse or misinterpretation of their data, which were particularly acute for datasets with known limitations or those developed for specific purposes other than REI planning. These concerns were addressed by highlighting the limitations of each map and implementing restrictions that ensured individual layers could only be used in combination with other layers in the final overlay for REI assessments.

8.2.2 Key findings and expected future activities

Despite significant progress, several data gaps remain to be addressed before project completion:

Wind energy analysis: The current tool focuses primarily on large-scale solar energy potential. DP06 is working to incorporate wind energy analysis but faces challenges in finding Swiss-wide calculations that reflect the most recent technological developments in wind turbine efficiency and installation requirements. This addition would enable a more comprehensive comparison between wind and solar potential across Switzerland.

Biodiversity Validation: The three independent biodiversity metrics are currently being validated by multiple biodiversity experts from various fields, including science, NGOs, and government administrations.

Weighting of Sub-Criteria: Policymakers and authorities have expressed feeling overwhelmed by the task of weighting the sub-criteria themselves and have pressed for expert recommendations. In response, targeted surveys will be conducted within each thematic category (energy, biodiversity, and landscape), asking domain-specific experts to assess and weigh the criteria relevant to their field. To support their decision-making, experts will be able to visualise the corresponding maps directly within the tool. This approach aims to establish expert-based weightings within each category, while the weighting of the main categories will remain subjective and based on stakeholder preferences.

Bird conflict mapping: The DP will integrate the forthcoming bird conflict map for wind turbines, scheduled for publication by the Swiss government by the end of 2025. This dataset will provide crucial information on potential bird conflicts specific to wind energy development, enabling more informed and sophisticated recommendations.

Energy production scaling: DP06 is working on improving the tool to estimate the potential energy production based on user settings and selected areas. This will provide clearer guidance on where renewable energy installations can be located to support Switzerland's energy transition.

3d visualisation: To enhance the tool's usefulness for decision-makers, 3d visualisations will be added to illustrate what renewable energy projects could look like in the landscape. This should facilitate a clearer understanding of potential changes and support more informed decisions.

By addressing these remaining data needs and methodological updates, the decision-support tool developed for the DP will be enhanced, thereby strengthening its ability to provide reliable and clear ES-related data. Through its application in policy and industry, the decision-support tool aims to integrate scientific frameworks and studies, expert knowledge, and industry insights into an accessible format tailored to the needs of policymakers and industry representatives.

8.3 Progress in integrating evidence in decision-making

8.3.1 Decision Windows Identified to date

DP06 is part of a broader effort to incorporate ES evidence into spatial planning and the prioritisation of REI. As previously explained, these initiatives align with cantonal spatial plans, which seek to balance the expansion of renewable energy, the conservation of biodiversity, and sustainable land use.

To achieve this goal, two key decision windows (Table 8.2) have been identified:

- Scenario comparison for spatial planning: This decision window focuses on developing and refining spatial planning scenarios according to stakeholder-driven criteria. Through scenario-based workshops and spatial analysis tools, it incorporates biodiversity conservation and land-use priorities. The process aims to provide policymakers with clear, evidence-based comparisons of potential future development paths.

- Prioritisation of REI: This decision window involves optimising the placement of renewable energy projects while addressing environmental constraints and socio-economic trade-offs. The approach leverages multi-objective modelling and workshops to assess how different energy expansion scenarios align with policy goals and ecological sustainability.

Table 8.2. *Main elements of the decision windows identified by DP06*

	DW1: Scenario Comparison for Spatial Planning	**DW2: Prioritisation of Renewable Energy Infrastructure**
Policy Context	This decision window centres on developing and comparing spatial planning scenarios based on stakeholder preferences. The aim is to provide clear visual representations of potential future developments, integrating various criteria such as renewable energy potential and biodiversity conservation.	This decision window prioritises REI through scientific analysis and stakeholder consultations. The process uses multi-objective optimisation to balance trade-offs between energy production, environmental constraints, and land-use compatibility.
Decision Window Timing	The tool underwent testing during workshops, where stakeholders provided significant feedback that informed its refinement for a second round of testing. It was launched in January 2025 as part of a collaboration with the MOSAIC project.	The prioritisation process is ongoing and could potentially rely on uncertainty analysis.
Primary Objective	This decision window seeks to compare various spatial planning scenarios based on criteria driven by stakeholders, ensuring that land-use decisions strike a balance between differing priorities.	The key objective is to enhance the prioritisation of renewable energy infrastructure by evaluating trade-offs between robustness and potential solutions.

	DW1: Scenario Comparison for Spatial Planning	DW2: Prioritisation of Renewable Energy Infrastructure
Role of ES Evidence	ES evidence is used to overlay biodiversity data with land-use scenarios	ES assessments facilitate multi-objective optimisation by highlighting trade-offs between the expansion of renewable energy and the conservation of ecosystems, thereby ensuring balanced land-use planning.
Stakeholder Engagement	Workshops with stakeholders have been held to prioritise criteria, enhance scenario designs, and ensure alignment with local planning priorities.	Engagement mainly involves workshops where stakeholders assess model outcomes and deliberate on the feasibility of various energy infrastructure sites based on multi-criteria evaluations.
Challenges	One of the primary challenges is ensuring that stakeholder preferences are properly reflected in the final scenarios while upholding scientific rigour. Another difficulty lies in integrating diverse data sources into a cohesive framework.	A key challenge lies in exploring the uncertainties involved in the trade-off analysis. Identifying the balance between robust solutions and flexibility in policy implementation is a complex task.

8.3.2 Scenario Comparison for Spatial Planning

Integration of evidence

The online web tool *Swiss SolarWind Explorer* integrates key ES layers to support strategic energy planning by visualising spatial trade-offs between renewable energy development, biodiversity, and sustainable land use. It is particularly suited for national-level use, where it can help inform a more balanced allocation of energy targets across cantons, considering not only size but also the availability of low-conflict areas based on policy preferences. Federal agencies, such as the Federal Office for the Environment (BAFU) and the Federal Office for Spatial Development (ARE), as well as national coordination bodies like the Conference of Cantonal Planners (KPK), will be key users of the tool in this context. Although direct use by these actors has not yet been confirmed, updates and improvements are being shared. The initial feedback received following the launch of the tool has been valuable. Looking ahead, opportunities to organise round tables or policy dialogues will be explored, potentially involving political representatives, to discuss strategic trade-offs and explore scenario simulations using the tool. These efforts are still in the early stages, but they could play a crucial role in facilitating more coordinated planning at the national level.

Role of different actors, and their interactions

The development of this tool was shaped by strong transdisciplinary collaboration. Throughout several workshops and consultations, stakeholders from public authorities, NGOs, academia, and industry provided input that helped define and validate the decision criteria now used in the tool. While the criteria themselves are fixed to ensure transparency and consistency, stakeholders can still assign weights to each criterion within a group (energy, landscape, biodiversity) and weigh the importance of the groups themselves. This approach enables users to reflect on their own values and planning goals while working within a shared, evidence-based framework. To support wider uptake and ensure the tool remains user-friendly, a survey is being prepared to gather input from a network of over 80 stakeholders involved in the project on how the criteria in each group could be weighted. This could provide a sense of legitimacy to the 'expert setting' that many authorities and industry stakeholders have requested to help them justify and streamline planning processes, especially when the approach is transparent and well-communicated.

Challenges

One challenge in this decision window is the mismatch between the abstract or long-term nature of policy goals (such as those in the Biodiversity Strategy or the Spatial Planning Act) and the concrete, measurable outputs typically produced by scientific tools. While energy targets are often quantitative and time-bound (e.g., specific TWh targets for renewable energies in the Swiss Energy Law), biodiversity and sustainable land use goals tend to be broader, less measurable, and sometimes lack legal enforcement, making it harder to translate them directly into planning recommendations.

Another key challenge was deciding which spatial criteria to include in the tool. Although a wide range of suggestions was gathered through stakeholder engagement, not all the criteria were retained. Some were excluded based on feedback from scientific and industry experts, either because the data led to misleading outcomes, the criterion was not considered relevant within its group, or the underlying data quality was insufficient. This balancing act between the participatory collected criteria and the expert opinion was especially tricky in the development phase of the tool.

To make the platform accessible beyond GIS professionals, we prioritised a user-friendly, web-based interface that communicates scientific evidence in a clear and visual way. Rather than presenting fixed outcomes, the tool enables users to explore different scenarios and trade-offs, fostering dialogue and transparency in energy planning and helping build a shared understanding among diverse interests.

8.3.3 Prioritisation of Renewable Energy Infrastructure

Integration of evidence

At the cantonal and local levels, the tool helps identify suitable areas for renewable energy development by allowing users to compare locations based on evidence related to ecosystem services, landscape quality, and energy potential. The spatial criteria employed, such as biodiversity maps, land-use intensity, and energy potential, were selected through a participatory process involving diverse stakeholders. While the underlying data layers remain fixed to ensure consistency and transparency, users can apply their own weights to the individual criteria as well as to the broader categories of energy, biodiversity, and landscape. This flexibility supports stakeholder-specific interests by allowing preferences and trade-offs to be reflected in the analysis. Currently, 18 cantons are utilising the tool, and some are providing valuable feedback that helps us improve its functionality. With one canton, a closer relationship has been developed to explore how the tool can best support cantonal planning processes. This collaboration has led to the development of new features that address specific needs at the cantonal level. As part of the ongoing development, 3D visualisations of wind turbines and solar parks are being integrated. Additionally, the energy potential at the visualised sites will be calculated to provide more information and enhance the decision-making process.

Role of different actors, and their interactions

This part of the process was shaped through close collaboration with a diverse range of stakeholders, including planning authorities, scientists, NGOs, and representatives from the energy sector. Through several workshops organised by a knowledge broker, stakeholders helped identify which criteria to include and how they should be categorised and used in the tool. one key takeaway was that users are generally more confident assigning weights to broader categories like energy, biodiversity, or landscape. However, they often find it more challenging to assess the importance of detailed criteria within these categories, particularly when they lack expertise in those areas. To support them, a stakeholder survey is being prepared in which experts in each field can assist in setting appropriate weights for these criteria. This will provide recommended "expert setting" that reflects the input of a broad group of involved stakeholders, making the tool more straightforward to use and giving it greater legitimacy in planning processes. In addition, participating in the survey itself helps users engage more with the tool, which can lead to increased prominence and application of the *Swiss SolarWind Explorer*.

Challenges

A central challenge at the cantonal and local level is finding the right balance between technical evidence and the practical needs of planners. While the tool draws on a wide range of scientific data, it should also be accessible to users who may not have a technical background in GIS or environmental modelling. This accessibility should enhance the tool's application in real-world planning issues. Some criteria, initially included through the participatory process because they were mentioned by multiple stakeholders, were later questioned by scientific or industry experts. Some of the data for these criteria either led to misleading outcomes, the criteria were not considered relevant within their category, or the underlying data quality was insufficient.

Social acceptance plays a crucial role in the successful planning of renewable energy projects, particularly at the local level, where opposition can arise even for sites with low-conflict potential, as determined by the DP analysis. Factors such as early engagement with communities, perceived fairness, and local benefits (such as lower energy costs or shared revenues) are key to building local acceptance but lie outside the scope of what can be modelled in a spatial tool. To support this, contextual information has been included on the landing page, and these issues are discussed with cantonal planners and industry stakeholders. By simplifying the interface and allowing users to explore a range of planning scenarios with adjustable assumptions, the tool serves as a practical aid that supports evidence-based decisions while respecting the importance of local processes and community engagement.

9 Maritime Spatial Planning and Thematic Planning of coastal public Infrastructure in Latvia

9.1 Introduction

The Latvian DP addresses two strategic and spatial planning processes to develop national planning documents for the management of marine and coastal ecosystems: (i) the Maritime Spatial Plan (MSP) of Latvia, which covers the entire marine waters of the Republic of Latvia (including internal marine waters, territorial waters, and the Exclusive Economic Zone (EEZ)); and (ii) the Long-Term Thematic Plan for the Development of Coastal Public Infrastructure (the Coastal Plan), which covers the coastal parishes (the smaller territorial units of municipalities) extending up to approximately 10 km inland from the shoreline.

Marine and coastal ecosystems in Latvia, as in the rest of Europe and beyond, are facing increasing pressure from human activities. These include growing demands for space for new and emerging developments such as offshore and onshore wind farms, marine aquaculture, and the expansion of built-up coastal areas. At the same time, the Baltic Sea is encountering various environmental challenges, including eutrophication, pollution, slow water exchange, and decreasing salinity. These factors have significant negative impacts on the functioning of marine and coastal ecosystems, leading to the degradation of benthic habitats, nursery and spawning areas for fish species, and a consequent decline in fish stocks.

According to international as well as national regulations and guidelines, the marine and coastal planning shall apply ecosystem-based approach to the management of human activities, which includes the uptake of biodiversity and ecosystem service information in the decision-making process. As recognised by the Maritime Spatial Planning (MSP) Directive (Directive 2014/89/EU), "healthy marine ecosystems and their multiple services, if integrated in 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".

Both planning documents addressed by the DP respond to the challenges and ambitions outlined in the MSP Directive. The aim of Latvia's Maritime Spatial Plan (MSP) is to balance environmental, societal, and economic interests and to promote the sustainable development of marine space by permitting or restricting specific activities in the sea and along the coast. The Coastal Plan focuses on developing a cohesive network of public infrastructure in the Baltic Sea's coastal (terrestrial) areas, supporting the balance between nature conservation and economic interests, facilitating the creation of joint tourism products, and striving for good governance of coastal areas.

An ecosystem-based approach was already applied in the development of Latvia's first MSP, adopted in 2019. This involved mapping various ecosystem features and services, and assessing potential negative impacts on natural assets and ecologically significant areas. The approach included aggregating data on areas important for provisioning services (e.g., fish catch), conducting indicative (Tier 1) mapping of regulating service potential, and applying a multi-criteria method to identify areas valuable for tourism and leisure. The Coastal Plan, adopted in 2016, similarly incorporated assessments of anthropogenic pressures along the coast, visitor numbers, and the condition of public access infrastructure.

The information compiled and generated by the DP contributes to the ongoing interim evaluation and update of the MSP, which is scheduled to be finalised by 2029 and will also include the integration of the coastal and inland areas. Updating the plan requires up-to-date and scientifically robust information on the condition of marine and coastal ecosystems, the status and use of fish stocks, suitable areas for marine aquaculture, the distribution of regulating services, and the supply of cultural services in coastal areas. This information is urgently needed to prevent further deterioration of marine and coastal ecosystems and their services amid increasing pressure from new developments.

9.2 Progress in generating evidence

9.2.1 Data identification, collection and processing

The interim evaluation of the implementation of Latvia's MSP included a comprehensive analysis of data on the marine ecosystem and biodiversity, trends in the use of marine resources, and an assessment of the implementation of the tasks outlined in the MSP. The interim evaluation of the Coastal Plan's implementation focused on coastal development trends, including natural and environmental processes, as well as the condition and development of public infrastructure. DP07 has compiled and generated ecosystem services–related information as input for the interim evaluation of both planning documents. This information was used by the Ministry of Smart Administration and Regional Development (MoSARD), the competent authority for spatial planning in Latvia, and was integrated into the interim evaluation reports on the implementation of the MSP and the Coastal Plan.

The types of data identified as necessary for preserving ecologically valuable areas and planning the use of marine space:

- Marine ecosystem extent and condition**:** benthic habitat mapping, distribution of birds and seals, essential fish habitats (for nursery and spawning), condition of fish stocks, etc.
- Provisioning services: catch of commercially important fish species, areas suitable for marine aquaculture
- Regulating services: the contribution of aquatic vegetation to bioremediation, nutrient storage, erosion control, and water flow regulation; the contribution of aquatic animals, such as mussels, to bio-deposition, nutrient flows, and sequestration.

The types of data identified as necessary for preserving and planning the use of coastal areas:

- Condition of coastal ecosystems, including data from national-scale habitat mapping, assessment of coastal landscape quantities (e.g., aesthetic qualities, landscape diversity and naturalness, recreation potential, and accessibility).
- Provisioning and regulating services provided by inland coastal areas
- Cultural ecosystem services: the use of coastal areas for active or immersive interaction, passive or observational experiences, education and knowledge, cultural heritage, and aesthetic experiences.

The data on marine and coastal ecosystem services processed by the DP07:

Provisioning and regulating services of marine ecosystem - using process-based modelling:

The DP has processed the modelling results on provisioning services (potential of marine aquaculture) as well as a set of regulating services (bioremediation, nutrient storage, erosion control, water flow regulation and carbon sequestration) as input to the interim evaluation of the MSP.

The original modelling results were produced by the researchers of the Estonian Marine Institute (University of Tartu) with contribution from BEF-LV in the frame of the Interreg project MAREA (Forsblom et al., 2022. MAREA project Output O.T1.1). The field survey point data on species biomass, Copernicus environmental data layers, as well as experimental data on the functioning of marine ecosystem components, served as input for modelling. In case of provisioning service, the macroalgal growth models and Boosted Regression Trees were used to model the relationship between macroalgal growth yields and different environmental variables, while the Dynamic Energy Budget (DEB) models were used for modelling mussel growth and the flows of nutrients in mussel farm. The modelling of regulating services was primarily based on species distribution models and the aggregation and normalisation of aquatic vegetation data.

To feed in the modelling results into the interim evaluation and update of the MSP, the BEF team has aggregate them on the level of CICES classes (first, by normalising specific indicator values on the scale 0 to 1) as well as produced further aggregated maps on areas suitable for fish, mussel or algae aquaculture and overall map on areas with of high regulating service value.

Coastal cultural ecosystem services (CES) assessment - using participatory GIS survey

A PGIS survey on the use of coastal areas for recreation was conducted by BEF-LV and the University of Tartu in 2021 as part of the MAREA project. The survey was targeted at recreational users of the Latvian and Estonian coastlines. It was distributed online using ArcGIS Survey123 platform as well as included face-to-face interviews. A total of 1,417 responses were collected (808 from Latvia and 609 from Estonia), which corresponds to the minimum sample size of each country's total population (95% confidence level, 4% margin of error). The respondents were asked to place their favourite coastal locations on the map and select all CES-related activities they engage in at these locations. Further in-depth questions were asked regarding their favourite activity, including rating the coastal features in terms of their suitability for practising the selected activity, and motivations for practising the favourite activity in relation to the well-being categories. The survey results were used to assess the distribution of the CES use along the coasts of Latvia and Estonia, how coastal ecosystem features influence the perceived suitability of coastal areas for CES, and how recreational users perceive the well-being benefits gained from spending time on the coast.

DP will use the results of this study to inform the sustainable coastal tourism planning and the updating of the MSP.

Coastal landscape assessment - using field survey and spatial data analysis:

The national-scale coastal landscape and cultural ecosystem assessment, as an input to the interim evaluation of the Coastal Plan, was carried out by the BEF-LV team in 2024-2025. It covered the entire Latvian coastline from the shore up to 5 km inland. The study was based on a coastal landscape characterisation and assessment approach using indicators derived from landscape metrics and field observations (Swanwick, 2002; Veidemane et al., 2024). First the landscape typology was developed and relatively homogeneous seashore landscape areas delineated using different land cover data sets.

Borders of the landscape areas were refined during the field survey, resulting in a total of 178 landscape areas (106 inland and 72 beach areas). The BEF-LV team carried out the field survey in summer 2024 to assess the landscape characteristics, which cannot be derived from the maps (e.g. aesthetics, recreational facilities, accessibility) by using defined methodology and a set of semi-quantitative indicators. In total, more than 550 observation points were recorded along the entire Latvian coastline.

Based on the results of the field survey and analysis of the spatial data, each landscape areas were assessed according to the following criteria and indicators:

- Landscape aesthetics (openness of landscape, scenic views, attractive landscape elements, share of scenically attractive roads, visual pollution)
- Landscape uniqueness (unique landscapes on a national/regional scale)
- Landscape diversity (diversity of land use/shoreline types, small-scale landscape elements, settlement structure)
- Landscape naturalness (share of semi-natural habitats/natural shoreline stretches, share of protected areas, presence of industrial objects)
- Cultural heritage in the landscape (number of cultural history monuments, presence of traditional land/sea use practices, presence of historical spatial structures, visually outstanding cultural history objects)
- Recreation and tourism, including public accessibility (density of tourism attractions/objects, accommodation possibilities, presence of nature parks, national parks, accessibility, number of visitors RP).

The applied indicators are related to the following CES: Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions (3.1.1.1); Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions (3.1.1.2); Characteristics of living systems that are resonant in terms of culture or heritage (3.1.2.3); and Characteristics of living systems that enable aesthetic experiences (3.1.2.4).

Results were visualised on maps and provided to the MoSARD as input for the interim evaluation of the Coastal Palan, as well as published in the National Landscape Atlas.

Other data sources used as input for marine and coastal ES assessment:

- Data on fish landings from fishery logbooks of fishermen, collected and processed by the Fishery and Food Safety Research Institute BIOR. MoSARD has commissioned a study to provide the needed fishery information.

- Coastal visitor counts – regular fieldwork is commissioned to estimate the number of visitors using coastal ecosystem services and to assess the pressure on coastal habitats.

- Annex I habitat mapping data from the coastal inland part provided by the Nature Conservation Agency

- Various land use and land cover data sets from classified remote sensing data, topographic maps, State Forest Register, Rural Support Service, etc.

Table 9.1. Summary of methods applied

Method	Ecosystem Service	Details
Processing and visualisation of fishery log books	Provisioning service	Wild fish supply measured by fish landings of main commercial fish species (annual data in tonnes)
Aggregation of process-based modelling results by ecosystem service classes	Provisioning service	Farming potential of algae, mussels, and trout (farm biomass yield)
	Regulating services	Aquatic vegetation bioremediation potential Filtration/sequestration/storage/accumulation by microorganisms, algae, plants, and animals (6 indicators and maps) Aquatic vegetation erosion and flood protection potential Aquatic vegetation habitat maintenance potential on hard and soft bottoms Spawning/nursery areas of 5 fish species Aquatic vegetation oxygen production potential on soft bottoms Aquatic vegetation carbon storage potential on hard and soft bottoms
Mapping of the essential fish habitats	Regulating services	Mapping of potential spawning and nursery areas for main commercial fish species
Coastal landscape characterisation and assessment using indicators derived from landscape metrics and field observations (parameters of indicator quantified in scale 1–5)	Cultural services	Landscape qualities: Aesthetic quality Uniqueness Landscape diversity Landscape naturalness Cultural heritage Recreation potential
PGIS survey on use of CES (favourite sites & activities) and contribution to well-being	Cultural services	Active or immersive interactions Passive or observational interactions Education and knowledge Resonant in terms of culture or heritage Aesthetic experiences Symbolic & religious interactions
	User-perceived factors of site suitability	Beach character Beautiful landscape Transparent water Birds, fish, plants Presence of people, etc.
	User-perceived well-being categories	Mental well-being Physical well-being Feel closer to nature Sense of belonging Knowledge Aesthetic inspiration

9.2.2 Key findings and expected activities

In the context of MSP updates, crucial information pertains to the areas identified as suitable for marine aquaculture, given the growing interest in developing this sector. The aggregated information on regulating services indicates areas of high ecological value, providing essential input for planning offshore wind parks and other developments. Foreseen data generation involves analysing marine ecosystem condition data and its relationship to ecosystem service supply.

Assessment results on coastal landscape qualities, as well as the use of coastal areas for recreation, provide important information for coastal planning, ranging from the local to the national scale. Though for the Interim assessment of the Coastal Plan, the most useful information generated by the DP was the survey results of coastal accessibility, which provides direct input to the planning of improvements of coastal infrastructure. As the next step, it is planned to cluster the coastal landscape areas based on their landscape qualities, which will provide guidance on coastal tourism development potential and specialisation.

9.3 Progress in integrating evidence in decision-making

9.3.1 Decision Windows identified to date

DP07 has identified key decision windows where ES evidence can support policymaking. These windows include the revision and update of the Maritime Spatial Plan (MSP), scheduled to begin in October 2025. This process presents a significant opportunity to integrate biodiversity ES data into maritime spatial planning, ensuring that sea-use policies align with sustainability objectives. The MSP update will inform long-term national policy and expand the scope for evidence-based decision-making, particularly in relation to marine biodiversity conservation and ecosystem resilience.

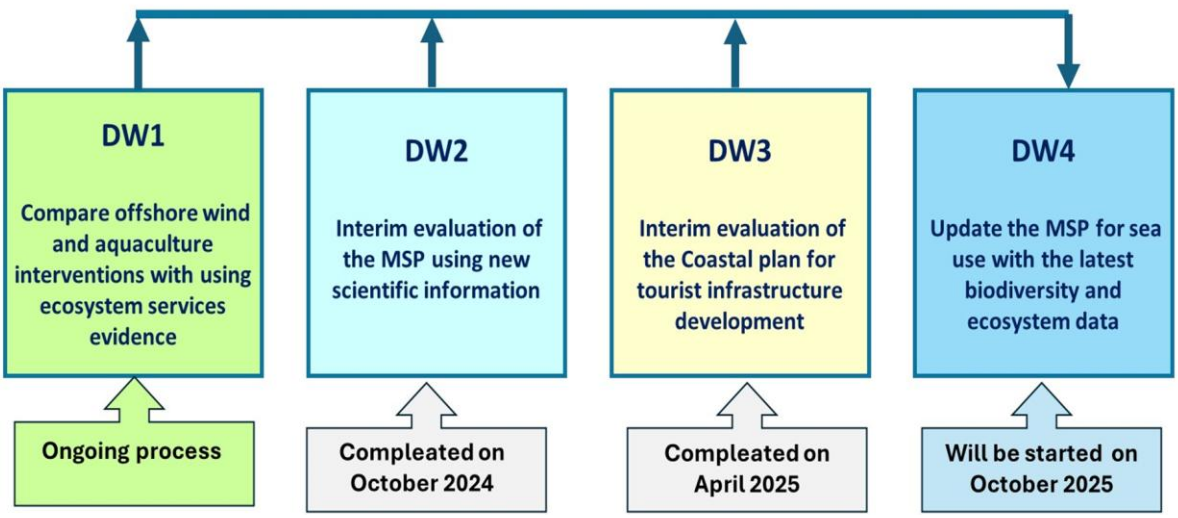


Figure 9.1. *Overview of decision windows in the Latvian DP*

Another significant decision window relates to the interim assessment of the coastal public infrastructure (mainly tourism) development plan (Coastal Plan). This evaluation assessed the socio-economic and environmental effects of existing and planned coastal developments. While key conclusions have already been drawn, opportunities remain for further stakeholder engagement and refinement, particularly regarding long-term ES monitoring and adaptive management strategies.

In addition to these finalised or upcoming processes, the Environmental Impact Assessment (EIA) framework for offshore wind and marine aquaculture developments represents an ongoing decision window. The EIA process has started, defining the conditions and methodologies for impact assessments. This window extends beyond 2025, providing continued opportunities to integrate ES-based assessments into regulatory frameworks.

These decision windows mark critical points in Latvia's marine and coastal policy cycle, offering opportunities to embed ES evidence into policy formulation, adoption, and implementation. By aligning ES assessments with these strategic decision-making processes, policymakers can enhance the effectiveness, coherence, and sustainability of maritime spatial planning and coastal infrastructure development in Latvia. The following table (9.2) provides a detailed comparison of these decision windows.

Table 9.2. *Main elements of the decision windows identified by DP07*

	DW1: Compare offshore wind and aquaculture interventions with the use of ES evidence	**DW2: Interim evaluation of the MSP using new scientific information**	**DW3: Interim evaluation of the coastal plan for tourist infrastructure development**	**DW4: Update of the MSP for sea use with the latest biodiversity and ecosystem data.**
Context	The addressed interventions focus on recent initiatives regarding offshore wind parks and marine aquaculture developments. The environmental impact assessment process has begun, identifying conditions, aspects to be assessed, and types of impacts. This process will continue in 2025 and beyond.	The interim evaluation of the MSP aimed to assess progress in implementation. The process has been completed, included in the official report, and approved by policymakers.	The Coastal plan evaluation aims to focus on supporting tourism infrastructure development by assessing landscape and environmental impacts. The conclusions primarily address aspects of coastal public tourism infrastructure and landscape quality.	The update of MSP will integrate new biodiversity and ES data to enhance the sustainable use of the sea. SELINA project activities and results will serve as a basis on applying the ecosystem service approach and methods. The revision processes are scheduled to start in October 2025. There is a possibility of-creating new decision windows for integrating ES, e.g., the Strategic Environmental Assessment process.

	DW1: Compare offshore wind and aquaculture interventions with the use of ES evidence	DW2: Interim evaluation of the MSP using new scientific information	DW3: Interim evaluation of the coastal plan for tourist infrastructure development	DW4: Update of the MSP for sea use with the latest biodiversity and ecosystem data.
Decision Window Timing	The environmental impact assessment (EIA) process for ELWIND, the joint Estonian-Latvian cross-border offshore wind park project in the Baltic Sea, was initiated in May 2023 and is ongoing. This assessment process will continue into 2025 and beyond, with findings gradually being integrated into policy decisions. Two sea areas for the development of aquaculture activities were designated by the Government in 2024. An environmental impact assessment (EIA) process must be carried out for this activity.	This decision window has been finalised. The Interim Evaluation Report, assessing MSP progress and implementation, was completed and officially approved by the Government in October 2024. No further action is required under this window.	The evaluation of the Coastal Plan has been completed, and its implementation regarding public infrastructure, including tourism infrastructure, has been assessed. No further action is required under this window.	The revision and update of the MSP are planned to begin in October 2025, based on insights from DW2 and DW3, as well as the latest data on marine protected areas. This will provide an opportunity to apply current ES data on a broader scale, as well as in coastal terrestrial ecosystems, fisheries, and tourism. The update process aims to incorporate ES, EC and BD assessments more comprehensively.
Primary Objective	The primary goal is to assess and compare the impacts of offshore wind and aquaculture interventions using evidence from ES assessments. This ensures that environmental impacts, trade-offs, and potential benefits are clearly understood before permitting decisions are made.	The interim evaluation was conducted to assess the implementation of the MSP and to integrate new scientific information where relevant. This process ensures continuous improvement and alignment with ecosystem-based management principles.	The interim evaluation of the Coastal plan aims to guide sustainable tourism infrastructure development by incorporating EC and ES assessment. The objective is to balance tourism expansion with environmental protection and landscape integrity.	The update of the MSP will integrate the latest biodiversity and ecosystem condition and services data to enhance planning decisions, ensuring that sea use planning aligns with conservation objectives and supports sustainable marine resource management.
Role of ES Evidence	ES evidence plays a crucial role in evaluating the environmental impacts of offshore wind and aquaculture projects. ES data helps compare different intervention options and assess their long-term ecological and socio-economic implications.	The interim MSP evaluation incorporated ES evidence to assess how well environmental considerations were addressed. Findings from the ES assessments helped refine policy directions and identify areas that needed further improvement.	ES data informs the assessment of tourism infrastructure impacts on coastal ecosystems and landscapes. This evidence supports decision-making by ensuring that tourism development aligns with environmental sustainability goals.	Biodiversity and ES data will be fully integrated into the MSP update process. The goal is to ensure that spatial planning decisions consider the health of ecosystems, resource availability, and the long-term sustainability of marine areas.

	DW1: Compare offshore wind and aquaculture interventions with the use of ES evidence	**DW2: Interim evaluation of the MSP using new scientific information**	**DW3: Interim evaluation of the coastal plan for tourist infrastructure development**	**DW4: Update of the MSP for sea use with the latest biodiversity and ecosystem data.**
Stakeholder Engagement	The Baltic Environmental Forum has actively participated as a stakeholder in public hearings and provided a written opinion. Stakeholder consultations help ensure that offshore wind energy and aquaculture projects align with environmental and socio-economic considerations.	The evaluation process involved key stakeholders from the blue economy, including local municipalities, policymakers, scientists, and maritime spatial planners. Their input helped to shape the assessment findings and ensured alignment with regulatory frameworks.	Stakeholder engagement has focused on local authorities, tourism organisations, environmental agencies, and local communities, ensuring that tourism planning reflects both economic and ecological interests. Additionally, the civil defence sector, fisheries and ports had an opportunity to express their views on public infrastructure development patterns.	The MSP update process will involve a strong engagement with marine biodiversity experts, government agencies, and planning bodies. Fishery and energy sectors will also play a crucial role, as new limitations for these sectors might be proposed. This inclusive approach ensures that diverse perspectives contribute to sustainable sea use planning.
Challenges	A major challenge is defining the specific assessment conditions and determining the key environmental aspects to be evaluated. The limited availability of ecosystem service data for new offshore projects makes it difficult to compare interventions comprehensively.	This decision window has been completed, so there are no further challenges to address. However, ensuring that scientific data remains relevant and up-to-date is an ongoing concern for future assessments.	One key challenge is ensuring that the conclusions on the impacts of coastal public infrastructure are correctly integrated into decision-making. Balancing tourism expansion with the protection of coastal ecosystems remains a complex issue.	A significant challenge is assessing environmental conditions, particularly the use of fish indicators and their relationship to ecosystem conditions. Integrating diverse datasets into a cohesive MSP framework will require careful coordination and planning. Setting suitable areas for the multi-use of marine space and addressing new priorities will also require new methods and knowledge.

9.3.2 Compare offshore wind and aquaculture interventions with the use of ES evidence

Integration of evidence

The EIA for ELWIND - the joint Estonian-Latvian cross-border wind park project in the Baltic Sea was initiated in May 2023. The preparation of the EIA report and the related procedures includes the transboundary impact assessment process, informing and consulting the countries likely to be affected by the proposed activity.

To date, the primary objective has been to highlight to all involved parties the importance of marine and coastal (including terrestrial) cultural ecosystem services, as well as the various regulating services provided by the allocated research area for offshore wind energy and its surroundings. As impact assessment studies are still in progress, the most recent evidence and assessments will be made available to the EIA expert team, relevant stakeholders, the interested public, and competent authorities.

For the development of aquaculture activities, two marine areas in the Gulf of Riga (Baltic Sea) were designated—Roja and Mērsrags—according to Cabinet of Ministers Order No. 664, "*On the Determination of Two Areas in the Gulf of Riga of the Baltic Sea for the Installation and Operation of Equipment Necessary for Aquaculture Activities*" issued in August 2024. One area is located offshore from Roja, approximately 2.2 nautical miles from the coast, and the other offshore from Mērsrags, approximately 2.6 nautical miles from the coast.

Similar to the offshore wind energy EIA, relevant data and information will be submitted during the EIA process, which is expected to commence in 2025. In this case, the focus will be on regulating ecosystem services and potential impacts on fish provisioning services. As the proposed aquaculture farms are located within marine protected areas, the EIA will need to give particular attention to nature conservation values and the likely effects on them.

These two initiatives—offshore wind development and aquaculture activities—are planned for different locations and do not overlap.

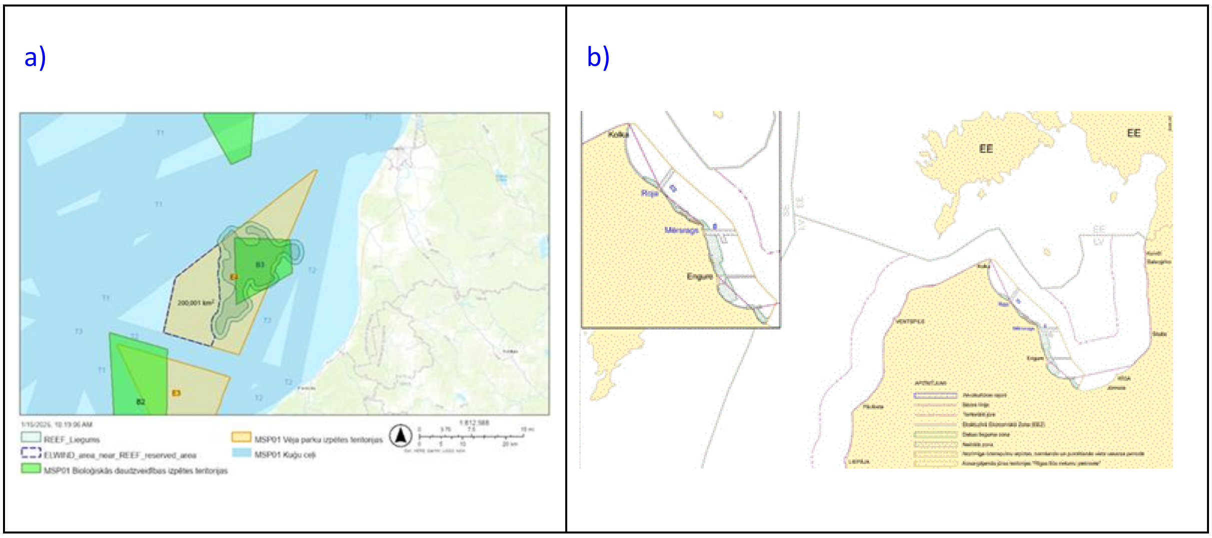


Figure 9.2. *Marine research areas intended for a) offshore wind energy park and b) aquaculture development; Source: a) https://likumi.lv/ta/id/358789-par-izpetes-laukuma-noteiksanu b) https://m.likumi.lv/doc.php?id=354264#*

Role of different actors, and their interactions

The EIA process is still ongoing, therefore, the main collaboration activities are still ahead. Up to date, in addition to the involvement of technical experts, the EIA process for the ELWIND offshore wind park actively engaged state institutions and organised multiple public consultation events. These consultations were designed to keep local communities and stakeholders informed about ongoing developments and to gather their input. Developers also played a key role by coordinating with institutions and commissioning additional investigations required for the successful implementation of the EIA programme. While developers emphasise openness and inclusiveness, the messaging directed toward the public conveys a clear intent to proceed with the offshore wind park regardless of stakeholder feedback, which raises concerns about justice and fairness in the decision-making process.

A strong example of effective evidence uptake, achieved through intensive meetings and discussions, is the relocation of the initially proposed wind park research area more than 7 kilometres further offshore. This decision followed findings from a marine protected habitat research project conducted by the Nature Conservation Agency concerning the Alku Shoal. This adjustment reduced potential risks to biodiversity and avoided overlap with a zone that could be designated as a future marine protected area.

A national and regional (Kurzeme) study on landscape qualities and associated cultural ecosystem services, conducted in 2024, has been presented at stakeholder meetings and will be promoted for integration into the EIA process and decision-making in the coming years.

Similarly, the tendering process for aquaculture development, launched in 2025, requires the winning bidder to conduct an EIA as a prerequisite. This implies that public consultations and collaboration with state institutions and municipalities are expected in the near future. It also indicates that ecosystem services-related data and knowledge will be applied progressively over the next few years. It has been agreed that the right to use the designated sea areas for aquaculture (e.g., trout farming in cages) will be granted only if the EIA yields a favourable outcome.

Challenges

In general, the major challenge is defining specific assessment criteria and identifying key environmental aspects to be evaluated. Furthermore, the limited availability of ecosystem service data for new offshore projects hampers the ability to conduct comprehensive comparisons between alternative development scenarios.

One of the key barriers is the inflexibility of developers in reconsidering alternative offshore wind research areas designated by the MSP for the development of the ELWIND offshore wind park project. Instead, the focus remains on delineating a site boundary for the construction of the wind park within a single predefined research area for offshore wind energy development. This results in a complex planning process that must reconcile the designated offshore wind energy zone with biodiversity research areas, findings from marine habitat studies, the designation of new marine protected areas, existing shipping lanes defined in the MSP, and other relevant factors—including the assessment of ecosystem services.

Similar to the offshore wind park case, developers of marine aquaculture projects have, to date, shown inflexibility in reconsidering site locations. Their interests are predominantly driven by economic considerations, often overlooking existing environmental and nature conservation policies. As a result, the remaining policy instrument—the EIA process—must integrate and present all relevant scientific evidence for the permitting process. The assessment should evaluate the potential impacts of the proposed project on marine ecosystems and their services in the Gulf of Riga, Baltic Sea, as well as assess the suitability of the selected location for cage-trout farming from both ecological and economic perspectives.

9.3.3 Interim evaluation of the MSP using new scientific information

Integration of evidence

At the time of preparing the Interim Evaluation of the MSP at the end of 2023, all relevant and up-to-date information on marine and coastal ecosystems and associated ecosystem services was collected, aggregated, and supplemented with new assessments. However, the structure of the interim assessment report limited the inclusion of this comprehensive data, allowing for only a few representative examples to be presented. Furthermore, critical information regarding potential future marine protected areas was not yet available, thereby postponing decisions on possible zoning changes. These decisions will be made once the necessary data becomes available, ensuring that any adjustments to sea use priorities within the MSP are based on sound and informed evidence.

Role of different actors, and their interactions

Stakeholder involvement in the preparation of the Interim Evaluation of the Marine Spatial Plan (MSP) was ensured through the Marine Spatial Planning and Coastal Planning Coordination Group (Coordination Group), established in November 2022. This group includes representatives from all relevant ministries and agencies, non-governmental organisations, blue economy stakeholders such as port authorities, local municipalities, and regional planning bodies.

By April 2025, a total of 15 Coordination Group meetings had been held, with seven dedicated explicitly to various MSP-related issues. These included topics such as marine and coastal ecosystems, fish resources and aquaculture potential, tourism, and cultural ecosystem services. The draft Interim Evaluation Report of the MSP was presented during the 6th meeting in October 2023 and again during the 7th meeting in December 2023. Comments and proposals received during these sessions were incorporated into the final report, which the Government officially adopted on October 1, 2024.

Challenges

The approval process for the Interim Evaluation Report of the MSP within the government was notably lengthy, spanning from December 2023 to October 2024. This delay was primarily due to conflicting interests between the energy, fisheries, transport, and nature protection sectors. While information on ecosystem services (ES) was considered, it did not play a critical role in decision-making compared to concerns regarding the potential impact on marine protected areas. Ultimately, a final agreement on the approach to the report was reached, with the understanding that solutions would be sought to enhance offshore wind park development in the next phase, during the update of the MSP.

9.3.4 Interim evaluation of the coastal plan for tourist infrastructure development

Integration of evidence

The Interim Evaluation Report of the Coastal Plan highlights the implementation of the ecosystem service approach in coastal planning. For example, The Report points out that "*Many of nature protected areas are with high recreational and tourism development potential, so it is essential to find a balance between nature conservation and tourism development goals. This can be achieved using an ecosystem services approach.*"

Furthermore, the report highlights that, "*For the sustainable and integrated development of the coast, the ecosystem services of all three groups are equally important, as they are closely interconnected. For example, tourism, as a cultural service, is linked to both the supply service—coastal fishing and agriculture—and the environmental regulating service— maintenance of habitats. In turn, fisheries are directly connected to the environmental regulating service—maintenance of habitats—because the coastal protected marine habitats, such as sandbanks and reefs, provide essential fish spawning areas and nursery grounds, thereby contributing to the diversity and abundance of fish species caught*".

Due to the narrow scope of this policy document, accessibility to the shoreline for the use of cultural ES was addressed in the Interim Evaluation of the Coastal Plan's implementation. Other evidence-based assessments were not directly incorporated into the report's content. However, the importance of ecosystem data, along with related ecosystem and ecosystem service assessments, was emphasised in the section dedicated to good governance in the coastal area. Additionally, the concluding section highlights the need to operationalise existing ecosystem service assessments within the decision-making process.

Role of different actors, and their interactions

Stakeholder involvement in the preparation of the Interim Evaluation Report of the Coastal Plan was facilitated through the same Coordination Group (Marine Spatial Planning and Coastal Planning Coordination Group), as the processes governing both the sea and coastal land are viewed as closely interconnected and were evaluated accordingly.

Since January 2024, eight Coordination Group meetings have been organised to discuss various aspects of ecosystems and ES in relation to the balanced development of coastal (water and terrestrial) areas, considering them as a single socio-ecological system. To enhance the effectiveness of the Coordination Group and ensure a broader perspective, the informational sessions on the latest data and research findings were complemented by practical teamwork and field visits to coastal municipalities. For example, the 11th Coordination Group meeting, held in June 2024, was organised as a workshop in Engure Municipality, focusing on local community interests and identity issues.

Figure 9.3. The 11th Coordination group workshop in Engure with discussions on land-sea interaction, landscapes and local identity

The final meeting to discuss the text of the Interim Evaluation Report of the Coastal Plan took place on November 13, 2024. The objections and new proposals received during this meeting were considered in the finalisation of the report before its submission to the government.

On November 13, 2024, the final meeting to discuss the Interim Evaluation Report of the Coastal Plan took place. The received objections and proposals were considered.

Information on all Coordination group meetings is published on MoSARD website: *Jūras un piekrastes telpiskās plānošanas koordinācijas grupa.*

Figure 9.4. The 12th Coordination group meeting - workshop in Carnikava (Adazi municipality)

Challenges

The development of the Interim Evaluation Report for the Coastal Plan revealed that the plan's current scope, which primarily focuses on developing public tourism infrastructure, is too narrow. It does not adequately encompass the full range of relevant ecosystem services, such as coastal fish provisioning, landscape qualities, cultural values, and local identities. Furthermore, it does not address key concepts like ecosystem accounting, natural capital, or the importance of freshwater resources.

On a positive note, the Interim Evaluation Report outlines several next steps and actions for the development of coastal areas. One key recommendation is to draft a proposal for a stronger integration of the two policy documents—maritime spatial planning and coastal zone development. As part of the update to the Marine Plan 2030, there is a need to thoroughly assess land-sea interactions and evaluate the potential impacts of new activities on the development processes of coastal municipalities. In this context, an ecosystem service assessment approach will make a significant contribution.

9.3.5 Update of the MSP for sea use with the latest biodiversity and ecosystem data.

Integration of evidence

Currently, the main focus of the work is to establish the working conditions for the update of the Maritime Spatial Plan. Therefore, the description of Decision Window 4 provides information on stakeholder interactions and capacity-building efforts in preparation for the upcoming process.

Role of different actors, and their interactions

The preparation for the revision (update) of the Maritime Spatial Plan has begun. Amendments to the Cabinet of Ministers Regulation No. 740, "Procedures for the Development, Implementation, and Monitoring of the Maritime Spatial Plan," were made in March 2025, outlining the procedure for drafting amendments to the MSP. Based on these amendments, the Ministry of Smart Administration and Regional Development (MoSARD) will prepare the terms of reference for the development of the MSP amendments, in accordance with the proposals included in the MSP Interim Evaluation Report. These terms of reference will be agreed upon within the Coordination Group.

To facilitate data access and knowledge sharing, MoSARD has developed the Maritime and Coastal Planning online platform, “Jūras un piekrastes plānošanas rīks,” as part of the Baltic Sea2Land project. The tool's functionality has already been tested by the Coordination Group, which provided feedback on improvements to both the content and technical aspects.

Figure 9.5. *The Maritime and coastal planning platform. 1st version.*
https://experience.arcgis.com/experience/dc0f3099465d46d680389717fd5dd536/

The planning platform includes a dedicated section (box) on ecosystem services, where all related data and information will be compiled, regularly updated, and expanded. The tool also provides direct links to key policy documents, including the Maritime Spatial Plan and the Coastal Plan.

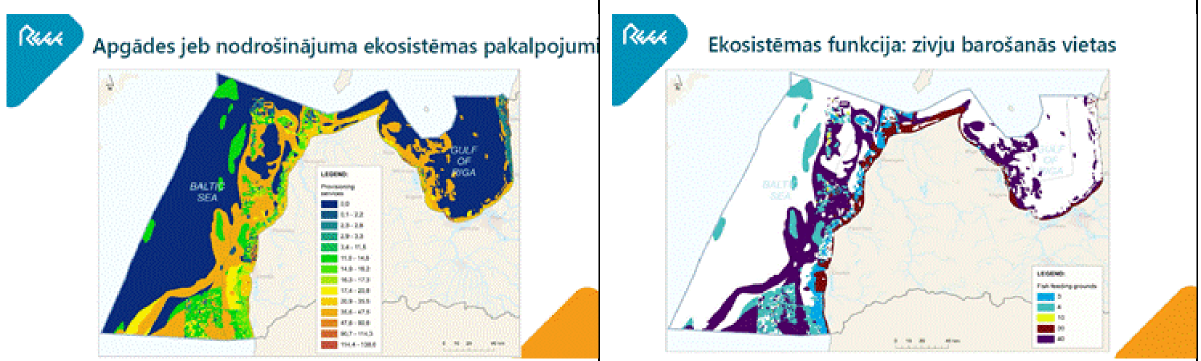
The stakeholder engagement process continues through the established MSP and Coastal Coordination Group. In addition, knowledge sharing and collaboration are further supported through the Community of Practice on Ecosystem Services, facilitated by the SELINA project.

In January 2025, the second meeting of the Latvian Community of Practice (Latvijas Sadarbības kopiena) was organised by the project team, comprising the MoSARD and the BEF. The meeting focused on ecosystem services and biodiversity issues in marine, coastal, and terrestrial areas, as well as on current activities and support provided by the SELINA project. Participants were also introduced to the FIEA and engaged in discussions on developing a standardised template to guide commissioners in conducting ecosystem service assessments.

Detailed information on the activities of the Community of Practice is available on the BEF website: https://www.bef.lv/projekti/selina-l

__Figure 9.6.__ Presentation on SELINA project ongoing activities (prepared by BEF)

Preliminary results from the LIFE REEF project have highlighted several important ecosystem service functions, such as fish feeding grounds and nursery habitats for fish fry. Detailed information can be found on the project's official website or through associated publications: https://reef.daba.gov.lv/public/



Aggregated map of provisional ecosystem services	Ecosystem function- fish feeding grounds

__Figure 9.7.__ Current affairs on the assessment of marine biodiversity and ecosystem services. Source: LHEI (S.Strāķe)

An additional meeting was held in March 2025 with key experts and planners involved in marine ecosystem and ecosystem service assessments to discuss enhanced integration of these aspects in the upcoming revision of the Maritime Spatial Plan (MSP).

In January 2025, the 14th meeting of the Coordination Group took place, focusing on upcoming marine and coastal planning activities and current developments, including the topic of multi-use of sea space. An interactive discussion was held on the concept of multi-use, which offers opportunities to combine activities from different sectors while minimising potential conflicts.

An expert was invited - maritime spatial planner Bettina Käppeler from the Federal Maritime and Hydrographic Agency of Germany, sharing valuable experience on the multiuse of sea space in Germany and Europe.

In March 2025, the 15th Coordination Group meeting was convened to initiate preparations for the update of the MSP. The latest findings from LIFE REEF project were presented, alongside information from the updated Status Assessment of the Marine Environment (*Jūras vides stāvokļa novērtējums*). The ecosystem services (ES) approach was emphasised as a fundamental principle of sustainable marine planning. A workshop was conducted to identify additional data and information needs for the MSP update, resulting in a proposal list spanning multiple sectors, including energy, transport, fisheries, tourism, and national defence. Meeting participants received valuable insights into the socio-economic evaluation of marine use from the perspective of ecosystem services.

According to the amended Cabinet of Ministers Regulation No. 740, the Coordination Group was expanded to include additional representatives from non-governmental organisations (NGOs) and the private sector. As a result, the Coordination Group now includes representatives from more than 30 organisations and institutions, reflecting a broader spectrum of stakeholders and enhancing the inclusiveness of the maritime and coastal planning process.

Figure 9.8. *The 15th Coordination Group meeting.*

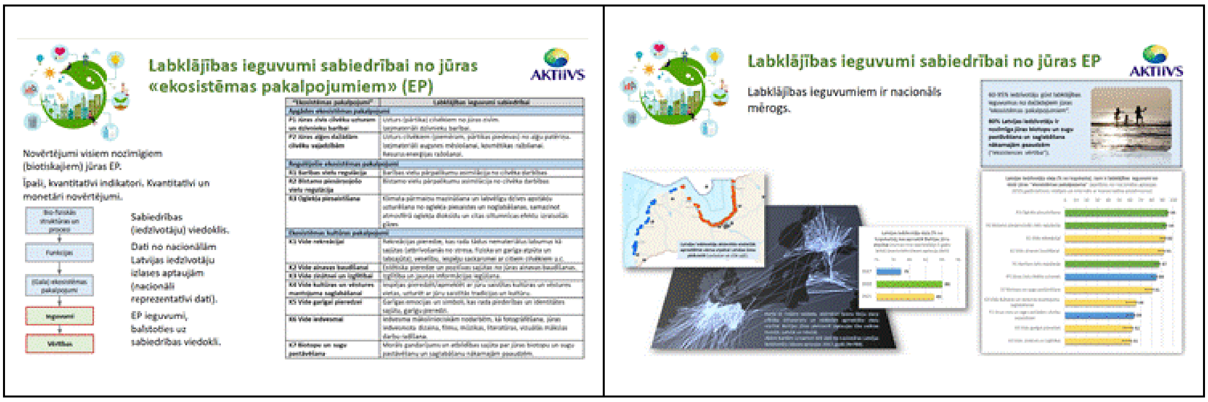


Figure 9.9. *Presentation on marine ES socio-economic evaluation. Source: www.aktiivs.lv (K.Pakalniete)*

Challenges

The results of actions in Decision Window 1 (DW1), including the marine protected habitats research from the LIFE REEF project, proposals for new strictly protected marine areas, and the outcomes of the Environmental Impact Assessment (EIA) for the ELWIND offshore wind park, must be evaluated and incorporated into the update of the Maritime Spatial Plan (MSP). However, it is too early to assess the results of knowledge integration and the outcomes of the policy reconciliation process at this sta

10 Outcomes from evaluating the appropriateness of the Integrated Ecosystem Assessment Framework for the public sector

This chapter presents the first round of testing of SELINA's FIEA version 1.3 (Figure 10.1) within the context of the public DPs. As outlined in earlier chapters, during the first phase of the project, WP8 focused on generating relevant ecosystem evidence (Task 8.2) and facilitating its integration into decision-making (Task 8.3). The FIEA testing builds on these foundations by evaluating how well the framework performs in real policy settings and whether it could effectively support the use of ecosystem evidence at appropriate decision windows. This effort was closely coordinated with WP9 to ensure alignment between public and private sector testing approaches.

The chapter describes the rationale, design, and implementation of the FIEA testing in the public-sector DPs, drawing on interviews, workshops, and activities conducted with policy and scientific stakeholders. It explores early insights into the framework's applicability, its perceived usefulness, and areas where improvements may be needed to increase uptake and impact.

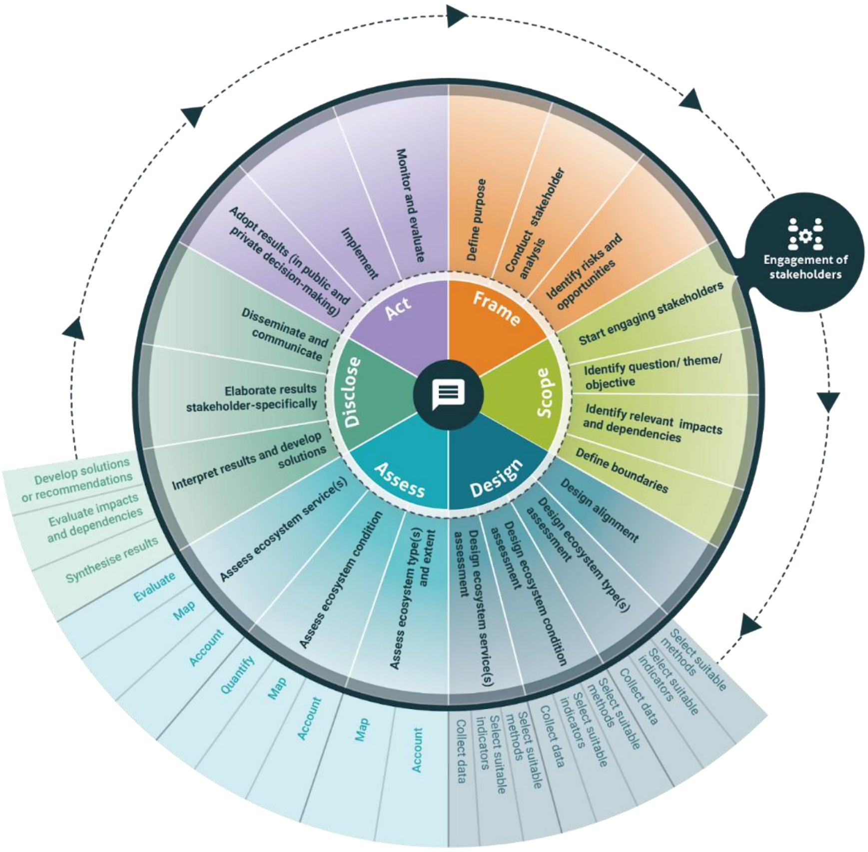


***Figure** 1: Framework for Integrated Ecosystem Assessment - "Pensoft Design" (version 1.3).*

10.1 General assessment of the FIEA

Perceived Value

The FIEA was widely recognised as a valuable conceptual tool for supporting decision-making processes that involve the integration of BD, ES, or EC evidence. Its structured, stepwise logic was appreciated for providing a systematic way to organise assessments, especially in contexts where environmental objectives must be considered alongside administrative, social, or economic goals. DPs noted that the framework helped clarify workflows and made the identification of information needs more transparent.

Importantly, DPs also found value in how the framework breaks down assessment into distinct but connected stages. This structure supported internal discussions on how environmental knowledge could inform specific actions, and the ability to visualise the whole cycle (Figure 10.1) was seen as especially helpful for reflecting on past work and planning future activities.

While the FIEA is not intended to replace or direct the decision-making process itself, it was considered helpful in aligning evidence-gathering efforts with policy needs. By structuring how and when assessments are carried out, the framework contributes to better-informed decisions, without prescribing what those decisions should be or how they are made.

Conceptual and Practical Limitations

Despite its strengths, several limitations were consistently noted. A recurrent concern was the level of conceptual complexity, especially for stakeholders unfamiliar with ES or EC terminology. While the framework seemed intuitive to research partners, its language and structure could pose barriers for users in policy-making or administrative roles.

DPs also viewed the framework as more suited to ideal scenarios where time, capacity, and data are available. In practice, however, public sector actors often operate under constrained conditions, where decision-making is time-bound, information is incomplete, and interdepartmental coordination is limited. Consequently, the framework was sometimes perceived as overly demanding or abstract, particularly in contexts that require fast, actionable insights rather than step-by-step theoretical guidance.

Furthermore, while some DPs recognised the framework's strength in clarifying "what should be done," they felt it lacked clear direction on "how to do it," particularly in contexts where institutional mandates, political timing, or sectoral priorities already shape much of the decision-making process.

10.2 Insights on specific stages of the FIEA

Framing and Scoping Phases

The early stages of the framework, which focused on identifying issues, clarifying objectives, and engaging relevant stakeholders, were widely regarded as the most practical and beneficial. These stages can help public authorities articulate policy priorities, document existing knowledge, and identify key actors and institutional dynamics. For many, the structured framing and scoping process was perceived as a means to bring clarity and coherence to complex policy environments.

Design and Assessment Phases

The middle stages of the framework, where methodologies are selected and data is gathered or analysed, were considered more challenging. The level of technical expertise required, coupled with uncertainties regarding data availability and data integration, was recognised as a risk that could create obstacles for many users. Particularly, scientific DP partners noted that some issues that could emerge are related to the types of models to use, how to evaluate trade-offs, and what kind of evidence would be acceptable. These stages were often experienced as resource-intensive and technically complex, requiring additional support at different scales.

Moreover, although the iterative nature of assessment is valued in theory, it can be challenging to implement in practice. Many public actors operate within rigid planning cycles and institutional calendars, leaving limited options for the adaptive and reflexive learning that the framework entails.

Disclose and Act Phases

The final stages, which concentrate on communicating findings and implementing decisions, were recognised as highly relevant but often fell outside the direct control of DPs piloting the framework. Many participants emphasised that scientific partners could produce assessments and engage stakeholders, but final decision-making remained in the hands of different authorities. This division of roles made the full implementation of the "disclose" and "act" phases challenging.

10.3 Alignment with DP's decision-making process

The extent to which the FIEA framework aligns with ongoing policy and planning processes is a key factor in determining its successful uptake. The evaluation with public DPs revealed that the framework was perceived as more beneficial when introduced early in the decision-making process, particularly during the strategic planning or agenda-setting phases. In such contexts, decision-makers are still defining objectives, scoping alternatives, and engaging stakeholders, which are activities that closely align with the framing and scoping steps and sub-steps of FIEA. Moreover, when employed at these early stages, the framework serves as a structuring tool, helping to clarify institutional priorities, align different departments around shared goals, and highlight evidence gaps requiring attention before implementation. Several DPs also noted that it can stimulate internal reflection and enhance coordination.

By contrast, if the FIEA is introduced at more advanced stages of policy processes, such as during implementation or after significant decisions have been made, its perceived impact could be more limited. In these instances, existing workflows, priorities, and commitments are already established, leaving little flexibility to apply a comprehensive, stepwise analytical framework. Under such conditions, DPs find it more practical to select specific elements of the FIEA and integrate them into their processes, rather than attempting to follow the full cycle.

In many instances, institutional realities also shaped how and when FIEA could be applied. For example, political transitions could disrupt the continuity required to implement the whole framework. Similarly, policy processes with tight timelines or teams with limited staff capacity might also restrict engagement with some of the steps, particularly if external technical support is not available.

The FIEA also faced challenges in contexts where policy frameworks were already well-defined, particularly in DPs with well-established environmental assessment systems, legally mandated planning tools, or spatial frameworks. In such environments, DPs required greater clarity regarding the added value of FIEA.

Overall, successful alignment between FIEA and decision processes appears to depend on three key factors:

1. Timing: Whether the framework is introduced before key decisions are made.
2. Institutional openness: The extent to which public bodies are flexible, collaborative, and willing to engage with new methods.
3. Complementarity: The ability of the framework to enhance, rather than replace or conflict with existing planning tools and regulatory obligations.

Customising the framework to reflect better the timing, structure, and language of real-world decision-making will be essential for it to function as more than a conceptual guide.

10.4 Recommendations from public DPs

To enhance the applicability and usability of the FIEA in diverse public policy settings, several suggestions have emerged from DPs experiences. These recommendations (Figure 10.1) aim to support future adaptations of the framework and facilitate its integration into real-world decision-making processes.

Figure 10.1: *Recommendations for the FIEA, as discussed with public DP representatives*

1) To support broader adoption, the language used throughout the FIEA could be made more accessible. Using more intuitive and action-oriented terms would help ensure that the framework resonates not only with scientific or technical experts but also with practitioners and policymakers who may be unfamiliar with academic or ES-related terminology.

2) Recognising that public authorities engage in decision-making at different stages, it may be helpful for the FIEA to offer more clearly flexible entry points. Allowing users to engage with specific stages based on their current planning phase or institutional priorities could make the framework more adaptable to various policy contexts and decision-making processes.

3) The inclusion of practical guidance materials (e.g., SELINA's Terms of Reference Guidance developed under D4.3), such as case studies and examples of completed processes, would support users in operationalising the framework. Tailored assistance, especially for different sectors or governance levels, could also make implementation more straightforward.

4) Providing concise explanations and visual aids to illustrate the connections between ES, EC, and BD would help users apply the framework more effectively. This could support a more consistent understanding of key concepts across different stakeholder groups-

5) As decision-making processes often evolve, the framework could be more adaptable to specific needs. Highlighting the possibility of revisiting earlier steps, adjusting priorities, and iterating over time would make the FIEA more relevant in dynamic policy environments where flexibility is often required.

6) Public institutions operate under a wide range of timelines. Offering examples and strategies for applying the framework in settings with limited resources, fragmented responsibilities, or fixed planning schedules could support a broader range of users. Building on existing DP processes and showing how FIEA can complement them would further support this integration.

11 Conclusion and next steps

This deliverable provides a mid-term evaluation of progress in generating and integrating ecosystem evidence across the SELINA public DPs. It assesses how scientific information has been mobilised to inform public decision-making in various contexts, with a focus on methodological development, stakeholder engagement, and practical application of evidence. A key emphasis is on identifying decision windows, which are critical moments where scientific input can influence outcomes. In this deliverable, decision windows (outlined and described by each DP in Chapters 3 to 9) were collaboratively identified by public and scientific partners. This process ensured that the mapped windows reflected both the strategic and procedural knowledge of public partners and the analytical perspectives of researchers.

While the concept of decision windows provides a useful lens for identifying strategic opportunities to introduce ecosystem evidence into policy processes, its practical application could face caveats worth discussing. While these are not specific to the concept itself, they reflect broader challenges in aligning scientific knowledge with real-world decision-making.

First, even when a decision window is identified and evidence appears well-timed and relevant, its uptake is not automatic. As Barton et al. (2022) noted, decision-making processes are often influenced by political dynamics, institutional constraints, and competing interests. These factors can limit the role of scientific input, even in seemingly opportune moments.

Second, Jacobs et al. (2023) emphasise that plural and sometimes contested value frameworks shape how evidence is interpreted and received. As decision windows are moments when evidence has the potential to influence outcomes, such value tensions can directly affect whether that potential is realised. Even when evidence is presented promptly, its impact may depend as much on how it is framed and perceived as on its content or scientific rigour.

Recognising these caveats, WP8 treats the concept of decision windows not as fixed moments of influence, but as potential chances for evidence integration. Their identification is therefore seen as an iterative and collaborative process that must consider the decision-making context identified earlier in the project. Across the DPs, mapping and aligning with these decision windows could also prove helpful to clarify when and how evidence can be most effectively used, guiding the organisation of data production and stakeholder engagement.

Several challenges have emerged in operationalising this approach. Policy timelines are often unpredictable, shaped by shifting political priorities or institutional dynamics, which makes it difficult to anticipate when decision windows will open or close. Even when such opportunities are identified, the specific information needs of decision-makers are not always clearly defined, and ecosystem evidence often competes with other concerns.

Another recurring issue is that policy processes do not consistently require indicators, nor are these always aligned with the priorities of stakeholders. This can limit their perceived usefulness, not because the evidence itself is weak, but because the institutional conditions for uptake are not in place. These governance-related constraints underscore a broader need, which is ensuring that ecosystem assessments are not only scientifically sound but also integrated into decision-making procecess that can effectively use them. Exploring these structural barriers would be a valuable direction for future work.

Besides these strategic challenges, DPs have encountered technical limitations in producing ES, EC, and BD evidence. Access to relevant data, especially high-resolution datasets, has frequently been delayed or restricted due to administrative barriers or institutional fragmentation. This has impacted the project's ability to generate spatially detailed outputs and to properly validate models. Other common issues include inconsistent data quality and differing technical capacities for advanced modelling.

As WP8 progresses toward its final phase, an important next step will be assessing whether and how the FIEA framework (Framework for Integrated Ecosystem Assessment) can help address the challenges identified across the DPs. While the FIEA is not expected to resolve all institutional or technical limitations, it may provide a structured approach to enhance communication, inform evidence generation, and establish clearer connections between assessment stages and decision-making needs. Deliverable 8.3 will delve into the potential of FIEA in greater detail, examining its practical utility and identifying areas for adaptation to better align with real-world policy contexts.

The ongoing use of the decision window framework will be essential in guiding DPs to completion, ensuring that scientific evidence is delivered where and when it is most relevant. The results of this phase will directly inform Deliverable 8.3, one of the key final outputs of WP8, which will offer a comprehensive synthesis of how ES, EC, and BD evidence have been incorporated into public decision-making. It will provide both an evaluation of project achievements and practical guidance for the future application of ecosystem-related evidence in policy.

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Annex I: Links to supplementary materials

The following resources are available via Google Drive:

- Preliminary survey on DP methodological needs: Available at https://drive.google.com/drive/u/0/folders/1J5dYiYmcRycDwpGTnraZOkazyxC3P31M

-Interview Guideline (first round): Available at: https://drive.google.com/drive/u/0/folders/11FdqLPfLFz1HpFsUtXLyNEMMmvFxK5Zx

- Individual DP Meetings for Task 8.2 (first round): Available at https://drive.google.com/drive/u/0/folders/1CcXonHz09sQadreaNG3LEJ3Cpbr93AFD

- Individual DP Interview results for Task 8.3 (first round): Available at https://drive.google.com/drive/u/0/folders/1PG_ZmH2cvoye4XLDhfaRteDo1iEQ30WM

- Comprehensive results from public DP interviews (Task 8.2): Available at https://drive.google.com/file/d/196gYtjbg1kymhZGlRJUzG1BzZzsq9S-y/view?usp=sharing

-Results from DP meetings for Task 8.3 (second round) and FIEA validation: Available at https://drive.google.com/drive/u/0/folders/1KEO9Q9_aqXlLOa_gHmmNbzKfLwe-kjG1

-Results from the first round of FIEA testing by public DPs: Available at https://drive.google.com/drive/u/0/folders/1ZpRFRmexhst_2Kdp72a0K-oeSRU_A4Mr

-Slide deck on comprehensive FIEA feedback from public DPs: Available at: https://docs.google.com/presentation/d/1w3ZwFiLOIA0jRQBpoTs3e6i0Fy-B8AbG/edit