from
Nexus **Thinking** to
Nexus **Doing**

REXUS

NbS in the WEFE Nexus

A framework for integrating Nature-based Solutions into strategies to address interconnected Water, Energy, Food and Ecosystem challenges

Funded by
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Acronyms and Abbreviations

CBD	Convention on Biological Diversity
CLD	Causal Loop Diagram
COP	Conference of the Parties
EbA	Ecosystem-based Adaptation
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
EU	European Union
GBF	Kunming-Montreal Global Biodiversity Framework
GCM	Global Climate Model
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MCA	Multi-criteria analysis
MEA	Millennium Ecosystem Assessment
NAP	National Adaptation Plan
NbS	Nature-based Solutions
NbSI	Nature-based Solutions Initiative
NCPs	Nature’s Contributions to People
NGO	Non-governmental Organization
PES	Payment for Ecosystem Services
PSDM	Participatory Systems Dynamics Modelling
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SuDS	Sustainable Drainage Systems
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WEFE	Water-Energy-Food-Ecosystems

Introduction to this REXUS Framework guide

The Water-Energy-Food-Ecosystems Nexus

Climate change, population dynamics, economic growth and urbanization are putting pressure on scarce resources (World Economic Forum 2024). These challenges have grown in recent years and interact in dynamic ways, often amplifying the overall impacts on people and nature. Growing demand for resources creates trade-offs, which are complicated by the impacts of climate change (World Economic Forum 2024). To address these challenges, it is important to understand the links between the water, energy and food sectors (Simpson and Jewitt 2019) and recognize that focusing on one sector in isolation cannot lead to sustainable solutions (Sivakumar 2021). This guide aims to help practitioners consider both the challenges and potential solutions across sectors (in this case water, energy and food) and highlights the important role that ecosystems play – referred to in this document as the Water-Energy-Food-Ecosystems (WEFE) Nexus.

The WEFE Nexus approach is a powerful concept for addressing the interrelationships between resource systems (e.g., food, water and energy) and ecosystems (Carmona-Moreno et al. 2021). It recognizes the dependencies and impacts that water, food and energy systems have on each other and on ecosystems, and the challenges that are presented when they interact. It also highlights the difficulties of efficiently using and managing natural resources to achieve water, energy and food security and build resilience across sectors. These are the WEFE Nexus challenges. The WEFE Nexus approach encourages better coordination and use of natural resources by considering trade-offs and moving towards synergies between different objectives. However, progress in terms of incorporating Nexus thinking into practical policy-making has been slow (Sivakumar 2021).

Considering the WEFE Nexus challenges in an integrated manner will help reveal solutions that are more effective than if the challenges are addressed individually. These solutions can include traditional 'grey' solutions, Nature-based Solutions (NbS), hybrid solutions or changes to regulations or incentives (often referred to as the enabling environment). A WEFE Nexus strategy – a set of solutions to address the WEFE Nexus challenges – could use several of these options in combination. NbS can address WEFE Nexus challenges by helping to secure ecosystem service provision and enhancing the climate resilience of the whole system.

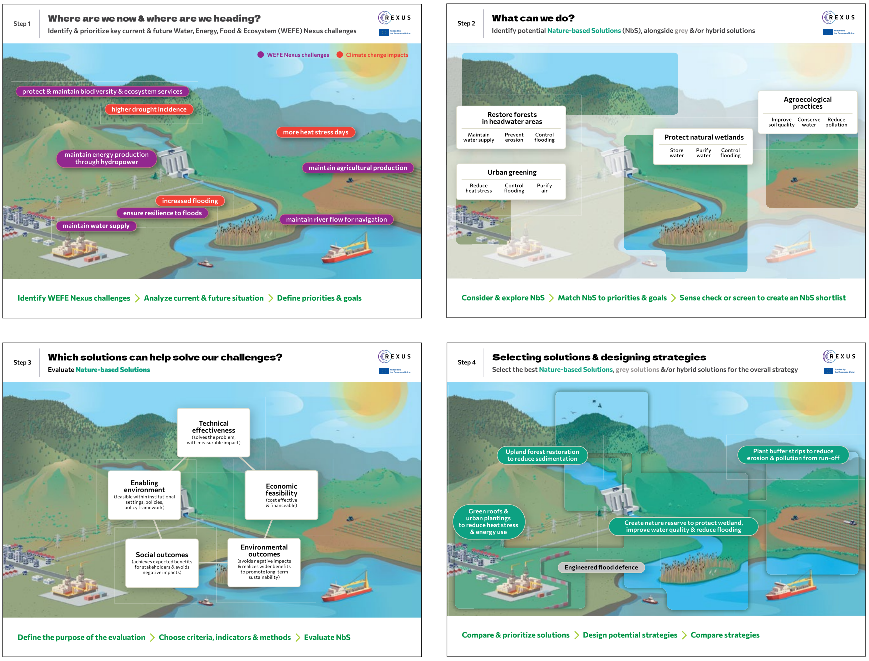
The REXUS Project

The REXUS Project[1] aimed to close the gap between science and policy, moving from 'Nexus thinking' to 'Nexus doing'. It has brought together scientific tools and an integrated vision necessary to analyze real-world conditions, including trade-offs and climate risks. By employing a methodology called Participatory Systems Dynamic Modelling (PDSM), it has helped design sustainable and actionable solutions that increase resilience across sectors. These solutions will form the basis of forward-looking and participatory decision-making to develop WEFE Nexus strategies.

The REXUS Framework (Figure 1), developed as part of the REXUS project, is designed to help practitioners think about solutions to WEFE Nexus challenges, particularly how NbS can fit into integrated WEFE Nexus strategies. For more information on how wider REXUS activities link to the REXUS Framework, please see Annex 1.

Figure 1

REXUS Framework Infographic



1 REXUS finished in October 2024 but aims to continue supporting the move to 'Nexus doing' beyond the duration of the project through its outputs.

Step 1

Where are we now & where are we heading?

Identify & prioritize key current & future Water, Energy, Food & Ecosystem (WEFE) Nexus challenges

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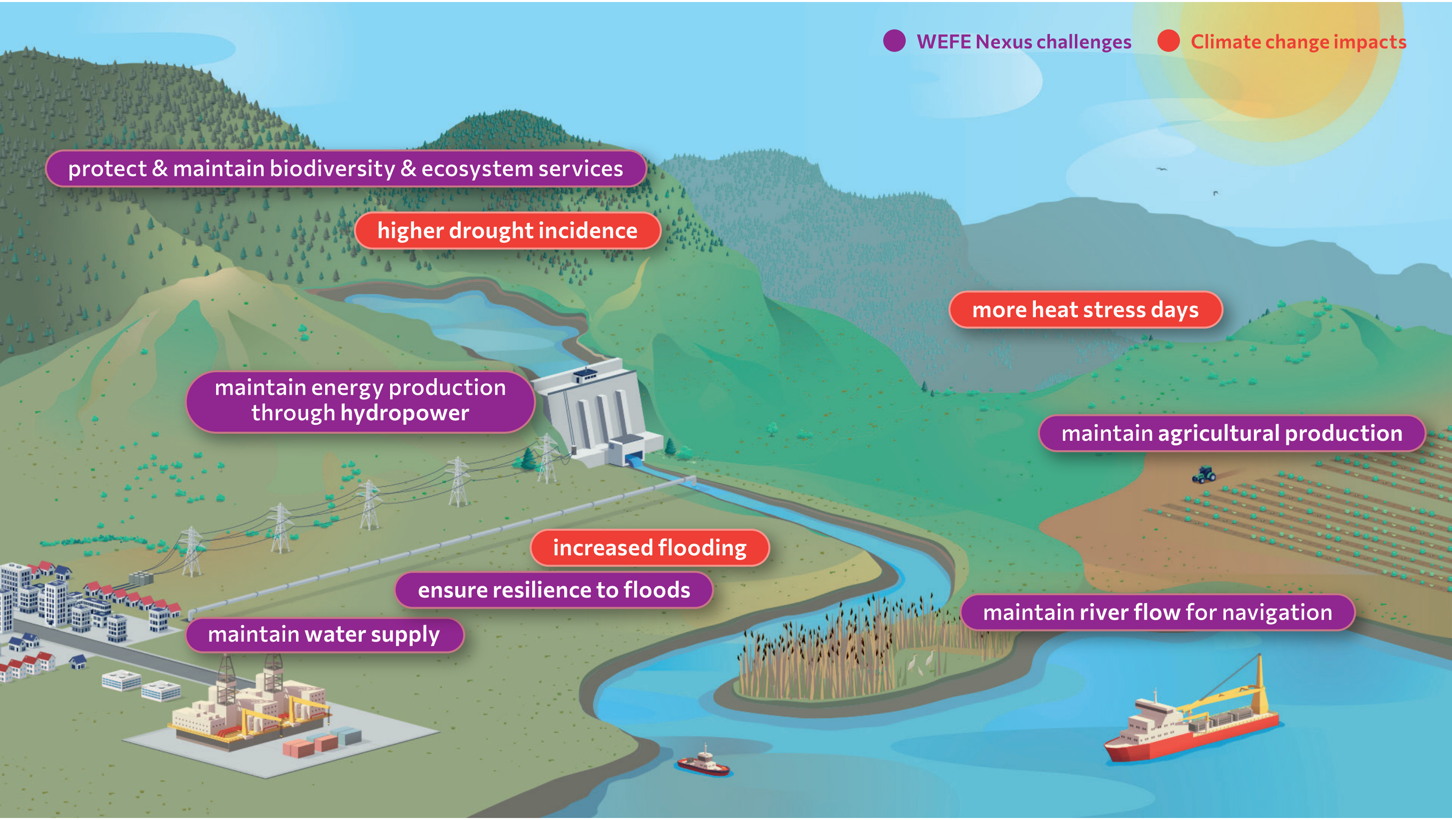
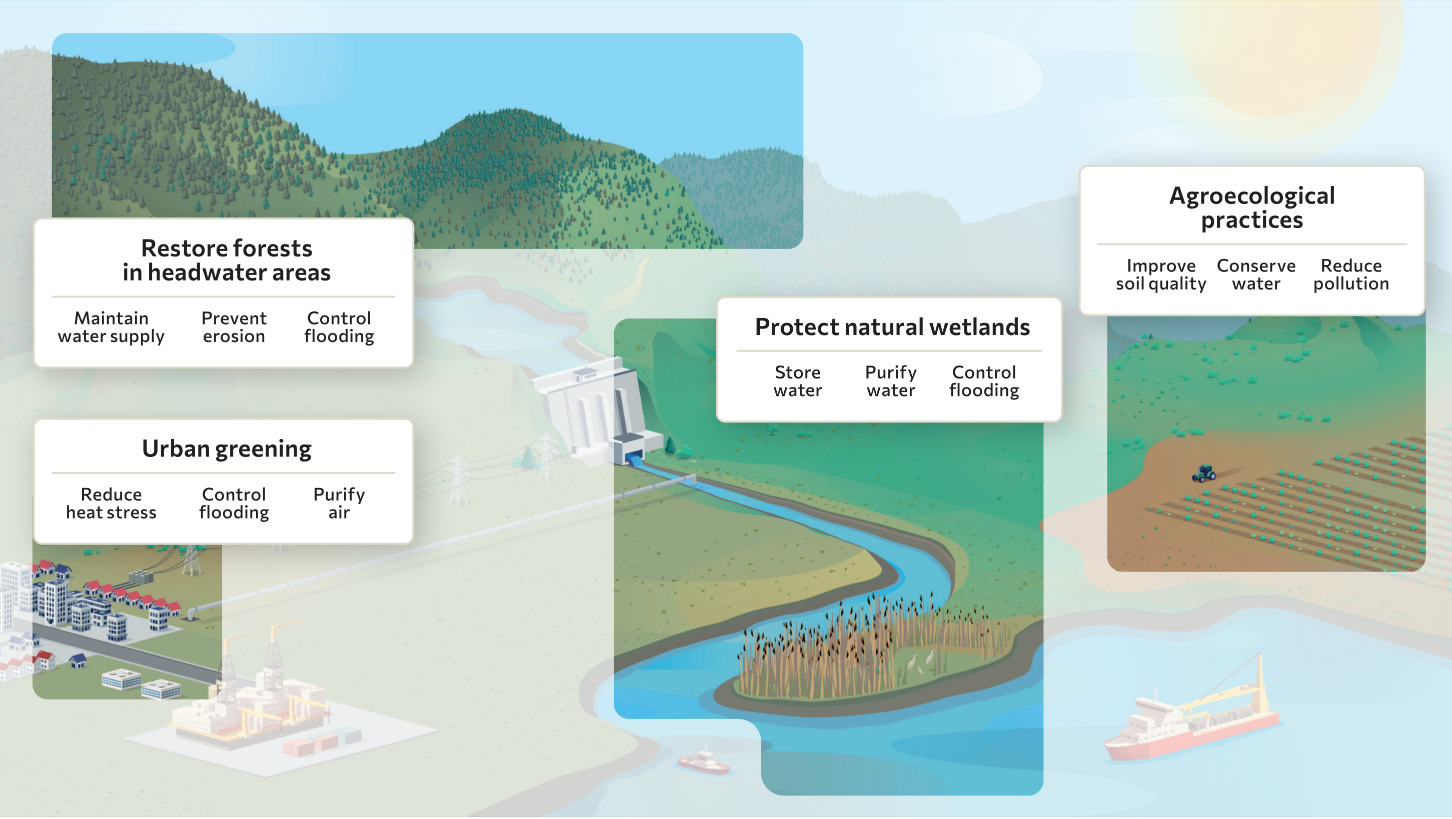


Identify WEFE Nexus challenges > Analyze current & future situation > Define priorities & goals

Step 2

What can we do?

Identify potential Nature-based Solutions (NbS), alongside grey &/or hybrid solutions



Consider & explore NbS > Match NbS to priorities & goals > Sense check or screen to create an NbS shortlist

Step 3

Which solutions can help solve our challenges?

Evaluate **Nature-based Solutions**

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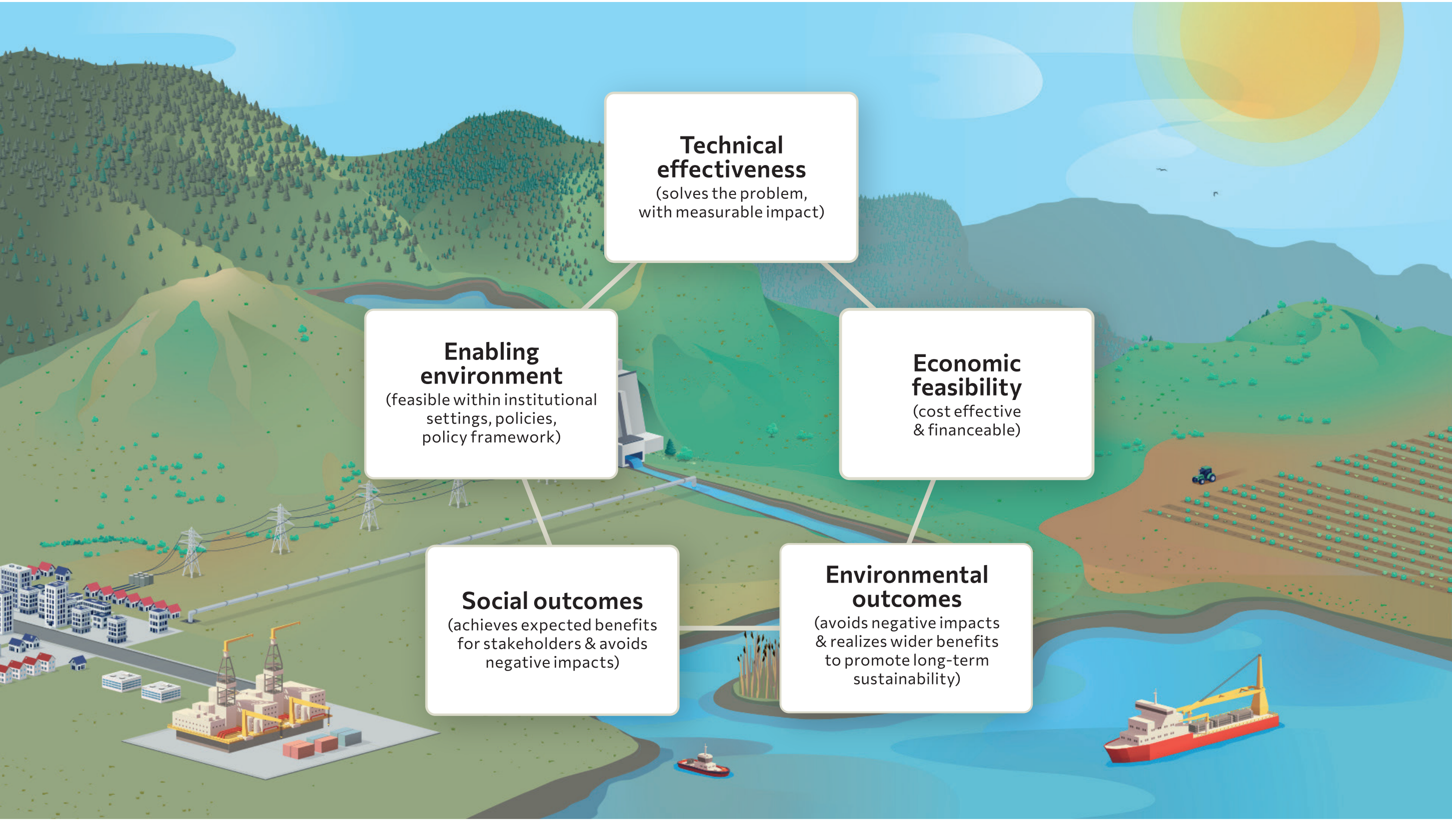

Define the purpose of the evaluation > Choose criteria, indicators & methods > Evaluate NbS

Step 4

Selecting solutions & designing strategies

Select the best Nature-based Solutions, grey solutions &/or hybrid solutions for the overall strategy

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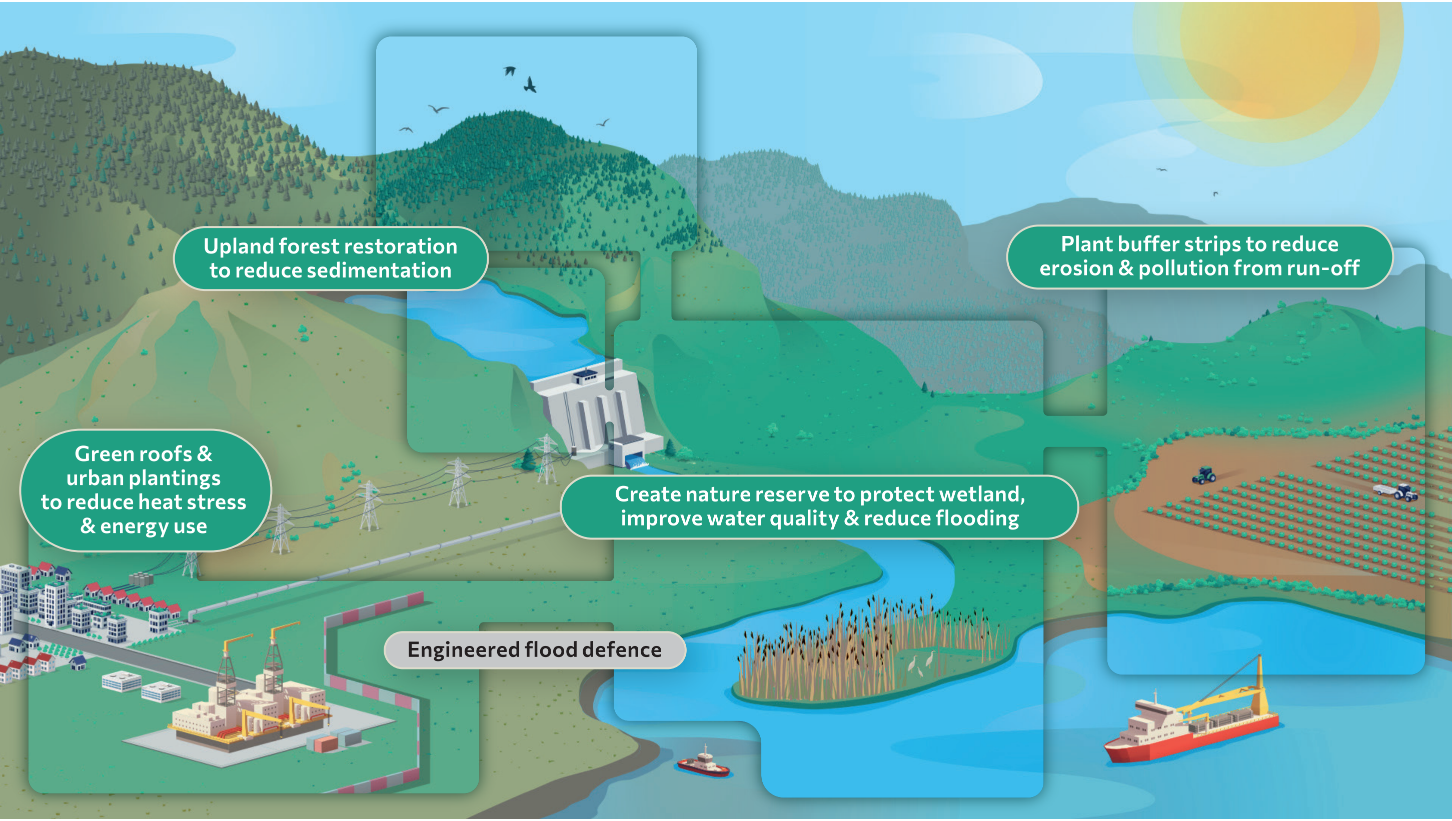


Compare & prioritize solutions > Design potential strategies > Compare strategies

BOX 1

REXUS PILOTS

REXUS worked with the following five pilots to understand how NbS can be better integrated into decision-making to address WEFE Nexus challenges:

- Pinios River Basin – Greece.
- Peninsular Territory of Spain.
- Nima River Watershed – Colombia.
- Isonzo / Soča River – Italy, Slovenia.
- Lower Danube – Romania, Bulgaria, Serbia.

More information on these pilots can be found on the REXUS website and in the REXUS Baseline Description document.

As part of this process, the REXUS Framework has been used to help stakeholders in pilot areas understand the potential impacts of different solutions on the WEFE Nexus overall. Instead of being a decision-making tool, it aims to support relevant stakeholders to identify and consider a range of potentially suitable solutions to their specific WEFE Nexus challenges and increase the resilience of their solutions. This document guides practitioners through the key steps for doing this.

About this guide

The purpose of this guide

This interactive guide to the REXUS Framework takes practitioners through the steps of the REXUS Framework to help them select suitable solutions to address their WEFE Nexus challenges. There is a particular focus on ensuring that Nature-based Solutions (NbS) are considered alongside other solutions. This guide highlights a range of materials for selecting solutions that can address WEFE Nexus challenges and enhance resilience to the impacts of climate change. It considers the information that will likely be needed and how the various solutions could be assessed in a given context. Examples of solutions that could be included in an overarching WEFE Nexus strategy are also provided, both from the wider REXUS project and the associated pilot areas. The guide also discusses starting points for the next steps (implementation and monitoring) once solutions are identified.

Who is the guide for?

This guide is aimed primarily at practitioners. The guide is designed to help all those involved in the planning, assessment and stakeholder consultation stages of choosing solutions to include in a strategy to address WEFE Nexus challenges. Box 2 provides some potential use-cases for applying the guide.

BOX 2

USE-CASES

This guide is aimed at technical experts from water, energy, food and ecosystem-related sectors. This could include technical experts from fisheries agencies, river basin authorities, irrigation authorities, agricultural groups, research institutes, environmental organisations, and energy companies (among others).

The REXUS Framework guide is designed to help technical experts determine how to indentify and select solutions to address challenges across sectors, to promote synergies and reduce trade-offs. The framework process outlined in this guide specifically ensures that the potential for NbS to contribute to water, energy, and food security is fully captured when designing strategies, allowing users to:

1. Understand how NbS can help to address WEFE challenges in the area being considered.
2. Determine how NbS can complement or even be substituted for grey infrastructure and produce multiple benefits.
3. Compare different solutions (e.g. NbS with grey) to select those that are likely to produce the most benefits and the fewest trade-offs across the WEFE Nexus.

This process could be applied over a wide range of spatial and temporal scales, including local, regional, national and global.

EXAMPLE USE CASE

This hypothetical use case illustrates how technical experts could use the REXUS Framework guide as part of the process to develop a new strategy (in this case through a management plan) at the river basin scale.

PRIMARY ACTOR/ PRACTITIONER

River basin authority

TECHNICAL EXPERT

Senior water modeller

SCALE

River basin scale

SCENARIO

A river basin authority is due to update its river basin management plan. The authority needs to ensure sufficient water supply for agriculture to maintain agricultural productivity, and also meet other water consumption needs. A senior water modeller is trying to understand what innovative solutions are available, especially in the face of climate change and given that current measures (mostly grey infrastructure) are not fit for purpose. They begin to ask questions such as "Where could water use efficiency be improved?" and "How could water supply be increased?"

The senior water modeller thinks that some of the challenges could be improved by collaborating with other sectors. For example, the irrigation systems in place in local agricultural areas are outdated and inefficient and result in high water loss. They are also aware that the reservoirs in the area are having to be dredged more frequently, and water quality is decreasing as a result of increased sediment. They've noticed that this seems to be linked to vegetation removal in the upper area of the catchment, which has increased in recent years to supply a local biomass plant.

They have heard that 'NbS' have the potential to increase water retention and reduce erosion, and wonder if NbS might help to manage water into the future. However, they are unsure of how NbS compare with traditional solutions that they are more familiar with. They would therefore like to understand what NbS are, what 'types' of NbS have the potential to secure water resources into the future, and whether they would also have additional benefits for other sectors.

The modeller uses the REXUS Framework guide to understand which NbS are relevant for their challenges, how to determine their likely outcomes and how they compare with traditional solutions, as well as how to incorporate them into an overarching strategy combining different solutions.

How to use this guide

This guide is designed to be interactive and to facilitate easy navigation between different sections. Throughout the guide, examples are provided from the REXUS pilot areas to illustrate how the REXUS Framework has been applied in practice. More detailed information on the work the REXUS project has done and some of the methodologies and concepts that could be used as part of the REXUS Framework are provided in the Annexes. An explanation of the interactive features in this document, and how to use them, is provided below.

Feature	Explanation	How to use it
Highlighted in blue	**More information** is provided as a pop-up.	Hover the mouse over/click the feature and a box will appear to the right of the document
Underlined word in purple	**Link** to elsewhere in the document	Click the word and the document will scroll to the relevant feature (e.g., a box, figure or other section of the report).
Underlined in blue	**External link** to websites or other resources	Click on the word to be taken to an external source of further information.
	This feature provides a **'tip'** relevant to the section of the document. This could refer to other sections or highlight important things that should be considered at this stage.	Click on the feature and a blue box will appear containing the tip.
	Additional resources and detailed methodologies associated with different sections of the document are provided in the technical annex.	Click on the feature to go to the associated resources within the guide.
	Case study examples for each step of the framework process are provided from the REXUS project.	Click the feature to navigate to an example of how the REXUS project included different steps of the framework.
	The **Return button** enables you to return to the first point in the main guide where a technical annex is referenced.	Click on the feature to navigate back to the section of the main guide from the technical annex.

Nature-based Solutions and multiple benefits

What are Nature-based Solutions?

Nature-based Solutions (NbS) are actions that protect, conserve, restore, sustainably use and manage nature in a way that helps address social, economic and environmental challenges while providing multiple benefits (Box 3). These benefits include providing ecosystem services that benefit biodiversity and human well-being. NbS are increasingly recognized in both policy and practice as an approach that tackles multiple challenges and provides multiple benefits (Cohen-Shacham et al. 2016).

BOX 3

KEY DEFINITIONS

Nature-based Solutions (NbS) are *"actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits".* (United Nations Environment Assembly 2022)

Ecosystem-based adaptation (EbA) is *"the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change"* (Secretariat of the Convention on Biological Diversity (CBD) 2010) *"that takes into account the multiple social, economic and cultural co-benefits for local communities"* (CBD 2010).

Ecosystem services are *"the contributions of ecosystems to the benefits that are used in economic and other human activity"* (United Nations et al. 2021, p. 27) including the benefits that contribute to human well-being.

NbS can include a variety of activities; for example i.e., restoring upland forest areas to reduce the risk of landslides or constructing wetlands to improve water quality (Box 4). They can be used in addition to, or in some cases instead of, other solutions.

BOX 4

CONSTRUCTED WETLANDS AS NBS TO IMPROVE THE ENVIRONMENT FOR PEOPLE AND NATURE IN ITALY

This NbS project in northern Italy created nine hectares of constructed wetlands – the Gorla Maggiore water park – on the Olona River between 2011 and 2012. It primarily aimed to reduce water pollution from nearby urban areas. The wetlands successfully improved water quality and analysis (Liquete et al. 2016) suggests they were more effective than alternative grey infrastructure solutions, while providing additional benefits. These constructed wetlands provided multiple ecosystem services by reducing flood risk at a local level and providing green spaces for nearby city-dwellers. Furthermore, they provide habitat for wildlife, supporting bird and amphibian populations (Liquete et al. 2016).

(Liquete et al. 2016)

The multiple benefits of Nature-based Solutions

NbS have the potential to not only address specific challenges, like flooding, (often referred to as a primary benefit) but to also generate additional benefits (often referred to as co-benefits; Box 5). In the example of constructed wetlands in Box 4, the primary benefit was increased water quality, and the co-benefits were reduced flooding, green spaces and habitat creation. In contrast, the grey infrastructure solution (a storage tank) might only provide the primary benefit. Therefore, NbS have huge potential to deliver multiple benefits and achieve synergies with other goals, like biodiversity conservation.

As with any solution, it is important to not underestimate the potential for disbenefits and trade-offs (Box 5). Focusing on delivery of a particular outcome from a solution may mean maximizing one benefit to the detriment of others. For example, if the focus of a reforestation project is on maximizing carbon mitigation benefits, tree species may be chosen that sequester large amounts of carbon (but do not provide many benefits for wildlife or people) over using a mix of location-appropriate species (that sequester less carbon but provide a range of habitats for wildlife and varied food sources for local communities) (Seddon et al. 2021). Both synergies and trade-offs between different outcomes may be inevitable and need to be identified as early as possible when assessing solutions.

BOX 5

TYPES OF BENEFITS

- **Primary benefits** from NbS and grey solutions are the positive contributions they make to achieving the main aim(s) of implementing the solution. For example, if the key purpose of a solution is to increase the resilience of coastal communities by reducing coastal flood risk, the primary benefit of the solution might be the 'avoided damages' resulting from the reduction in the frequency or severity of coastal flooding (Le Coent et al. 2021).

- **Co-benefits** are the additional benefits from solutions. For example, a solution that aims to reduce coastal flooding risk may also lead to an increase in the extent of high-quality fish spawning areas (a biodiversity benefit). In turn, the increase in fish populations could support local livelihoods (a socio-economic benefit). Raising awareness of the multiple benefits and beneficiaries of solutions like NbS can help stakeholders take a more holistic view and find the set of solutions that best address their challenges and priorities.

- **Disbenefits** are negative effects of solutions. They are also referred to as disadvantages or disservices. Disbenefits can be social, environmental or economic. They can be experienced by the population at large or a specific group of stakeholders. For example, growth in property prices in a neighbourhood where NbS were implemented may benefit homeowners in the area, but could mean renting is less affordable resulting in social exclusion (Anguelovski et al. 2019). Similarly, increasing biodiversity might result in more pollen or mosquitoes, having negative consequences for human health (Ommer et al. 2022). Where there are disbenefits in one part of the Nexus but co-benefits in another, there can be trade-offs, for example between biodiversity and human health in the example above.

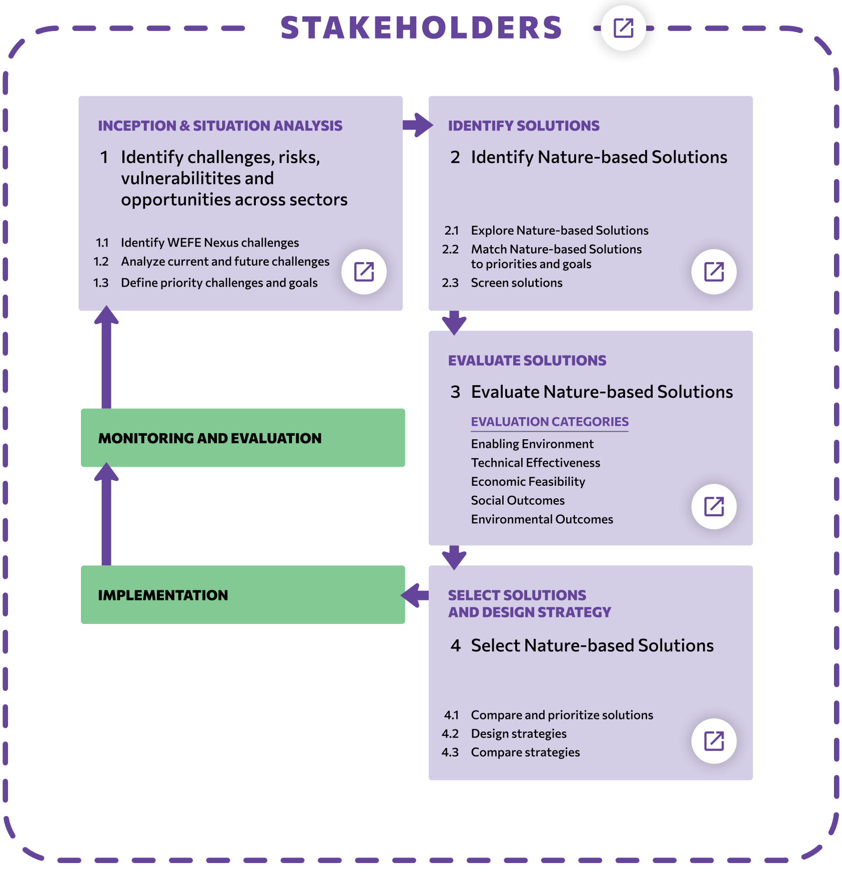
- **Intangible benefits** are benefits that are difficult to assign a monetary value to. They are often linked to human perception. For example, improved mental well-being, recreation opportunities or improved social cohesion are harder to quantify than reduced flooding. A range of methodologies exists to assess and/or quantify these benefits (Viti et al. 2022).

Framework steps

This section outlines the four broad steps of the REXUS Framework (Figure 2), highlights some good practice principles for stakeholder engagement (Box 6) and summarizes how the REXUS Framework can be linked to other frameworks (Box 7). The four steps aim to support the consideration and integration of NbS into strategies that address WEFE Nexus challenges. Although these steps can be used for all types of solutions, this guide highlights key aspects that are especially important for incorporating NbS, drawing on lessons learned in REXUS pilot areas. In this guide, relevant resources are provided for each step, with detailed methodologies available in the Annex.

Figure 2

The REXUS Framework



Stakeholder Engagement

The REXUS Framework (Figure 2) is built on and informed by stakeholder engagement, which was a core part of the REXUS project. The participatory processes undertaken by REXUS (e.g., stakeholder meetings, workshops, interviews) played a major role in the successes achieved in the different pilot areas.

Recognizing that the complex challenges that occur across the WEFE Nexus need multidisciplinary solutions that work across the whole system, the REXUS stakeholder engagement strategy targeted actors across sectors. The aim of this approach was to ensure a diverse range of priorities, mandates, knowledge, and societal roles were included in discussions. It also encouraged cooperation and integration of different knowledge from stakeholders and actors that do not normally work closely with each other, which helped to increase the understanding of WEFE Nexus challenges from different perspectives. The mutual learning and knowledge exchange that resulted from the stakeholder engagement helped to reduce conflict and increase support for the decisions made.

Stakeholder engagement under the REXUS project was built on three core ideas:

- **Co-production:** WEFE Nexus challenges and candidate solutions were identified and explored in a collaborative and inclusive manner. This integrated technical and practical knowledge and perspectives from stakeholders helped develop a comprehensive picture.
- **Cross-fertilization:** Knowledge exchange under REXUS was promoted through Learning Action Alliances (LAAs). LAAs facilitated in person engagement (e.g. through workshops) and online interactions through an online knowledge platform that acts as an information repository for pilot areas. The aim of the LAAs was to favour mutual learning between different actors, including technical and practical experiences (e.g., good and bad practices) to support the co-creation process.
- **Capacity building:** Different knowledge generated through the project was introduced and demonstrated though workshops and interviews, with the intention of enhancing technical and institutional capacities for Nexus management.

Guidelines for Stakeholder Engagement: These were developed to describe the stakeholder engagement approach that was developed through REXUS. The approach to implementing the REXUS Framework was structured around the steps outlined below (see the REXUS Guidelines for Stakeholder Engagement for further detail and methodologies). All pilots completed all of these steps, but the participatory activities were adapted in each case:

Preparation phase: This included a stakeholder mapping exercise to identify the stakeholders to be invited to join pilot LAAs (see Section 3.2. of the REXUS Guidelines for Stakeholder Engagement). It also included a kick-off meeting to introduce the project, start to identify and discuss some of the main WEFE Nexus challenges, and determine how the REXUS project could help to address some of these challenges in the pilot areas. This links to Step 1 of the REXUS Framework (Figure 2).

Problem identification and framing: This step aimed to gain a deeper understanding of the key WEFE Nexus challenges for each of the pilot areas, as well as the drivers of these challenges and connections (synergies and trade-offs) between sectors. This was mostly achieved through stakeholder interviews (to define the system and its interlinkages) and a workshop during which stakeholders contributed to a participatory mapping exercise (to further explore challenges, where they occur (hotspots), drivers, risks and opportunities). Problem identification and framing was key to informing and ensuring the usefulness of Steps 1 and 2 of the REXUS Framework (Figure 2).

Assessment of Nexus solutions and pathways: A participatory scenario exercise was conducted through a stakeholder workshop. Using a simplified map of the main challenges identified in the first workshops, stakeholders were asked to identify future trends up to 2050 under a scenario where no change in the course of action is expected (business-as-usual). Stakeholders were then asked to develop a sustainable vision that defined and incorporated some key WEFE sectoral goals to be achieved by 2050. Stakeholders then proposed potential solutions to achieve this vision of a sustainable future, drawing inspiration from a longlist of solutions provided by the facilitators. This helps to inform the identification of viable solutions in Step 2 and understand what impacts are important to evaluate in Step 3 of the REXUS Framework (Figure 2).

Validation and action plan: During this step, the proposed solutions were refined and an action plan was developed. A further stakeholder workshop was conducted to validate the action plan with the selected solutions to address WEFE Nexus challenges in pilot areas. This links with Step 4 of the REXUS Framework (Figure 2).

Some general principles of effective stakeholder engagement that informed the REXUS project and that should be integrated into decision-making processes on WEFE Nexus challenges are provided in Box 6.

BOX 6

GOOD PRACTICE PRINCIPLES FOR ENSURING EQUITABLE ENGAGEMENT OF STAKEHOLDERS AND RIGHTSHOLDERS IN THE DESIGN OF NbS

Effective stakeholder engagement is underpinned by an understanding of who the stakeholders are and the relationships between them, such as their decision-making roles and status. Stakeholder engagement can provide important input, context and feedback for different activities, including by:

- Incorporating Indigenous and local knowledge that is critical to understand the challenges and to identify and assess / validate solutions.
- Helping gather data (e.g., historical climate data), particularly where information for specific areas may not be available or registered in official records.
- Providing qualitative information, such as perceptions of environmental challenges and climate risks in the local area.
- Contributing to participatory monitoring to ensure stakeholders are informed as well as motivated to invest in and implement solutions.
- Providing information on local prices and costs associated with planning and implementing solutions.
- Incorporating a broad range of perspectives in and improving the transparency of decisions.
- Agreeing on the methods to evaluate solutions and validate expected impacts of the solutions.

Consultation processes can also be an opportunity to share information (and dispel misinformation) on NbS, build trust and help develop a common understanding of the challenges and opportunities.

Any consultation process (e.g., workshops, interviews or surveys) should be representative of all local stakeholder groups, with particular attention to ensuring the equitable participation of groups who may typically be underrepresented in public consultations such as women, elders, youth and migrants, as locally relevant. This is important for ensuring that the knowledge, needs and perspectives of the whole community are taken into account when identifying solutions. To ensure equitable participation of these groups in consultations, it may be necessary to identify and appropriately accommodate different practical and social needs that are key to participation. This may include considerations around the timing and location of meetings, accommodating accessibility and/or language requirements, having an awareness of power imbalances between participants and adapting the format of engagement accordingly, and so on.

Stakeholder consultations in which vulnerable groups are well-represented and able to contribute will support more accurate assessment of the potential social impacts of the proposed solutions, helping to prioritize actions, needs and expectations. Throughout the process of stakeholder consultation, both decision-makers and stakeholders gain insights into the system and its performance under different solutions, including how some solutions can address multiple challenges.

The Guidance for using the IUCN Global Standard for Nature-based Solutions (International Union for Conservation of Nature 2020) highlights the importance of stakeholder engagement under Criterion 5: NbS are based on inclusive, transparent and empowering governance processes. According to the criterion, the following should be in place:

C-5.1 A defined and fully agreed upon feedback and grievance resolution mechanism is available to all stakeholders before an NbS intervention is initiated.

C-5.2 Participation is based on mutual respect and equality, regardless of gender, age or social status, and upholds the right of Indigenous Peoples to Free, Prior and Informed Consent (FPIC).

C-5.3 Stakeholders who are directly and indirectly affected by the NbS have been identified and involved in all processes of the NbS intervention.

C-5.4 Decision-making processes document and respond to the rights and interests of all participating and affected stakeholders.

C-5.5 Where the scale of the NbS extends beyond jurisdictional boundaries, mechanisms are established to enable joint decision-making of the stakeholders in the affected jurisdictions.

Further resources:

BiodivERsA Stakeholder Engagement handbook – provides best practice guidelines for stakeholder engagement in research projects.

Stakeholder Engagement Guide for Nature-based Solutions – provides guidelines for effective stakeholder engagement for NbS projects.

Real Deal – A community of Europeans who are taking action to build a new model of environemtal citizenship for Europe.

BOX 7

LINKS TO OTHER FRAMEWORKS

The REXUS Framework is designed to be complementary to other processes and frameworks that might be used to help identify solutions to WEFE Nexus challenges. However, unlike frameworks that focus on specific elements of the Nexus (like water), the REXUS Framework aims to consider challenges and solutions across the WEFE Nexus.

The aim is for the REXUS Framework to be aligned with other processes and to be used to support and enhance them. Unlike some other sector specific frameworks, the REXUS Framework focuses on promoting the consideration of NbS through cross-sectoral dialogue to address WEFE challenges in an integrated way. The steps of the REXUS Framework are closely linked to other frameworks and so can be used in conjunction with other processes. For example, many of the activities in Step 1 of the REXUS Framework (Figure 2) link closely with the early scoping phases of different planning processes, including those listed below.

- **The World Business Council for Sustainable Development** (WBCSD) developed their ‘NbS Blueprint’ (WBCSD 2024) with six stages to ‘Build a business case for NbS’:

1. Identifying key challenges and opportunities;
2. Exploring NbS relevant to challenges and opportunities;
3. Collecting information on benefits and trade-offs;
4. Developing an initial design;
5. Cost estimation;
6. Cost-benefit analysis across other solutions.

- **The World Bank** provides an eight-step implementation framework for nature- based flood protection (World Bank 2017):

1. Defining problem, scope and objectives;
2. Developing financial strategy;
3. Ecosystem, hazard and risk assessments;
4. Nature-based risk management strategy;
5. Costs, benefit and effectiveness analysis;
6. Selecting and designing intervention;
7. Implementing and constructing;
8. Monitoring.

- **The Connecting Nature Framework** (Holscher et al. 2022) defines three phases – Planning, Delivery and Stewardship – with seven elements – technical solutions; governance; financing and business models; nature-based enterprises; co-production; impact assessment; and reflexive monitoring – each with their own steps.

- **The United Nations Office for Disaster Risk Reduction (UNDRR)** provides a toolbox for integrating NbS into disaster and climate risk management (United Nations Office for Disaster Risk Reduction and United Nations University - Institute for Environment and Human Security 2023).
They provide five tools for five steps in planning for NbS:
1. identifying and mapping country context;
2. summarizing the status of NbS in the country;
3. identifying suitable measures;
4. identifying stakeholders;
5. creating opportunities for NbS in integrated planning.

STEP 1

Identify challenges, risks, vulnerabilities and opportunities

Inception & Situation Analysis

1 Identify challenges, risks, vulnerabilities & opportunities across sectors

1.1 Identify WEFE Nexus challenges

1.2 Analyze current and future challenges

1.3 Define priority challenges and goals

When to use this step

This step will help answer the following questions:

- What are the dependencies on nature (e.g., what ecosystem services do people particularly depend on)?
- What are the relevant WEFE Nexus challenges (e.g., ecosystem degradation from pollution, climate change etc.)? How serious are they?
- What are the risks that these challenges pose? How are they interlinked?
- How vulnerable are the areas that provide the ecosystem services that people depend on? What are the pressures on those areas (e.g., pollution)?

Many of the activities described in this step relate to the early stages of a 'situation analysis'. A situation analysis helps to understand the current and likely future WEFE Nexus challenges, information that is fundamental to building a strategy that considers the context for Nature-based Solutions (NbS). This is often referred to as the 'inception phase'. This step aims to understand the WEFE Nexus challenges that need to be addressed.

TOOLS, APPROACHES AND EXPERIENCES FROM REXUS

CASE STUDY 1
Participatory mapping of challenges and ecosystem services across the WEFE Nexus system

CASE STUDY 2
Fit-for-Nexus climate projections

1.1 Identifying WEFE Nexus challenges

Individuals, communities, businesses and governments (including in the water, food and energy sectors) depend on nature. They also often have a negative impact on it. The scale of that impact affects the services provided by ecosystems. Damaging the landscapes that provide clean water, pollination and other ecosystem services causes significant problems in the present and future. Therefore, WEFE Nexus challenges are not just about the state of nature but also the impacts and dependencies on nature. These need to be understood to demonstrate how solutions, and particularly NbS, can help address multiple challenges.

Part of the process of identifying challenges is to find relevant data. Data can both help support the assessment phase and answer some of the initial questions around what the WEFE Nexus challenges are. Information may be available from a variety of sources, including National Adaptation Plans (NAPs) and the agencies developing them. In many cases, at least some data will be available that can feed into the process. Existing data can be used, and/or supplemented with new data. At this stage, consider:

- Making an inventory of available data and numerical models (e.g., biophysical, economic, and others) of the study area that include information on the ecosystems.
- Collecting additional data that can support the NbS evaluation, both technical and socio-economic data is relevant in this.
- Identifying potential gaps in data that will be needed for decision-making.

Considering the multiple impacts and dependencies is particularly important within a landscape, where there might be multiple pressures from different sectors or activities. For example, a hydrological study may indicate that a river can support irrigation of eight nearby fields, so eight extraction licenses are issued. However, if that analysis does not consider how the resulting reduction in flow could impact the amount of power that a nearby hydropower plant can generate, it could cause energy problems for people, communities and businesses in the area. Reduced flow could also have adverse impacts on aquatic biodiversity. For example, the hydropower dam might block migration routes of fish which could reduce successful reproduction of fish populations and reduce yields from fisheries.

The specific combination of WEFE Nexus challenges facing a particular area will be unique. However, some challenges may be relevant across different areas. By working with pilots, REXUS has identified a list of categories of WEFE Nexus challenges that can be a helpful starting point (Table 1). Understanding the WEFE Nexus challenges in a given context requires stakeholder engagement. See Case Study 1 for how one of the REXUS project pilots identified WEFE Nexus challenges in their area.

Table 1

Example categories of WEFE Nexus challenges identified by REXUS

WEFE Nexus Challenges
WATER
Ensuring resilience to floods
Ensuring resilience to droughts
Dealing with poor chemical water quality
Dealing with sedimentation and erosion
Ensuring water availability
Providing water for agriculture
ENERGY
Ensuring energy efficiency
Ensuring energy generation
Ensuring energy access / security
FOOD
Maintaining agricultural production
ECOSYSTEMS
Conserving and protecting ecosystems
Restoring ecosystems

CASE STUDY 1

Participatory mapping of challenges and ecosystem services across the WEFE Nexus system

Participatory mapping was used in the REXUS project to identify challenges, risks, vulnerabilities and opportunities within the pilot areas. To do this, REXUS partners carried out scoping interviews with stakeholders to understand threats, as well as ecosystem services that are important to people. The answers were used to create materials for a participatory mapping exercise, such as 'tokens' for different ecosystem services and infrastructure. At stakeholder workshops, people were then asked to use these materials to show on a map the areas that were important for the WEFE Nexus.

Participants were provided with a map of the pilot area that included indicative resources, economic activities, technologies and infrastructures. They were asked to explore how well the elements on the map represented their understanding of natural resources, land use, ecosystem services and socio-economic activities and to add missing elements to the map. They were also asked to identify pressures, their locations and why they are important.

This exercise was combined with the co-design of a Causal Loop Diagram (CLD) (see Case Study 5 for more information) where participants were asked to identify: the most important pressures in the pilot area; the resources and other elements that these pressures are impacting; the drivers behind the pressures; and the way different pressures are interconnected.

At the end of this exercise, participants were asked to identify the main WEFE Nexus challenges.

1.2 Analyze and assess current and future challenges

Decision-making to improve the performance of the WEFE Nexus in relation to specific objectives should be based on a good understanding of the system, including quantitative data about the current and future challenges. Once key WEFE Nexus challenges have been identified, deeper analysis and assessment will help understand the scale of the challenge (e.g., where flooding happens, how frequently flooding happens and why flooding happens) now and in the future.

The type of analysis will depend on a number of factors, including:

- the time and funding available.
- the scale of the assessment (e.g., in relation to the boundaries of the natural resources system, the socio-economic system, the administrative and institutional systems).
- the time period of analysis (e.g., decadal, annual, seasonal - noting that different sectors within the WEFE Nexus plan with different time horizons).
- the assumptions concerning external factors (e.g., climate change, socio-economic change or political change).

Current challenges

It is useful to know the current situation or 'state' of the area and the factors influencing it, such as environmental conditions, infrastructure, resource demand and ecosystem service provision. This requires a *base case analysis*, which can be supported by modelling tools to help quantify the problem. The analysis should consider three systems and their interactions:

1. The *natural system* is bounded by the climate and geophysical conditions (including hazards, grey infrastructure and ecosystem services). An ecosystem baseline assessment could be done to understand the type and location of natural and semi-natural assets (e.g., aquatic ecosystems, forest habitats, (proposed) protected areas or natural infrastructure), the ecosystem services currently provided by these assets, and whether these assets are threatened by climate change and natural hazards, among other things.

2. The *socio-economic system* is formed by the demographic, social and economic conditions of the economy (for instance, ways in which demands on natural resources may change). An analysis could study the current and future demand for ecosystem services under different scenarios, including developments that threaten ecosystems such as mining, land conversion, proposed developments and encroachment.

3. The *administrative and institutional system* is formed and bounded by legal, regulatory or institutional constraints on natural resources management, including WEFE cross-sectoral plans. An analysis could consider the governance constraints and enablers for managing, protecting and restoring ecosystems.

The interactions between these systems in the base case analysis can be analyzed by setting up ecosystem functioning models that incorporate socio-economic pressures on ecosystems (Poff 2018). Where possible, these can then be integrated with other physical and economic models to understand the broader picture (Mendoza et al. 2018).

Future challenges

It is important to also consider the vulnerability that ecosystems – and the people who rely on them – have to future changes in multiple systems, including climate change, demographic change and shifting settlement patterns. While there may not be a particular WEFE Nexus challenge in an area now, challenges may arise in the future. Strategies to address WEFE Nexus challenges should take climate change into account – in terms of how it could exacerbate existing challenges, how it could result in new ones and how it could impact the effectiveness of solutions implemented now (i.e., will the solutions be resilient to climate change?).

An important part of the planning process to develop a robust and resilient suite of solutions is to include and address expected future WEFE Nexus challenges, i.e., define storylines or scenarios on how the future might develop. Such storylines should consider socio-economic change (e.g., population growth changes, economic growth, urbanization, land-use change, migration, political developments and transboundary issues), environmental developments (e.g., climate change impacts, including changes in weather and sea level rise) and policy developments (e.g., new policies and changed priorities).

The analysis that describes the future performance of the system under present policies and regulations is the *reference case analysis*, often known as the 'business as usual scenario'. Future development under the reference case can be quantified or visualized using the same modelling tools applied for the base case analysis.

Assessing climate change vulnerabilities may have already been done through the NAP process. The associated climate risk assessments may help identify key vulnerabilities in a given context. Modelling, stakeholder consultation and other approaches are likely to be needed to understand the challenges at different scales.

See Case Study 2 for how DRAXIS, one of the REXUS partners, analyzed climate change scenarios in different REXUS pilot areas.

CASE STUDY 2

Fit-for-Nexus climate projections

Background

The Pinios river basin is located in central Greece, covering an area of approximately 11,000km². It is one of the most productive regions for agriculture in Greece. 90% of total water consumption in the basin is used to irrigate crops. The river basin is already experiencing challenges with achieving sufficient water supply to meet irrigation needs and other water demands, such as maintaining environmental flows in rivers. Periods of drought mean that productive land is threatened by desertification, which is reducing agricultural production.

As part of the REXUS project, partners DRAXIS analyzed climate change projections under different scenarios for the river basin. This was to determine how key climatic variables are likely to change into the future under different conditions, in order to assess how this is likely to impact resource security, exacerbate existing challenges and present emerging challenges in the region.

Approach and methodology

The analysis used Global Climate Models and Regional Climate Models to examine climate variables including mean temperature, precipitation and potential evapotranspiration. The analysis was done for a reference period 1986-2005 and a future period 2031-2090. For future conditions, a business-as-usual scenario was developed using a high-emissions scenario (the Intergovernmental Panel on Climate Change's Representative Concentration Pathway 8.5 (RCP8.5)) and a mitigation scenario (RCP4.5). The modelled outputs provide climate conditions under the reference period and for the two future scenarios.

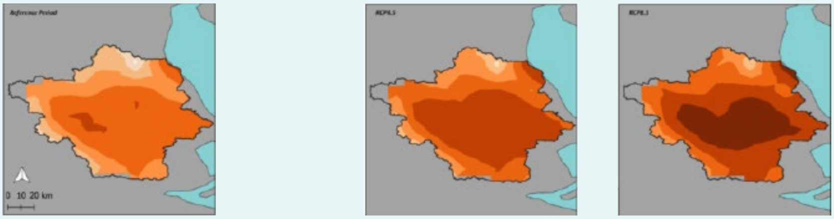
Results

The maps below show climate conditions in the Pinios river basin for the reference period and under two future scenarios (Figure CS2-1). Mean temperature is predicted to increase for the mitigation scenario (RCP4.5) and business-as-usual scenario (RCP8.5). Increases in mean temperature are not evenly spatially distributed. The maximum mean temperatures for the mitigation scenario are similar to the reference period (16-18°C) but occur over a much larger area. However, the mean minimum temperature is predicted to increase by up to 10°C in the business-as-usual scenario (Table CS2-1). Mean annual precipitation for the period 2031 to 2090 is projected to decrease in both the business-as-usual and the mitigation scenarios. The most significant decrease is predicted in the northern parts of the basin. Under both future scenarios, increasing future trends in daily mean potential evapotranspiration are projected in all months for the period 2031-2090, in comparison to the reference period. The largest increase in potential evapotranspiration compared to the reference period is observed during the months of May, June and July, with approximately +11% relative change. Maximum daily potential evapotranspiration under the RCP4.5. scenario is 4.5mm but only occurs over a small area. Whereas, in the RCP8.5 scenario, this maximum mean occurs over a larger area.

Figure CS2-1

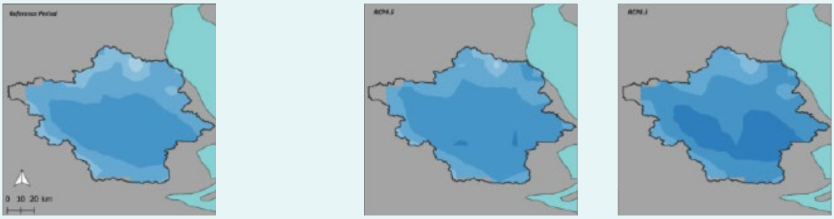
Mean annual temperature, precipitation and evapotranspiration under reference, mitigation and business-as-usual scenarios

Mean Annual Temperature (°C)



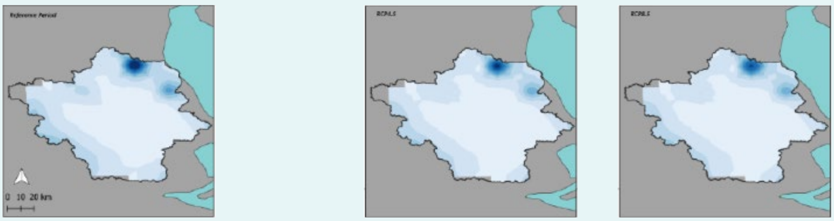
<8 | 8-10 | 10-12 | 12-14 | 14-16 | 16-18 | >18

Potential Evapotranspiration (mm)



2.0 - 2.5 | 2.5 - 3.0 | 3.0 - 3.5 | 3.5 - 4.0 | 4.0 - 4.5

Mean Annual Precipitation (mm)



<250 | 250-500 | 500-750 | 750-1000 | 1000-1250 | 1250-1500
1500-1750 | 1750-2000 | 2000-2250 | 2250-2500 | >2500

Conclusion and relevance to WEFE Nexus

This modelling exercise helped to understand how current challenges will likely be exacerbated under climate change. Overall, conditions in the Pinios River Basin are likely to become warmer and drier, with some areas more severely affected than others.

The results show that temperatures are likely to get higher, precipitation is likely to get lower and evapotranspiration will likely increase. This means that water will become increasingly scarce. This demonstrates the increasing need for solutions that can increase efficiency of water use in order to maintain agricultural production, whilst ensuring other water needs in an increasingly water scarce region.

Table CS2-1

Mean temperature and mean annual precipitation under a mitigation scenario (RCP4.5) and a business-as-usual scenario (RCP8.5) in the Pinios River basin, Greece.

	Mitigation scenario (RCP4.5)		Business-as-usual scenario (RCP8.5)	
	2031-2050	2070-2090	2031-2050	2070-2090
Mean temperature	+1.3°C (+9%)	+2.1°C (+15%)	+1.6°C (+11%)	+4°C (+29%)
Mean annual precipitation	-7mm (-1%)	-27 mm (-4%)	-17mm (-3%)	-78mm (-12%)

1.3 Defining priority challenges and goals

Once the WEFE Nexus challenges have been identified and analyzed (i.e., the *base case* and *reference case analyses*), goals can be formulated and prioritized to help select the right solutions (in Step 2). These goals are what the solutions need to achieve to address the WEFE Nexus challenges identified.

Where possible, this prioritization should consider the synergies and trade-offs arising from the impacts of multiple challenges across the WEFE Nexus. Fundamentally, these objectives are likely to focus on:

1. securing and improving ecosystem services related to water, energy and food.
2. building climate resilience and contributing to climate adaptation.
3. harnessing NbS to improve human health and well-being.

There can be primary and secondary objectives. While a primary objective might be maintaining or increasing key ecosystem services and their resilience to climate change, secondary objectives may include other benefits. To facilitate the evaluation of all candidate solutions within a proposed WEFE Nexus strategy, one primary and several secondary objectives should be identified. NbS can have a greater ability than grey solutions to address more than one objective and to provide multiple benefits (Seddon et al. 2020). Once the WEFE Nexus challenges are understood and prioritized, the solutions to those challenges can be explored. This is discussed in more detail in Step 2.

STEP 2

Identify solutions

When to use this step

This step will help answer the following questions:

- What types of Nature-based Solutions (NbS) exist?
- What types of NbS can address the WEFE Nexus challenges identified?
- Which of these NbS are suitable for the area of interest?

This step focuses on identifying candidate NbS to be considered, but it should be seen as part of the process to create a longlist of solutions (which would include grey and hybrid solutions as well as NbS) for more detailed assessment and consultation.

TOOLS, APPROACHES AND EXPERIENCES FROM REXUS

CASE STUDY 3
Participatory identification of solutions to incorporate NbS into the Jucar River Basin, Spain

2.1 Explore (Nature-based) Solutions

Once the WEFE Nexus challenges are identified and prioritized, a broad range of potential solutions can be explored. This could include grey solutions, NbS or hybrid solutions. Not all solutions are related to direct implementation on the ground. There might also be governance solutions, where new institutional or financial arrangements provide incentives for new ways of working.

The solutions considered should include measures and interventions from relevant policy documents (e.g., legislation, strategies, action plans etc.) and the solutions proposed by stakeholders in participatory processes (e.g., workshops and interviews), as well as additional solutions based on quantitative analysis and literature sources. Including clear references to existing policy documents is important because it shows how the solutions proposed link to and support the measures and interventions that have already received political and stakeholder backing (i.e. policies will only be put in place after they have gone through the relevant processes and been approved by the relevant authorities).

Information on a range of different solutions can be found in various resources, including:

- The WaterLOUPE platform's information catalogue by Deltares provides an overview of predominantly grey solutions and governance solutions related specifically to water scarcity.
- The PreventionWeb Knowledge Base from the United Nations Office for Disaster Risk Reduction (UNDRR) contains publications and resources from around the world on disaster risk reduction and resilience.
- The Framework for Ecosystem Restoration Monitoring (FERM) from the Food and Agricultural Organization of the United Nations (FAO) provides a registry of restoration projects around the world.
- The Water, Energy & Food Security Resource Platform Knowledge Hub by GIZ provides case studies of both grey solutions and NbS from around the world on the Water-Energy-Food Nexus.
- The Global Hunger Index provides case studies for multiple countries of initiatives to reduce food insecurity.

2.2 Match Nature-based Solutions to priorities and goals

The next step is to identify which solution or solutions best meet the identified priorities and goals. Given the wider experience and knowledge of how other solutions can do this, this section specifically focuses on NbS. The aim is to identify several NbS that could help address the identified properties and goals. These NbS can be added to a *longlist* of candidate solutions (that also includes grey and hybrid solutions) to support the development of a strategy.

An important part of this process is to map the prioritized challenges against the ecosystem services that will help address them. Table 2 below provides some examples of this.

Table 2

Example ecosystem services associated with the WEFE Nexus challenges

WEFE Nexus Challenge	Example ecosystem services to be provided by solutions[2]
Ensuring resilience to floods, ensuring resilience to drought, ensuring water availability, providing water for agriculture	Water provisioning; water flow regulation; natural hazard protection
Dealing with poor chemical water quality, dealing with sedimentation and erosion	Water purification
Maintaining agricultural production	Food provisioning; life cycle maintenance; climate regulation
Ensuring energy efficiency, ensuring energy generation	Energy source; climate regulation
Soil quality and degradation	Erosion regulation; water purification
Conserving and protecting ecosystems, restoring ecosystems	Life cycle maintenance; recreation and tourism

BOX 8

REXUS CATALOGUE AND AIRNbS (developed / led by Deltares)

To support the identification of candidate solutions, the REXUS project has developed AirNbS[3]. This is a digital platform developed to support the process of identifying NbS that are relevant to specific WEFE challenges. The platform includes a catalogue of NbS

2 There are a number of different ways that ecosystem services can be classified. Table 2 draws on work done under REXUS (D3.10 - *Report on Socioeconomic indicators for Nexus analysis and management*) available here.

3 The AirNbS platform is inspired by the well-known AirB&B, which provides a user-friendly interface for travellers to select suitable accommodation based on various criteria such as location, required facilities and price. In a similar style, following smart combinations of criteria defined by the users, AirNbS aids in selecting individual solutions. https://airnbs.netlify.app/rexus

relevant to supporting WEFE Nexus objectives. Users are able to filter NbS by key WEFE Nexus challenges, ecosystems, spatial and temporal scale and degree of intervention, based on a roadmap that identifies the key aspects to consider when identifying relevant NbS (Restrepo & Barci 2022). For each solution, it provides a brief description, the geographic scales of implementation, the degree of intervention, the potential impacts on selected ecosystem services, an example case study and relevant references. For more information on how relevant NbS were identified through linking key ecosystem services to WEFE challenges see the NbS roadmap.

The AirNbS platform can help with identifying candidate solutions for the local context and Nexus problem analysis. This is an interactive guide that helps users to increase their understanding of NbS options and to identify candidate solutions for their specific context. It also enables stakeholder engagement. AirNbS does not identify a final solution, but it can help users to scope candidate NbS. AirNbS was used to identify NbS that could help to address WEFE challenges that fed into the participatory process of Assessing the Nexus solutions and pathways (see the 'Stakeholder Engagement' section).

Other catalogues of NbS include:

- The Nature-based Solutions Initiative (NbSI) Case Study Platform.
- Network Nature Case Study Map.
- Oppla Case Study Finder.
- The Panorama Solutions database.

airnbs

The next step is to identify which of the priority challenges NbS would respond to. Box 8 provides some resources that can be used to explore potential NbS to support the identified ecosystem services. Figure 3 shows an example of how primary and secondary objectives can be distinguished for a given NbS option and WEFE Nexus challenge. Understanding the problem (WEFE Nexus challenge) and the interconnected WEFE system (first column, for example within the water sector or between water and food sectors) will allow stakeholders to propose NbS options (second column, for example a single intervention or a set of interventions).

Measuring the multiple benefits of solutions can be challenging. While some contributions of a solution to various objectives can be measured (e.g., the number of jobs or increase in wages of local communities), others (e.g., the contribution to human health and well-being) can be more difficult to quantify. For example, an urban wetland might increase opportunities for recreation but measuring changes in the well-being of local residents is challenging. Assessing the potential for trade-offs is even more challenging. If the new urban wetland is not managed correctly, it could increase the risk of vector-borne disease for local communities and therefore decrease their health. This raises the challenge of how to balance the positive well-being impacts from greater recreational opportunities with the negative health impacts of an increase in vector-borne diseases. Despite the challenges in assessing the different potential outcomes and their interactions, trade-offs and unintended consequences should be considered, at least qualitatively, for all solutions.

Figure 3

Examples of primary and secondary objectives for a particular NbS

	WHAT IS THE PROBLEM /CHALLENGE?	WHAT OPTIONS COULD BE CONSIDERED?	WHAT IS IMPERATIVE TO TACKLE WITH THE SOLUTION?	WHAT OTHER ASSOCIATE TECHNICAL CO-BENEFITS COULD THE SOLUTION BRING?
	WEFE Nexus Challenge	**Candidate NbS option(s)**	**Primary objective(s)**	**Secondary objectives**
EX.1	**Within the water sector:** Expected increase in flood hazards, and poor river status	**One intervention:** Floodplain restoration and management	**Protect against floods/ reduce overall flood risk** by increasing flood control and water / retention functions on floodplains along the river	• Improve water quality • Increase biodiversity and habitats availability • Improve natural landscape (recreation potential)
EX.2	**Water and Food:** Expected increased flood hazards, poor river status, poor supply of water for irrigation.	**Set of interventions:** • Floodplain restoration and management • Meadows and pastures for flood storage • Increased water retention in the landscape to reduce runoff attenuation • Renewed drip irrigation systems and change of crops • Regenerative farming practices	• Reduce overall flood risk • Increase and ensure consistent availability of water for agriculture • Improve soil capacity to retain water and reduce irrigation needs	• Increase biodiversity habitats • Improve natural landscape (recreation potential) • Improve soil conditions to provide resilience during drought • Contribute to carbon sequestration

2.3 Screen candidate solutions

Once solutions have been identified, prioritization within the set of candidate solutions is needed. An inventory of all potentially relevant solutions may result in a large set of possible NbS, grey and hybrid solutions, depending on the size and complexity of the area and system concerned. In most cases it will not be practical to analyze all candidate solutions in detail. Therefore, a screening process is needed to select the most promising solutions that should be further analyzed and used for strategy design. This screening process considers the specificities of individual contexts. A tiered expert judgement approach is recommended for the screening process, in which general screening criteria are applied (Figure 4). A key part of this process is consulting with stakeholders on the longlist. The screening process will result in a set of the most promising solutions that can then be further used in the design of strategies. See Case Study 3 for an example of how a REXUS pilot implemented a participatory screening process.

Figure 4

General screening criteria for screening the longlist of solutions

EFFECTIVENESS	Solutions solve the most serious challenges and have the highest impacts on the management objectives
EFFICIENCY	Solutions have higher benefits at lower costs
FEASIBILITY	Solutions are compatible with the geography and available space
COMPATIBILITY	Solutions are compatible with existing sectoral plans
MINIMIZATION OF TRADE-OFFS	Solutions do not meet objectives at the expense of other possible implicit objectives
LEGITIMACY	Solutions do not rely on uncertain legal and/or institutional changes
SUSTAINABILITY	Solutions at least do not degrade the environmental and socio-economic conditions for future generations

CASE STUDY 3

Participatory identification of solutions to incorporate NbS into the Jucar River Basin, Spain

Background

Spain is characterized by relatively water-rich regions in the north and arid regions in the south. There are high demands for water irrigation and significant nuclear and hydroelectric power production. The Jucar River basin is situated in the South-East Mediterranean coastal area, covering approximately 42,735km². 80% of its land area is used for agriculture. The region suffers from drought, salinization, floods, erosion, conflicts over water resources, ground water pollution and overexploitation of aquifers.

Approach and methodology

The challenges prioritized by stakeholders formed the basis for developing the list of candidate solutions. To identify relevant NbS, each challenge was associated with the key ecosystem services that would need to be enhanced by it. Based on the identified challenges and ecosystem services, the AirNbS platform was used to identify potentially relevant NbS and examine their potential co-benefits as well as the overall range of WEFE Nexus challenges that they could be used to address.

Results

The potential and relevance of the candidate NbS were further assessed through examining policy documents associated with the Jucar basin context, as well as in relation to leverage points identified for each WEFE Nexus challenge using Causal Loop Diagrams (CLDs) that were elaborated through discussions with stakeholders (Table CS3-1). Leverage points are places within a complex system where a small shift in one thing can produce big changes at the system scale (Egerer et al. 2021).

NbS were integrated into a list of other relevant solutions identified using Causal Loop Diagram (CLD) analysis. A causal loop diagram is essentially a flow diagram that captures how elements of a system interrelate. It does this by showing the cause-and-effect linkages and feedback loops between different parts of the system (Sterman 2000). Solutions cards (Figure 8) with information for each solution were produced for stakeholders.

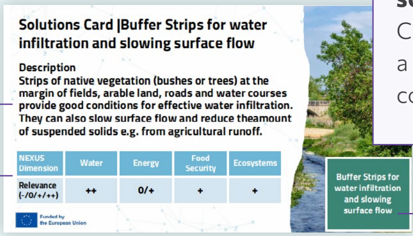
The cards included generalized scores related to the impacts different solutions would likely have on the water, energy, food and ecosystem aspects of the system. Stakeholders used the cards in a workshop to select and group solutions, developing a sustainable vision for the future. The outcome of the workshop were solutions and strategies that were considered favourably by stakeholders. Templates for the solutions cards are provided in Annex 2.

Table CS3-1

Prioritized challenges, associated ecosystem services and leverage points in the Jucar River Basin.

WEFE Nexus challenge identified by stakeholders	Associated Ecosystem Services (which would need to be enhanced to address the challenge) according to AirNbS	Leverage point
Soil degradation and desertification	Food provision Erosion prevention	Territory control, Farmers' environmental awareness, Sustainable agricultural practices, Forested and natural soil coverage
Unauthorized groundwater abstraction	Regulation of water flows	Farmers' environmental awareness, Farmers' technical capacity, Institutional Cooperation and Reputation, Territory control, Sustainable agricultural practices
Albufera wetland state	Water provision Water purification and waste treatment	Water volume allocated to the wetland, Protecting water quality
Jucar river baseflow	Water provision Water purification and waste treatment Regulation of water flows	Farmers' environmental awareness, Farmers' technical capacity, Institutional Cooperation and Reputation, Territory control, Sustainable agricultural practices

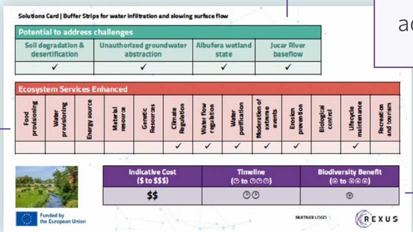
DESCRIPTION
Summary of what the solution is and how it works.



SOLUTION TOKEN
Can be used to identify on a map where that solution could be used.

NEXUS DIMENSION RELEVANCE
In the context of the challenges identified by stakeholders.

POTENTIAL TO ADDRESS CHALLENGES
Which of the identified challenges the solution could potentially help address.



ECOSYSTEM SERVICES ENHANCED
Which ecosystems the solution can help to enhance (depending on context).

INDICATION OF COST, TIME AND BIODIVERSITY BENEFIT
What could be the scale of costs associated with the solution? How long would it take for the benefits to be realised post implementation? Would the solution have benefits for wildlife?

STEP 3

Evaluate solutions

3 Evaluate Nature-based Solutions

EVALUATION CATEGORIES

- 3.3.1 Enabling environment
- 3.3.2 Technical effectiveness
- 3.3.3 Economic feasibility
- 3.3.4 Social outcomes
- 3.3.5 Environmental outcomes

When to use this step

This step will help to answer the following questions:

- What enabling conditions are in place that support NbS use and what are the opportunities to fill any gaps?
- Which of the five evaluation categories (enabling environment, technical effectiveness, economic feasibility, social outcomes and environmental outcomes) and associated criteria are most relevant to evaluate the outcome of solutions for specific WEFE objectives?
- How effective are the candidate solutions at addressing the identified WEFE Nexus challenges?
- What are the likely social, economic and environmental outcomes of the solutions, and which are most relevant?

As with other sections of this guide, Step 3 focuses on evaluating NbS. However, similar evaluation processes are needed for all solutions. Assessing the potential outcomes (both positive and negative) of solutions helps determine the degree to which they can meet objectives across Nexus sectors (and beyond). For example, does one solution have a large positive outcome for water, but little impact on food sector issues and a minor negative outcome for ecosystems, while another solution has a small but positive outcome for all WEFE sectors? This evaluation process helps to select and prioritize the solutions to include in the overarching strategy in Step 4.

TOOLS, APPROACHES AND EXPERIENCES FROM REXUS

CASE STUDY 4

Evaluating the technical effectiveness and economic benefits of forest conservation and restoration through ecosystem service modelling in the Nima River basin (Colombia)

3.1 Defining the purpose of the evaluation

The purpose of evaluating solutions may vary depending on the stage of planning that the evaluation it is informing (e.g., pre-concept, pre-feasibility, feasibility or design). Defining the purpose of the evaluation is key to understanding the level of detail required and which evaluation criteria should be included. More detail is likely to be required for the design stages than earlier stages in the planning process.

Potential purposes of evaluation include:

1 **Assessing the potential of the enabling environment to support solutions**. Assessing the policy and institutional context, especially for NbS, helps to understand what is in place to support the implementation of certain solutions. This process can help identify ways to increase the likelihood of NbS uptake – for example by highlighting subsidies that could apply to NbS and/or linking NbS activities to wider policy priorities. The enabling environment includes the level of technical skills, capacity and knowledge available to implement different solutions and incorporate NbS (e.g., Are there organisations in the area with experience of implementing NbS?).

2 **Gauging whether candidate solutions will achieve their intended objectives**. Assessing the technical effectiveness and adequacy of solutions helps to select individual solutions. For example, if the core aim of the strategy is to reduce the extent of flooding in an area, what contribution could a solution make to that aim in a given area of interest? And what other challenges in the area could that solution help address? It is unlikely that a single solution will solve all the WEFE challenges in an area, so these insights are key to inform the development of a strategy that effectively combines different solutions (e.g., green, grey or hybrid). As it can take a long time for the full benefits of NbS to materialise, it is important to take these time horizons into account.

3 **Understanding synergies and trade-offs**. Individual solutions can contribute to objectives in more than one sector and, in some cases, combining solutions can provide even more benefits (synergies. In contrast, a solution that meets one or more objectives may have negative impacts on another sector or objective (trade-offs). The ideal strategy would be choosing solution(s) that provide the most positive outcomes across sectors and minimise trade-offs.

4 **Assessing the economic viability of solutions**. Comparing solutions by completing a cost-benefit analysis in monetary terms can help to build the 'business case' for NbS – highlighting economic incentives to consider NbS and encouraging investment across sectors. Efforts to assess the economic viability of solutions should consider not only the cost of implementing the solutions, but the monetary and nonmonetary benefits that a solution could bring. Many of the ecosystem services that solutions could provide, have monetary value, both within Nexus sectors (such as reduced costs for water treatment) and beyond (such as increased revenue from tourism). These should be included as far possible. Although other benefits, such as recreational opportunities for local communities, are more difficult to value in monetary terms they can still have economic importance and should be included in the assessment. Including these values in a cost-benefit analysis of all solutions is important, but it is particularly key when trying to understand the cost-effectiveness of NbS compared to alternatives.

5 **Raising awareness and engaging stakeholders**. Stakeholders may not be familiar with the variety of solutions available or the evidence for the contribution they can make to addressing societal challenges. This evaluation phase can be a good opportunity to introduce NbS and their potential benefits to stakeholders involved in developing strategies.

3.2 Defining criteria and indicators

Each candidate solution needs to be assessed based on agreed evaluation criteria related to the priority challenges and goals identified in Section 1.3. For example, if ensuring water availability for agriculture has been identified as a priority WEFE Nexus challenge, solutions may be assessed against their potential to support ecosystem services such as water provisioning or water flow regulation. In this case, water availability could be used as a criterion (see Annex 4 for more examples). The most appropriate criteria to compare solutions should be agreed upon. Ideally, these criteria should be agreed with a broad range of stakeholders to ensure their requirements are considered.

Once appropriate criteria have been selected, related indicators are needed to assess the likely outcomes of solutions (e.g., through modelling) and measure their performance. For instance, the change in water availability resulting from a solution could be measured using indicators such as surface water availability (level, volume) and ground water recharge rate (m^3/ha per year). It is these set of indicators that will help assess the technical effectiveness of the solutions being considered. Box 9 provides some useful considerations when defining indicators.

BOX 9

CONSIDERATIONS WHEN DEFINING INDICATORS

When defining specific indicators for assessing the technical effectiveness of NbS, it is suggested that indicators are based on the intended and achievable objectives of NbS. Factors such as the the type and features of the NbS are important considerations. Additional considerations when defining indicators include:

- Anticipating whether the data needed for quantifying specific indicators are or will become available and at what spatial and temporal scale.
- Including indicators that address co-benefits and trade-offs due to changes in the physical, social and environmental outcomes.
- Considering the availability of the skills, funds and other resources to use an indicator - and accurately interpret the results - are available. While some indicators may be very useful to evaluate the impacts of NbS options, they may be too complex to use in every case.

(Kumar et al. 2021)

3.3 Choosing methods and performing the evaluation

The methodology used for evaluating solutions is largely determined by the evaluation categories and the associated indicators that are chosen. The complexity and detail of the methodology will be decided based on the resources available (time, data, capacity, etc.) and the level of detail required from the assessment so that the results can adequately inform the planning of solutions.

Within this guide, five categories are included for evaluating solutions:

1. The enabling environment.
2. The technical effectiveness of solutions.
3. The economic feasibility of solutions.
4. The social outcomes.
5. The environmental outcomes.

Although in principle the evaluation categories listed above can be conducted in any order, some types of evaluation may depend on information from another category. For example, a biophysical assessment of technical effectiveness is likely to be needed in order to assess the economic impacts of a solution. There is no single 'correct' way to evaluate solutions. The approach depends on the context and decision-making needs. It will also depend on the purpose of the evaluation (see Section 3.2) and the objective(s) for each solution. Evaluations should be as holistic as possible. Therefore, in an ideal world, they should include a range of evaluation criteria that consider environmental, social and economic feasibility and outcomes. The level of detail of the evaluation will depend on the availability of data, time and other resources (such as expertise). It will also depend on the purpose of the assessment. For example, it may be most useful to do a simple evaluation on a larger number of solutions but apply a detailed assessment for only a few. More detailed information on the assessment approaches can be found under each of the five categories.

Once the most appropriate methods, criteria and indicators have been selected, relevant data should be collected, and the analysis should be performed. Case Study 4 gives an example of how technical effectiveness and economic benefits were evaluated in one of the REXUS pilot areas, the Nima River watershed, Colombia.

The following sections provide more detail on methods that could be used for each of the five evaluation categories. Information is provided on suggested methodologies for measuring different outcomes of solutions (focusing on NbS) and their data requirements. In addition, supplementary resources on broad evaluation approaches are provided below and at the end of each section for the different categories.

Resources: Evaluating Solutions

- Evaluating the Impact of Nature-Based Solutions: A Handbook for Practitioners – provides decisionmakers with indicators and methodologies to assess the impacts of NbS across 12 societal challenges areas.

- A Framework for Assessing the Effectiveness of Ecosystem-Based Approaches to Adaptation – outlines a question-based framework developed to qualitatively assess EbA effectiveness.

- A Guide to Eco-DRR Practices for Sustainable Community Development – Using Potential Map of Ecosystem Conservation/Restoration to Promote Eco-DRR – provides information and methods that can be used to promote Eco-DRR.

- Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers – guides the design, implementation, and use of studies to value the benefits and costs of NbS.

- The Blue Guide to Coastal Resilience: Protecting coastal communities through Nature-based Solutions - provides DRR planners with step-by-step guidance for implementing various NbS in coastal areas.

- Implementing nature-based flood protection: Principles and implementation guidance - provides principles and implementation guidance for planning NbS for flood risk management.

- Words into Action: Nature-based Solutions for Disaster Risk Reduction – provides guidelines for the suggested steps for implementing a feasible, people centred approach in line with the Sendai Framework.

- Principles for just and equitable Nature-based Solutions – examines the issues that must be addressed to help ensure that the design, governance and implementation of NbS are just and equitable.

- Voluntary guidelines for the design and effective implementation of ecosystem-based approaches to climate change adaptation and disaster risk reduction – provides guidelines for practitioners and implementers for operationalizing EbA and Eco-DRR at the programme and project level.

- Handbook for the Implementation of Nature-based Solutions for Water Security: Guidelines for designing an implementation and financing arrangement – a guide to the development of investable and bankable NbS projects through different modes of governance, funding and implementation arrangements.

- Impact Assessment Guidebook – provides guidance for developing monitoring and evaluation plans for NbS.

- Nature-based Solutions Triple Win Toolkit - offers guidance to achieve a 'triple win' to enhance biodiversity, address climate change, and reduce poverty, through NbS in the context of Official Development Assistance spend.

- Powering Nature: Creating the Conditions to Enable Nature-Based Solutions – provides a systematic enabling framework to effectively implement, scale up and mainstream NbS.

- Nature-based Solutions (NbS) Policy Tracker: An AI Approach to Policy-making for Enabling NbS Worldwide – a global database of public policies that facilitate the delivery of NbS

- Guidelines for Integrating Ecosystem-based Adaptation into National Adaptation Plans – aims to support and motivate countries to adopt EbA as part of their National Adaptation Plans (NAPs).

- Guide to Cost-Benefit Analysis of Investment Projects – offers practical guidance on project appraisals, providing common principles and rules for the application of the cost-benefit analysis approach.

- Summary for policymakers from the IPBES about the methodological assessment for multiple values of nature and its benefits – provides different methods to value nature and demonstrates how these methods have been used.

CASE STUDY 4

Evaluating the technical effectiveness and economic benefits of forest conservation and restoration through ecosystem service modelling in the Nima River basin (Colombia)

In the Nima river Watershed, Colombia, the restoration and conservation of forests through a Payments for Ecosystem Services (PES) scheme was identified as a key NbS to address relevant WEFE challenges. This NbS has the potential to regulate water flows (moderating both flood and drought), support water purification (reducing water pollution), support water provisioning and support food provisioning.

An evaluation of the potential for forest conservation and restoration to produce these benefits was done through ecosystem services modelling using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) modelling suite. The purpose of the evaluation was primarily to generate awareness and interest in biodiversity and ecosystem services among stakeholders. It also aimed to demonstrate the importance of key threatened ecosystems in supporting the sustainable use and management of resources and potentially to support fund raising for the proposed strategies.

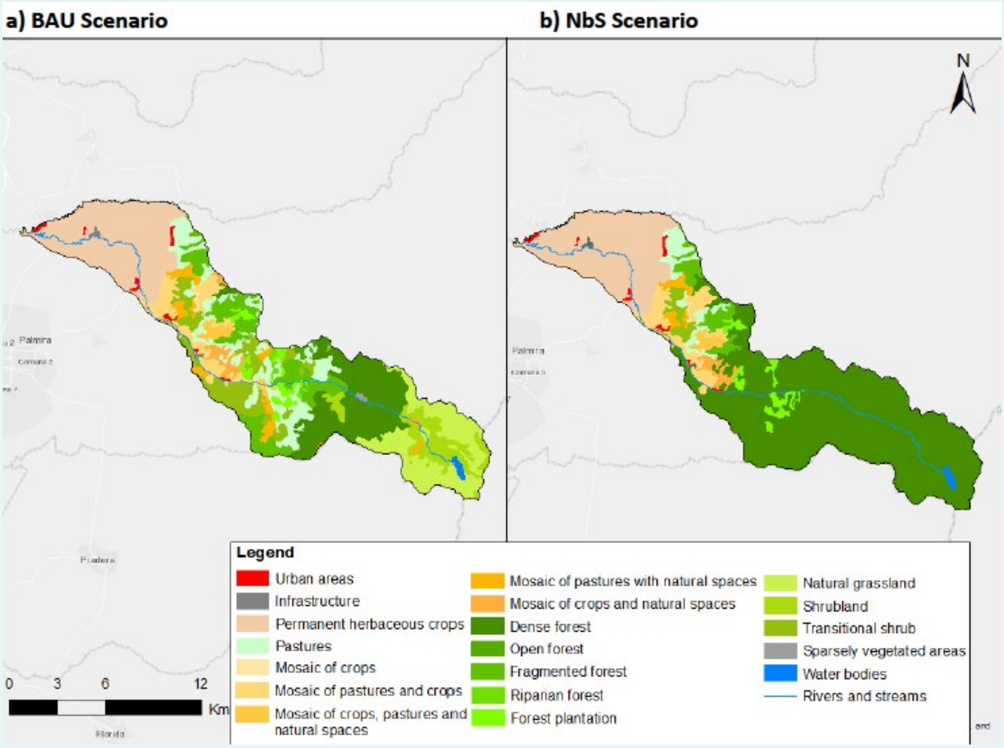
Scenarios were defined for a 'Business as Usual scenario (BAU)' and an 'NbS scenario'. The BAU scenario assumed current landcover, whereas the NbS Scenario involved widespread forest conservation and restoration (Figure CS4-1).

Biophysical estimates of the ecosystem services provided by forest ecosystems were established for both the BAU and the NbS scenario. The difference between these scenarios gives the estimated change in the quantity of ecosystem services due to forest restoration and conservation.

The biophysical impact on ecosystem services from NbS was calculated for **water flow regulation, water purification, water provisioning and food provisioning** services. An economic value was then associated with these services.

Figure CS4-1

Land cover for the a) BAU and b) NbS scenarios used in ecosystem services modelling to estimate the quantity and economic value of different ecosystem services in the Nima river watershed, Colombia



Results indicated that forest restoration and conservation would be beneficial for water flow regulation, with an increase of 2.86%. This amounted to an estimated economic value of over € 6.5 million per year in terms of the replacement cost for flood protection (replacing with a similar asset for flood protection under the current market price) (Table CS4-1).

For water purification services, nitrogen export was shown to decrease under the NbS scenario by 4.7%. This resulted in estimated savings of over € 265 thousand per year from avoided costs due to nitrogen removal.

Water provisioning increased marginally, by only 0.01%. On the other hand, food provisioning decreased slightly by 0.79% under the NbS scenario due to removal of land from production, which resulted in a decrease of over € 3.2 million in value from food produced.

Table CS4-1

Estimated impact of ecosystem services through the implementation of forest conservation and restoration in the Nima River watershed

Ecosystem Service	Biophysical ES quantity impact NbS – BAU)	% change between BAU and NbS scenario (NbS – BAU)	Economic ES valuation (€)
Water flow regulation (m^3 retained/year)	233,143	+2.86	+11,391,088.2
Water purification (nitrogen export (kg/year))	-1,690	+1.6°C (+11%)	+265,779.97
Water provisioning (m^3 available/year)	14,385	+0.01	+19,729.43
Food provisioning (tonnes of food/year)	-3,743.8	-0.79	-3,212,923.70
TOTAL			**+ 8,463,673.93 € /year**

3.3.1 Enabling environment

Assessing the policy and institutional context for solutions is important no matter what type of solution is being considered. However, there are additional specific challenges and considerations for NbS implementation (Pérez- Cirera, Cornelius and Zapata 2021). These challenges can include socio-cultural barriers to NbS uptake, such as the lack of recognition of the land rights of Indigenous peoples and local communities.

Institutional barriers to the implementation and scaling-up of NbS include misalignment of policy frameworks between sectors and often limited capacity for governments to effectively implement and monitor NbS.

Economic barriers also affect the potential for scaling up the use of NbS. For example:

- A lack of private and public funding for NbS.
- A lack of standard metrics to measure the social and environmental performance of NbS reduces willingness to invest.
- Wide distribution of multiple benefits among stakeholders leading to indirect or limited revenue streams.

Relevant policies are also key enabling factors for NbS. NbS need to fit within existing planning and investment decision-making processes. However, there are not many NbS-specific policies because it is a relatively new concept. Nevertheless, there may be opportunities to mainstream NbS into policies that are not NbS-specific, and to remove (unintentional) disincentives for NbS from existing policies (e.g., consider whether funding for flood mitigation policy unintentionally excludes NbS options). Assessing the enabling conditions for NbS helps to understand which factors could support the implementation of NbS and identify potential ways to increase uptake.

Aspects to consider

The key dimensions proposed to assess the enabling environment for developing, implementing and scaling NbS are:

- **Governance**: Good governance across the many policy areas and authorities involved in the deployment and financing of NbS.

- **Supportive policies**: Policies with the potential to accelerate NbS uptake, including sectoral policies, and appropriate regulatory requirements (regulations and technical standards) that have a powerful influence on the feasibility of using NbS for addressing societal challenges.

- **Policy goals**: The potential of NbS options to support the achievement of policy goals, even when they are not recognized in the policy.

- **Technical capacity**: The skills and knowledge needed to identify and implement NbS.
- **Funding and financing mechanisms**: Financing instruments and standardized financing models to make NbS attractive for potential funders and to increase their uptake.
- **NbS management**: Effective management of NbS, including mechanisms in place for ongoing monitoring, evaluation and adaptive management where needed.

Each dimension will have different evaluation criteria and related indicators. For a full list of suggested criteria and indicators under each dimension, see the template in Annex 3.

Methods: assessing the enabling environment

One proposed approach for assessing the enabling environment for NbS is multi-criteria analysis (MCA). The suggested steps for MCA are:

1. **Select criteria, indicators and sub-indicators** for the assessment. Validate these with relevant stakeholders in consultation workshops.
2. **Collect and review relevant documentation** of policies, instruments and governance structures for the assessment.
3. **Define weights** (from 0 to 100%) for each criterion and indicator according to its relative importance. Validate the weights with relevant stakeholders in consultation workshops.
4. **Score each** (sub) indicator on a scale from 0 (absence) to 3 (presence/compliance). Present, discuss and validate the scores with relevant stakeholders in consultation workshops.
5. **Run the MCA** to produce a prioritization of solutions.

Table 3 provides an example MCA results template for the NbS management dimension. A full template that includes all dimensions, criteria, indicators and suggested weights can be found in Annex 3.

Table 3

Example results from an enabling environment evaluation and its overall interpretation

		WEIGHT	SCORE
KEY DIMENSION	NbS Management		0.75
CRITERION	NbS monitoring	50%	0.5
INDICATOR	Monitoring and evaluation strategy	50%	3
	Adaptive NbS intervention management	50%	0
CRITERION	NbS safeguards	50%	1
INDICATOR	NbS safeguard system	50%	3
	Risk strategy	50%	3
INTERPRETATION	The management dimension is highly present and effectively supports NbS establishment. To make the environment more suitable, monitoring can be improved mainly in terms of planning and using iterative learning process that enables adaptive management of an NbS intervention throughout its lifecycle.		

3.3.2 Technical effectiveness

Technical effectiveness is the extent to which proposed solutions address the identified WEFE Nexus challenges and the (primary and secondary) objectives defined for the study area. Assessing technical effectiveness is key to understanding whether a solution is appropriate for the setting and whether and to what extent it will meet the solution's objectives.

Determining the technical effectiveness of NbS is generally harder than it is for traditional solutions because ecosystems are complex and there are longer timescales involved (GIZ *et al*. 2020). Although NbS may be less effective in the short term, they are more affordable and adaptive while delivering multiple benefits in the long-term (The Nature Based Solutions Initiative 2018).

Aspects to consider

Key criteria and indicators to assess the technical effectiveness of a solution can be determined based on its defined objectives (see Table 4). For example, if the defined objective is to reduce overall flood risk, one of the criteria could be to increase water retention, and a relevant indicator could be the groundwater recharge rate in mm/ha per year. Modelling could be used to estimate the groundwater recharge rate as a result of a solution being implemented in the first instance. For further examples of criteria and indicators identified within the REXUS project related to different WEFE challenges see Annex 4.

Table 4

Example indicators to measure the technical effectiveness of floodplain restoration and management for flood risk reduction, disaggregated by the primary and secondary objectives of the solution

NbS option	Floodplain restoration and management		
PRIMARY			
Objectives	**Criteria**	**Indicators**	**Source**
Protect agricultural lands against floods/Reduce overall flood risk by improving water flow regulation	Flood exposure/ damage	Number of people adversely affected by flooding in the project's influence area per year	European Commission 2021
	Flood magnitude	% of the peak flow reduction	Sun et al. 2020
	Water retention	Floodplain water storage volume	Jakubinsky et al. 2021
		Effective retention volume	Jakubinsky et al., 2021
		Groundwater recharge rate (mm/ha per year)	Righetti et al. 2022 Jakubinsky et al., 2021

Table 4 | Example indicators to measure the technical effectiveness of floodplain restoration and management for flood risk reduction, disaggregated by the primary and secondary objectives of the solution

NbS option	Floodplain restoration and management		
SECONDARY			
Objectives	**Criteria**	**Indicators**	**Source**
Improve water quality	Surface water/ ground water quality	Water quality measured by total suspended solids content (mg/L)	European Comission 2021 Jakubinsky et al. 2021
		Water quality index	
		Total nitrogen and total phosphorus removed from water	
Increase biodiversity habitats	Biodiversity	Presence of threatened species	Jakubinsky et al., 2021 Sun et al., 2020 European Commission 2021
		Species richness	

In addition to its benefits for the primary objective, the solution could create co-benefits that address other WEFE Nexus challenges. For example, upper catchment restoration (e.g., restoring forest areas upstream so that more soil and silt is 'held' in place by the roots and other below ground structures of vegetation) could fulfil its primary objective of reducing soil erosion and decreasing sedimentation of reservoirs. At the same time this NbS could reduce water pollution (because the trees and other vegetation will intercept rainfall and help 'filter' it) and therefore improve the chemical status of rivers. In turn, this would have benefits for aquatic biodiversity, including species linked to livelihoods. Considering the multiple benefits that a solution could achieve is necessary to maximize the potential of NbS to address WEFE Nexus challenges. While this is also the case for other solutions, options like grey infrastructure often have fewer 'additional' benefits to consider. For example, a sea wall to reduce coastal flood risk might be used by local communities for recreation, but it is unlikely to offer significant additional habitat for wildlife and won't absorb carbon. On the other hand, restoring a coral reef may help reduce coastal flood risk while also providing recreational benefits, habitat for wildlife, ongoing support for livelihoods like fishing and tourism and a range of other benefits.

It is also critical to integrate the inevitable degree of uncertainty around future conditions into the evaluation process, because it could affect the choice of solution(s) and the potential trade-offs. For example, in a context where temperatures are projected to rise significantly with climate change, what does that mean for how well a solution performs? For grey infrastructure, that increase in heat may mean that the materials it is built from warp or crack, meaning it can no longer fulfil its function. For NbS, it may mean that wildfires become more common in restored forest areas . In both cases, this will reduce the effectiveness of the solution. As natural systems, NbS often have much more potential to adapt to climate related changes than grey infrastructure, but the (lack of) resilience should be assessed for any solution considered. This will ensure that the solutions selected are resilient to future (climate) changes, remaining effective and increasing resilience across the WEFE Nexus in the longer term. It is therefore important to make use of climate projections to understand the exposure of the solution(s) chosen to climate impacts and consult experts, review literature and/or commission modelling studies to understand the likely implications of these impacts for the durability and long-term effectiveness of the solution(s). A combination of green, grey and hybrid solutions may prove to be the most optimal for combating the identified challenges.

Methods: assessing the technical effectiveness of solutions

A detailed evaluation of technical effectiveness generally involves quantitative modelling, including hydrological modelling, modelling of ecosystem services and more. This can be done in different ways, including using:

- models developed to map and value ecosystem services, including the Natural Capital project InVEST software, TESSA, Aries etc.
- models not designed for ecosystem services assessment that aim to quantify biophysical structures and processes related to single ecosystem services or ecosystem service groups (e.g., hydrological models (Cong *et al.* 2020)).
- statistical models applied to specific datasets (e.g., Tang *et al.* 2014).
- proxies such as matrix approaches or search tables to present ES based on land use maps/land cover classes (Barth and Dölln 2016; Brenner *et al.* 2012; Troy and Wilson 2006)
- mapping approaches such as deliberative mapping (Palomo *et al.* 2013).
- spatial interpolation (Mokondoko *et al.* 2018).

However, approaches like modelling can be very data- and time-intensive. Some decisions do not need precise quantification of the technical effectiveness of a solution: it is only necessary to know whether the solution will be beneficial or detrimental to the objectives (Brauman *et al.* 2022). In these cases, less detailed, qualitative methods may be used first before committing resources to a detailed assessment. Qualitative methods can include expert judgement, literature review of previous studies and drawing on results from similar projects (noting that NbS are often highly context specific so it may not be possible to transfer results from one area to another).

Ultimately, the type of analysis and the required information and outputs will depend on the decision being made. Both qualitative and quantitative approaches are likely to be valid, but it is essential to be aware of the limitations in methodologies used within the decision-making process.

See Annex 5 for more detailed information on different methodologies to assess technical effectiveness of solutions for different WEFE Nexus challenges.

3.3.3 Economic feasibility

Before deciding to implement any solution, it is important to understand how much it will cost, and what the (economic) outcomes of the intervention will be. This information will help decide which set of solutions can be included in an overarching plan. On a very practical level, it isn't feasible to implement a flood reduction solution if it costs twice the budget available for flood defences. However, if that solution also delivers benefits for energy generation and recreation, it may be possible to agree budget sharing between different ministries or departments to achieve multiple aims.

NbS can lead to net positive economic benefits due to the range of socio-economic outcomes associated with them, such as increasing adaptive capacity and building resilience (Le Coent *et al.* 2023). Often the economic benefits of NbS are undervalued as monetary assessments do not account for the full range of ecosystem services and co-benefits. Le Coent et al. (2023) found NbS to be cost-effective, with implementation and maintenance costs lower than those of grey solutions offering the same level of risk reduction. However, it can be difficult to calculate the cost-effectiveness of NbS because some social and biodiversity co-benefits (and potential disbenefits) are:

- more difficult to measure (e.g., changes in wellbeing are harder to measure than area of habitat restored).
- hard to assign a 'monetary' value to.
- only delivered in the longer term.

Understanding the cost-effectiveness of NbS compared to conventional alternatives can help build the case to include NbS in strategies to address a range of challenges. Including co-benefits in financial analyses can highlight the possibility of multiple funders co-investing in a project, or it can make the broader social case for investment. Balancing different priorities and considerations can also lead to adopting hybrid approaches that combine "grey" and "green" elements (Browder *et al.* 2019). To facilitate the uptake and mainstreaming of NbS, the economic case for NbS should be made based on the multiple returns and co-benefits they could deliver. This should include demonstrating the economic potential of NbS and highlighting the competitive advantages of incorporating NbS into strategies.

Table 5 provides example criteria associated with economic costs and benefits of solutions that could be considered. Though most of these can be used to assess all types of solutions, some are NbS-specific.

For more information on economic indicators for ecosystem services see Annex 8.

Table 5

Criteria and approaches to measure economic costs and benefits associated with solutions. Some of these are only relevant to NbS.

Criteria	Description
ECONOMIC COSTS	
Up-front investment costs	The initial capital and materials expenses and labour costs needed to implement grey and NbS options, covering all aspects of design and construction.
Recurring operation and maintenance (O&M) costs	The recurring costs to ensure that components of grey and NbS options are maintained and survive over the project life cycle.
Transaction costs	The costs associated with the time, effort, and resources to search out, initiate, negotiate, complete, monitor and get to an agreement (Gray *et al.* 2019). This also includes feasibility studies, securing permits, training staff on new techniques and stakeholder engagement costs (IADB, 2020). More information about transaction costs of NbS projects can be found in Gray *et al.* (2019).
Opportunity costs	The forgone values from implementing the options (e.g., restoration or protection efforts can take land out of production, as can flooding to build a dam for energy or water needs), or other forgone income (e.g., from land used for implementing solutions, as opposed to an alternative option., They and reflect what the landowner/ user is “giving up” (i.e., net revenues from competing land uses). They are the indirect costs of the solution.

Table 5 | Criteria and approaches to measure economic costs and benefits associated with solutions. Some of these are only relevant to NbS.

Criteria	Description
ECONOMIC BENEFITS (from services provided by solutions, including ecosystem services provided by NbS)	
Market prices	The economic value of resources that can be traded in markets. This is particularly relevant to food provision and energy provision.
Net factor income	The economic value of ecosystem inputs into the production of marketed goods and services. Since ecosystem inputs are often not priced, this method tries to calculate a monetary value for these inputs by subtracting the other input price from the final good or service.
Avoided damage cost	The economic value of the risk reduction benefits derived from solutions, including in climate change mitigation and adaptation.
Replacement cost	Relevant only to NbS, the replacement cost method estimates the value of an ecosystem service as the cost of replacing the service with human-built infrastructure/ similar asset at the current market price.
Stated preferences/ willingness to pay/ revealed preferences	Readiness to pay for a service or good. Based on the observation of individual behaviours and choices within existing markets, which are linked to the targeted ES. This includes the recreational value of a given site (e.g. the willingness to pay for a site visit)

Considerations

- What are the costs and negative economic impacts related to NbS planning, implementation, monitoring, management and maintenance? (see Table 5)
- What uncertainties could result in incurring additional costs?
- What economic benefits should be considered related to different solutions, including synergies with broader goals?

Methods: assessing the economic feasibility of solutions

Assessing the economic feasibility of solutions requires the quantitative economic valuation of costs and benefits of solutions (including NbS) (Table 5), generally followed by a cost-benefit analysis.

For more information on methods to estimate different costs and benefits, see Annex 6.

When valuing ecosystem services, a biophysical evaluation of is first needed to estimate the supply of services. Methods for estimating the supply of Ecosystem services in biophysical terms is described in 'Technical effectiveness' and Annex 5. The economic value of ES is derived from the demand for ecosystem services from people (the benefits to society), from which it is possible to derive the economic value where biophysical indicators then translated into a monetary value.

Solutions are compared through a Cost-benefit Analysis (CBA) using metrics such as the Cost-Benefit Ratio and Net Present Value.

For more information on how biophysical traits relate to economic outcomes, see Annex 7.

3.3.4 Social outcomes

Considering the potential social outcomes of any intervention, including NbS, is essential. To ensure the expected societal benefits are achieved, while avoiding or minimizing any negative outcomes, there needs to be an appropriate assessment of social outcomes during the planning stage to understand and anticipate potential impacts and help to ensure the sustainability of solutions. Solutions can also have unintended outcomes and trade-offs between people or societal groups which need to be assessed.

This assessment needs to identify any likely negative social outcomes of solutions as well as determine measures to reduce them. At the same time, it should explore ways of promoting positive social outcomes (for example, ways to reduce existing social inequalities). The identification of possible social outcomes, as well as ways to reduce the negative impacts and enhance positive impacts of solutions should be done in close collaboration with stakeholders.

It is useful to consider the different types of ecosystem services and how they link to benefits and/or disbenefits to people. Benefits from NbS for people can be both material (e.g., ecosystem services that provide food or regulate water), and non-material (e.g., cultural value and contributions of nature to human well-being) (Díaz et al. 2018). Where these benefits and services target the primary objective of NbS, they are evaluated under 'technical effectiveness'. Some (but not necessarily all) [material] benefits will have been covered by the 'economic feasibility' assessment discussed above.

Solutions that affect non-material ecosystem services deliver intangible benefits and disbenefits (Box 5). This includes the cultural, religious, ethical, philosophical and psychological importance of nature (Millennium Ecosystem Assessment [MEA] 2005; OECD 2020). These concepts are less easy to quantify compared to material outcomes. Table 5 provides examples of the potential intangible benefits from solutions due to increases in non-material ecosystem services. They are split into social benefits and cultural benefits.

Table 5

Examples of intangible benefits.

Social benefits	Cultural benefits
• Learning and inspiration • Physical and psychological experiences (e.g., a reduction in self-reported anxiety or stress) • Perceived ownership of space • Social rules on the use of resources and taboos (Source: adapted from Dumitru et al. (2021))	• Supporting identities • Sense of belonging to the community and social cohesion • Heritage, historical and cultural meanings • Traditional events organized around natural areas • Spiritual values, spiritual enrichment and designation of sacred species or places

Certain outcomes from solutions, such as enhanced biodiversity, can lead to both non-material and material benefits. For example, a solution may increase insect diversity in an area. Some people may report an increased quality of life and/or opportunities for learning from increased interactions with certain insect species, like butterflies or bees, in their local neighbourhood. This is a form of social benefit that has resulted from implementing the solutions. If any of the insect species present, or present in greater numbers, hold spiritual importance to local communities, this would also be a cultural benefit. Where some of the insects are pollinators of local crops, this would result in a material benefit. However, it is important to note that increased insect diversity could also cause disbenefits if it increases the instances of insect borne diseases for crops or local communities, for example.

Aspects to consider

Veerkamp et al. (2021) suggest multiple questions to consider when assessing the social outcomes of solutions, such as:

- What social conditions could be impacted by the solution?
- Who benefits from and who is negatively impacted by the solution?
- Does the solution enhance human well-being? Are there ways to design it to create more benefits?
- Are there negative impacts on particular stakeholder groups? Is there a way to avoid these?
- Could the solution increase inequality?
- Are there impacts on human relationships with nature?
- Are any traditional/Indigenous practices impacted by the measure?

Methods: assessing the social outcomes of solutions

Some potential social outcomes from NbS implementation can be assessed quantitatively. These are generally the material benefits. Social benefits and disbenefits related to regulating services (e.g., erosion control, flood risk reduction) and provisioning services (e.g., food and water provision) can be estimated using ecosystem service models (for more information see 'Technical effectiveness' and Annex 5).

Other social outcomes are much harder to quantify. These are generally related to the non-material ecosystem services that produce intangible benefits (Table 5). These require qualitative techniques, including participatory assessments and group valuations (MEA 2005). These approaches usually assess socio-cultural values attributed to ecosystem services based on a group or community-based valuation. Stakeholder engagement when planning solutions is described in the 'Stakeholder engagement' section. There may also be some formal requirements for the assessment of these impacts, for example an Environmental and Social Impact Assessment (ESIA) or specific requirements from donors (for example, a gender action plan following a robust gender analysis).

For more information on assessing non-monetary outcomes for NbS, please see Annex 8.

3.3.5 Environmental outcomes

It is important to understand the potential outcomes of solutions for the environment beyond their primary objective, with the aim to maximize benefits and minimize the risk of disbenefits (Box 4). In planning for any intervention, the first and most important step is to avoid adverse impacts. All actions in a landscape have the potential for positive and negative impacts. It is important to understand what negative impacts might occur so steps can be taken to avoid them, minimize them where they cannot be avoided, mitigate them and, if residual impacts remain, compensate for those impacts (in line with the mitigation hierarchy). It is also a vital part of the process to understand what the trade-offs might be and the potential benefits and who will receive them.

For example, forest restoration in one area may reduce the quantity of water available in other areas of a water catchment, and changing land use from farming back to forestry would reduce the area of habitat available to farmland specialist species. In the case of NbS, there should be an overall benefit for biodiversity and ecosystem services.

Understanding environmental outcomes requires an understanding of the current state of ecosystems and their functions, as well as the causes of their degradation and loss. Solutions should be planned using the best available information about the state of and pressures on ecosystems, biodiversity and ecosystem services.

Aspects to consider

- What environmental impacts need to be considered in the assessment (both positive and negative, e.g., impacts on biodiversity, soil quality, water cycle etc.)?
- What is the potential impact of the solution on ecosystem services?
- Which stakeholders are affected by these environmental impacts?
- How can any negative impacts be avoided, or minimized / mitigated if they can't be avoided?

Methods: assessing the environmental outcomes of solutions

Some environmental impacts will be identified during the technical effectiveness assessment. For example, if a NbS, such as wetland restoration has been selected, this will contribute to increased water retention and flood risk reduction. However, a holistic assessment of the environmental outcomes of solutions is still needed to ensure there are not unwanted environmental consequences for other locations. The assessment could include:

1. The **collection of data** and information relevant to the environmental context of the location, including conservation priorities and protected areas, environmentally sensitive areas, current land uses and future development plans for the area.

2 **Analysis of existing data** on the environmental context to identify the current state of ecosystems and the environment, including trends and drivers of change. This is intended to help provisionally identify environmental issues and potential benefits from proposed solutions.

3 Using **participatory approaches to engage with stakeholders** to identify potential environmental impacts of solutions. This could include participatory workshops, focus group discussions, field visits, etc.

4 **Identifying measures to reduce disbenefits and enhance benefits** of solutions. Templates can be used to guide this process

5 It may also be necessary to carry out **formal processes such as an Environmental and Social Impact Assessment (ESIA)** as part of the process to identify suitable solutions, refine the design and ensure that implementation is done appropriately.

Once implemented, solutions should be monitored to ensure that the expected outcomes are realized and that any unintended or unforeseen consequences are identified and remedied (see Next steps).

For more information on assessing the non-monetary outcomes of solutions, please see Annex 8.

STEP 4

Select solutions and design strategies

When to use this step

This step will help answer the following questions:

- How do Nature-based Solutions (NbS) compare with other solutions?
- How can individual solutions be incorporated into an overarching strategy that could include green, grey and hybrid measures?
- Which is the optimal strategy – i.e., the strategy that has the most synergies between contributions to achieving sectoral objectives and the fewest trade-offs?

These questions will help determine and design optimal solutions to achieve water, energy, food and ecosystem objectives. Building on Step 3, this step is used to prioritize solutions and combine them within strategies that contribute to water, energy and food security, whilst maintaining ecosystems. Synergies and trade-offs resulting from individual measures (see Step 3) can help to establish where solutions may work more effectively in combination. For example, restoring a floodplain in combination with levees for flood management could be more effective than either option alone (Green-Grey Community of Practice 2020). Also, soft measures might be needed to enable the implementation and uptake of certain practices. For example, to implement agroecological practices, it might be necessary to build capacity and share knowledge of the practices and their benefits.

TOOLS, APPROACHES AND EXPERIENCES FROM REXUS

CASE STUDY 5
Integrating NbS into Participatory Systems Dynamics Modelling for the co-design of strategies.

4.1 Compare and prioritize solutions

After evaluating the list of different individual solutions (including NbS, grey and hybrid options), candidate solutions can be compared against selected criteria to identify their suitability both individually and in combination. To support this comparison and combination exercise, it is useful to compile the results of the evaluation in a concise format.

An example of how this was done in the REXUS project in the form of a simple solutions card is shown in Annex 2.

A multi-criteria analysis (MCA; see Step 3: 'Enabling environment') can be a useful tool to rank different solutions and help select the most suitable ones. For example, scorecards can be used with chosen criteria, the indicators and the level of performance against these indicators.

An example of a scorecard can be found in Annex 9.

4.2 Designing strategies

When combining solutions into strategies, a useful principle to use is 'green where we can, grey where we must'. However, generally a combination of different types of solutions will be most effective at addressing societal challenges, including climate change adaptation (UNEP 2019). See Box 10 for some guiding principles for combining solutions.

There will be several viable combinations of solutions that are likely to be effective. However, to build a resilient WEFE Nexus, it may be sensible to prioritize solutions that have the potential to produce multiple benefits. In the context of climate change uncertainty, low-regrets solutions (including NbS) should be considered that offer flexibility over a range of different possible climate change futures (Choi et al. 2021).

While the aim is to design the optimal combination of solutions, there will be competing interests between different stakeholders who have different priorities. Therefore, a level of compromise is inevitable. When developing strategies, comparing the impacts of strategies one objective at a time can make it easier to identify where solutions could be changed to minimize trade-offs and maximize synergies.

BOX 10

GUIDING PRINCIPLES FOR COMBINING NBS AND GREY SOLUTIONS

Map the opportunities for NbS within the landscape. NbS require space and a suitable location within the landscape. For example, for flood peak reduction upstream, natural water retention wetlands or ponds may help reduce the sharp peak discharge that might otherwise be experienced further downstream. At the same time these measures will provide a groundwater-recharging function, as water is being kept in the area longer, allowing it to infiltrate into the soils. In this example, it would be necessary to map locations where natural water retention areas already exist as natural features in the landscape (e.g., local depressions, drained wetlands and frequently flooding agricultural fields).

Acknowledge that combining multiple solutions will often provide a better result. Following from the previous example, next to the upstream natural water retention measures, additional room for the river at further downstream location may also be found in changing land-use, widening floodplains or setting back levees. Together these measures may further benefit downstream communities by reducing the overall flood peak. Where needed, local properties may require extra levels of protection through grey solutions, e.g., by small levees or extra local drains.

Identify the linkages between ecosystems and grey infrastructure systems (Browder et al. 2019). Good practice entails identifying – at least at conceptual level – the linkages between ecosystems and the water, energy and food infrastructure; for example, the linkages between forest, wetlands, agricultural land use and the water infrastructure functions. Planners should be aware of the range of contributions NbS can make to enhancing water, energy and food related ecosystem services and other outcomes. This includes reducing grey infrastructure requirements; complementing grey infrastructure components, leading to enhanced overall service provision; safeguarding grey infrastructure assets by acting as a first line of defence; and/or providing system redundancy in the face of a changing climate.

Evaluate individual measures both on their primary benefits and on their co-benefits, synergies and tradeoffs. NbS – by definition – provide human well-being and biodiversity benefits. In grey solutions, co-benefits for people and biodiversity are less likely to occur. As multiple goals need to be reached that go beyond the the primary objective, it is good to evaluate measures for all these goals. For example the impact of the solutions on biodiversity and water quality, not just water quantity. Such co-benefits may also be expressed in terms of economic gain, when the improvement of water quality also benefits the quality of drinking water provision in the area.

Consider time frames. The benefits from different solutions may be generated in different time horizons. For example, a grey solution may take a long time to plan and construct but, once built, most will deliver benefits immediately. Conversely, NbS can take time to establish and deliver a full range of benefits but, unlike grey solutions that often have a defined lifespan, they may continue to deliver benefits long into the future.

4.3 Comparing strategies

It can be challenging to look at outcomes of solutions and/or strategies across a system, even though this understanding is necessary to produce strategies that consider the WEFE Nexus. Systems dynamics modelling is one approach that can be used to gain an understanding of systems interactions in the WEFE Nexus and the potential outcomes of different combinations of solutions.

Within the REXUS project, Participatory Systems Dynamics Modelling (PSDM) has been used as a tool to show relationships between different variables across the WEFE dimensions (Case Study 5). In a semi-quantitative way, this approach helps to show how the implementation of different combinations of solutions is likely to affect different parts of the system.

CASE STUDY 5

Integrating NbS into Participatory Systems Dynamics Modelling for the co-design of strategies

Background

Participatory Systems Dynamics Modelling (PSDM) was used in the REXUS project by Istituto di Ricerca Sulle Acque (IRSA) as a methodology for simulating the impacts of different solutions on the main WEFE Nexus challenges. In order to include NbS in the PSDM, a qualitative/semi-quantitative assessment of impact of different NbS was carried out.

Approach

PSDM uses a systems-thinking approach, where the dynamic evolution of a system over time is modeled based on the structure of interconnections between elements. This approach analyzes the complex web of interactions (including physical, ecological and socio-economic factors). This allows the assessment of the impact on the whole system of different solutions. It considers co-benefits and disbenefits as well as synergies and trade-offs.

The PSDM also uses a participatory approach to identify key elements and interlinkages in the system, including the WEFE Nexus challenges. This helped locate leverage points to implement solutions via a diagram of interconnections called a Causal Loop Diagram (CLD). See Figure CS5-1 for an example CLD for water use in the Lower Danube. This exercise builds the foundations for developing a stock-flow model, which incorporates mathematical expressions to quantify system interconnections. To include NbS in the PSDM, the multi-dimensional implications of the short-listed NbS were assessed to determine the potential benefits and co-benefits and the onset of trade-offs over time.

Results

In the case of the Lower Danube, NbS were matched with challenges and their associated key ecosystem services (Step 2). For example, maintaining and enhancing wetlands was prioritized as an NbS to respond to the challenge of securing water availability. Potential indicators to measure how effective these wetlands are at increasing and maintaining water availability were identified. A qualitative scale of the potential impact of different NbS was provided for water, energy, food, and ecosystem domains. The estimation of impact of different NbS was further refined with data from literature review and ecosystem service modelling to enable a more quantitative assessment.

Figure CS5-1

Example Causal Loop Diagram (CLD) depicting water use in the Lower Danube

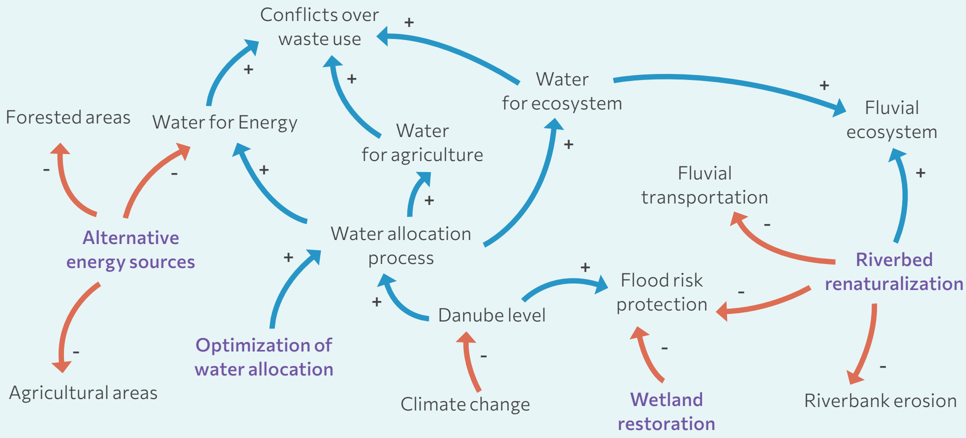


Table CS5-1

Prioritized NbS associated with WEFE Nexus challenges in the Lower Danube

WEFE Nexus Challenge	Nature-based Solution
WATER	
Lower Danube water levels: Increased periods with very low water level due to climate change with impact on agriculture (drought and desertification) and navigation	**Maintain and enhance natural wetlands**
	Wetland restoration and management to improve the hydrological regime and enhance habitat quality (room for river/lateral connectivity)
	Agroecological practices
FOOD	
Soil degradation/aridity	**Agroecological practices**
	Reforestation/forest restoration
Maintaining agricultural production	**Wetland restoration with multiple benefits**

Table CS5-1 | Prioritized NbS associated with WEFE Nexus challenges in the Lower Danube

WEFE Nexus Challenge	Nature-based Solution
ECOSYSTEMS	
Disconnection of the floodplain from the river	**Floodplain (wetland and forest) restoration and management** to improve the hydrological regime, enhance habitat quality and increase biodiversity
ENERGY	
Lower Danube water levels: Increased periods with very low water level due to climate change with impact on energy production from hydropower	**Maintain and enhance natural wetlands**
	Wetland restoration and management to improve the hydrological regime and enhance habitat quality (room for river/ lateral connectivity)
	Agricultural practices to improve water efficiency e.g., managing irrigation channels in agricultural landscapes
	Planting and habitat management to reduce energy demand e.g., from permaculture and aquaculture
	Reforestation of hydropower reservoir catchments

Table CS5-2

Example of challenge, the associated NbS and key ecosystem services identified that respond to the challenge and criteria related to the main objective. Based on these, a qualitative scoring was given to estimate the impacts over the WEFE Nexus.

Challenge	Nature-based Solution	Key Ecosystem services responding to the challenge	Criteria related to main objective	Potential Impact			
				W	E	F	E
Ensuring maintenance of water level	**Maintain and enhance natural wetlands**	• Water provisioning • Water flow regulation • Natural hazard protection	Water availability	++	+	+	++

NEXT STEPS
Implement and monitor solutions

The REXUS Framework focuses on the planning of Nature-based Solutions (NbS) among other solutions within a WEFE Nexus strategy. Once a strategy has been planned, it should be implemented and monitored. These particular aspects of moving from Nexus thinking to Nexus doing are beyond the scope of the REXUS framework, but some of the key considerations to ensure that strategies achieve their aims are highlighted below.

Detailed design and implementation

The steps of the REXUS Framework help consider which 'set' of solutions should be included in a strategy to help address the prioritised WEFE Nexus challenges. Depending on the level of detail achieved through evaluation in Step 3 and Step 4, some additional feasibility studies will be needed prior to implementation of NbS.

Stakeholder consultation continues to be a vital part of the detailed design process, which could include detailed studies to inform the location and detailed specifications of the NbS and other solutions to be implemented under the strategy. For example, it could help assess exactly where forest restoration efforts should be targeted within a broader area to maximise flood reduction benefits. Depending on the context, this detailed design stage may include legal or policy driven requirements before a strategy can be implemented, like conducting Environmental (and Social) Impact Assessments (ESIA), developing a management and maintenance plan and securing all necessary permits or permissions. Financing mechanisms will also need to be identified to fund the implementation and maintenance of solution. Securing financing is really key for all solutions, but is sometimes highlighted as a particular challenge for NbS. Fortunately, financing for NbS is expanding. Due to the ability of NbS to meet multiple objectives within and beyond the Nexus, the inclusion of NbS within WEFE Nexus strategies may even open up new or additional sources of funding to implement them (e.g. from climate and nature conservation focussed sources).

Once detailed design has been undertaken, permits and permissions are in place, and financing has been secured, the WEFE Nexus strategy can be implemented. At this stage, important considerations include securing people with the time and skills to create the solutions themselves (e.g., construct the irrigation system, or restore the upland forest area) in line with the vision, and ensuring no adverse impacts arise (e.g., measures are in place to avoid pollution and protect environmentally sensitive areas). Involving stakeholders in implementation (e.g., working with local communities and landowners to plant trees as part of restoration efforts) can help build further support and long term buy-in.

Monitoring and Evaluation

Monitoring and Evaluation (M&E) of solutions is essential to confirm whether each solution (singly and in combination with other solutions in the strategy) is achieving its intended objectives – or determine why it isn't. M&E provides the foundation for adaptive management and is key to addressing the uncertainties around solution effectiveness. There are still gaps in the evidence base regarding the effectiveness of NbS in different contexts, which robust M&E may help fill. In turn the information collected through M&E may support efforts to integrate and scale up NbS across different sectors. It also bolsters policies and legislation with useful data. Ideally, an M&E plan should be developed prior to implementation and linked closely to the objectives of the strategy. The evaluation of solutions during planning can form the basis of an M&E plan, as technical effectiveness indicators will have already been identified, as well as the key intended outcomes of solution implementation.

Resources

- *Guidebook for Monitoring and Evaluating Ecosystem-based Adaptation Interventions*, 2020.
- *Handbook System for the Design and Implementation of EbA*, 2022.
- *Implementing nature-based flood protection: Principles and implementation guidance*, 2017.

Conclusion

With growing pressures on the resources and services that people and nature rely on, taking a WEFE Nexus approach and considering the contribution that all solutions can make is key to developing effective strategies to resolve challenges and enhance resilience.

At the core of the REXUS Framework is stakeholder engagement. The REXUS project has shown the value of bringing all stakeholders together to discuss WEFE Nexus challenges and to co-create strategies that respond to their priorities. This REXUS Framework guide is one tool that can be used to close the gap between science and policy in managing resources to enhance resilience and deliver on the multiple societal objectives located at the WEFE Nexus.

The REXUS Framework outlines four, clearly defined steps that can help practitioners, and all those involved in developing strategies to address pressing WEFE Nexus challenges, and include NbS in their discussions and decision-making processes.

By following the REXUS Framework steps that are relevant to a particular context, and reviewing and using the data, tools and methodologies presented from both within and outside REXUS, practitioners, decision-makers and stakeholders can work together to integrate NbS into their strategies to help build resilience – moving from *Nexus thinking to Nexus doing*.

Glossary

B	**Base case analysis**	The current situation or 'state' of the area and the factors influencing it, such as environmental conditions, infrastructure, demands of resources and ecosystem services provided.
C	**Causal Loop Diagram**	A diagram that captures how elements of a system are interrelated by depicting cause-and-effect linkages and feedback loops (Sterman 2000).
	Cost-Benefit Analysis	A common method for evaluating and comparing projects and investments. CBA involves computing the costs and benefits of a project in monetary terms, relative to the baseline or 'without project' scenario (van Zanten et al. 2023).
	Cost-Benefit Ratio	A key indicator that can be used to compare present value costs and benefits of solutions. This divides the total present value of benefits by total present value of costs. A ratio greater than one indicates a net gain (Le Coent et al. 2021).
E	**Ecosystem Services**	"The benefits people obtain from ecosystems. According to the original formulation of the Millennium Ecosystem Assessment, ecosystem services were divided into supporting, regulating, provisioning and cultural" (IPBES 2019).
	Ecosystem-based Adaptation	"the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change" (Secretariat of the CBD 2009) and "that takes into account the multiple social, economic and cultural co-benefits for local communities" (Convention on Biological Diversity 2010).
	Environmental and Social Impact Assessment (ESIA)	This is a widely used procedure to investigate the environmental and social consequences of a project and proposes measures to mitigate potential negative impacts.
F	**Free, Prior and Informed consent**	A principle protected by international human rights standards that allows Indigenous Peoples and local communities to withhold or give consent to a project that may affect them or their territories, and allows them to withdraw consent at any stage, in a manner that is free from coercion, prior to the beginning of activities and well-informed.
G	**Grey solutions**	Solutions based on "built structures and mechanical equipment" such as sea walls (Browder et al. 2019).
H	**Hybrid solutions**	Solutions that use a combination of grey solutions and Nature-based Solutions (Sutton-Grier et al. 2015).

I	**Indicator**	Indicators are the measurable parameters about certain conditions, characteristics or performance that depict the wider technical, biophysical, environmental, socio-economic or climatic situation (GIZ et al. 2020).
L	**Leverage points**	Leverage points are places within a complex system where a small shift in one thing can produce big changes at system scale (Meadows 1999; Egerer et al. 2021).
M	**Mitigation Hierarchy**	“The mitigation hierarchy comprises four broad actions step that are designed to be implemented sequentially: (1) avoid, (2) minimize, (3) remediate, and (4) offset” (Arlidge et al. 2018).
	Multi-criteria Analysis	“Any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives. In MCA, desirable objectives are specified and corresponding attributes or indicators are identified. MCA provides techniques for comparing and ranking different outcomes, even though a variety of indictors are used.” (UNFCCC n.d.).
N	**National Adaptation Plan (NAP)**	"Under the Cancun Adaptation Framework, NAPs were introduced to identify adaptation needs and develop action plans to address those needs." (UNEP 2021).
	Nature’s Contribution to People	“All the contributions, both positive and negative, of living nature (i.e., all organisms, ecosystems, and their associated ecological and evolutionary processes) to people’s quality of life” (IPBES 2019).
	Nature-based Solutions	“Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits” (United Nations Environment Assembly 2022) (UNEP/EA.5/Res.5, paragraph 1).
	Nexus	In the context of REXUS, Nexus refers to the connections between water, energy, food systems and ecosystems.
P	**Participatory Systems Dynamic Modelling**	A process that involves stakeholders in the development of simulation models to explore the behaviour of a system over time (Sterman 2000). This method helps problem identification in socio-ecological systems to support decision making (Kopainsky et al. 2017).
	Practitioner	Anyone who is involved in developing a plan or strategy to address efficient use and management of natural resources.

R	**Reference case analysis**	The analysis that describes the future performance of the system under present policies and regulations (often known as the 'business as usual scenario').
	Resillience	"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management." (United Nations General Assembly 2017).
	REXUS	Managing REsilient neXUS systems through participatory systems dynamics modelling. Rexus aims to develop and validate knowledge and tools to facilitate the transition from Nexus Thinking to Nexus Doing. (*The Rexus Project:* https://www.rexusproject.eu/project-summary/)
	Risk	"The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species" (Intergovernmental Panel on Climate Change 2023).
V	**Vulnerability**	"The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards." (United Nations General Assembly 2017).
W	**Water-energy-food-ecosystems (WEFE) Nexus**	"The water–energy–food–ecosystems (WEFE) Nexus is an approach that moves away from the traditional focus on separate entities but rather integrates management and governance across the multiple sectors of food, energy, water, and ecosystems as being complex and inextricably entwined." (Carmona-Moreno et al. 2021, p.1).
	WEFE Nexus Challenges	The challenges at the intersection of resource systems (water, food and energy systems) and ecosystems, particularly how to efficiently use and manage natural resources to achieve water, energy and food security in resilient ways.
	WEFE Nexus Strategy	A set of solutions to address the WEFE Nexus challenges.

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Annexes

ANNEX 1
Summary of activities performed by different work packages (WP) of the REXUS project relevant to different steps of the REXUS Framework

Table 8 provides information on REXUS project activities that are relevant to each step of the REXUS Framework. This table can be used to identify other materials and analyses produced by REXUS that could support better integration of NbS into decision-making for WEFE challenges. It could also help to identify useful activities to carry out within the framework process.

Table 8

Activities performed in the REXUS project relevant to steps of the REXUS Framework

Step	Information provided by the REXUS project
Setting up the Stakeholder engagement process	• **Stakeholder mapping** (WP2): Identification of stakeholders to include in the Learning Action Alliances (LAAs), including desk study and interviews.
	• **Kick-off meetings with LAAs** (WP2): Introduced the project and discussed stakeholders' expectations and needs from the participatory process.
	• **Guidelines for stakeholder engagement** (WP2): Defined clear steps for engagement at the beginning of the project. This is a fundamental part of establishing LAAs. The guidelines are intended to provide a conceptual basis (e.g., why participatory approaches are a core activity in the REXUS strategy) and guidance for the practical application of the approaches. For more information, **deliverable 2.1 LAA Stakeholder Engagement. Guidelines** has been uploaded to the platform.
	• **REXUS learning platform** (WP2): To facilitate activity in different LAAs, promote continuity of LAA communities and disseminate success stories and lessons learned through the project.

Table 8 | Activities performed in the REXUS project relevant to steps of the REXUS Framework

Step	Information provided by the REXUS project
STEP 1 Identify challenges, risks, vulnerabilities and opportunities across sectors.	• **Baseline descriptions of pilots** (WP6): This activity assembled Nexusrelevant available information and data for each of the five REXUS pilot areas, including a scoping study of their sectoral and WEFE Nexus challenges, and national and regional objectives per sector.
	• **Analysis of institutional and governance structures** (WP2): Analysis of how conducive current governance structures, institutional arrangements and policy context in pilot areas in order to adopt a Nexus approach. This included a review of existing Nexus-relevant policy frameworks for water, energy, food and environment (including, the EU Water Framework Directive, Sustainable Development Goals and Nationally Determined Contributions)
	• **Analysis and description of the 'Nexus structure'** (WP4): This activity used Causal Loop Diagrams (CLDs) to define a preliminary model of the Nexus system and its interlinkages in each pilot area. The CLDs were validated with stakeholders in each pilot area. This formed the basis for building quantitative stock and flow models.
	• **Coupled resource stock-flow models** (WP4): These built on the pilot conceptualization performed though the CLDs and were based around the structure of dynamic Sankey diagrams. This approach was used to show changes to stocks and flows of resources under reference, baseline, and future scenarios.
	• **Agricultural water accounting and footprint** (WP3): This provided monthly and yearly water accounting and annual footprint values for different crops. It also provided average water accounting and footprint values for the future short (2030-2050), medium (2051-2070) and long (2071-2090) periods under two climate change scenarios (RCP 4.5 and RCP 8.5), for these crop types.
	• **Energy and carbon accounting** (WP3): This assessed needs, sources, carbon accounting, and footprints of energy based on different case studies and forecasting scenarios through the analysis of energy and food systems in the REXUS pilot areas.

Table 8 | Activities performed in the REXUS project relevant to steps of the REXUS Framework

Step	Information provided by the REXUS project
STEP 1 Identify challenges, risks, vulnerabilities and opportunities across sectors.	• **Land-use suitability mapping** (WP3): This activity developed land use maps for the pilot areas. It then analyzed future land use suitability of major crops for pilot areas. It did this by analyzing potential yield based on water, soil, climate and management of crops under different climate change scenarios.
	• **Climate projections** (WP3): Assessed expected changes in the main climatic variables for the pilot areas. Climatic variables included mean temperature, total precipitation and potential evapotranspiration. These were estimated for an intermediate emission scenario (RCP4.5) and a high emissions scenario (RCP 8.5) for future time steps of 2031-2050, 2051-2070 and 2071-2090 and compared to a reference period of 1986- 2005.
	• **Climate risk assessments** (WP6): This included hazard assessments through indicators for each WEFE sector and critical thresholds; exposure assessments (geographical datasets to identify, map and assess exposure of pilot areas to climate change); vulnerability assessments through indicators expressing the predisposition and susceptibility of WEFE sectors to climate change impacts; and adaptive capacity assessments based on criteria and a questionnaire to local stakeholders.
	• **REXUS data observatory** (WP3): a data repository in the form of an interactive platform to store key datasets and indicators related to the Nexus produced by different partners for the pilot areas. This has been made accessible to all REXUS partners in the consortium.
STEP 2 Identify solutions to address the challenges.	• **AirNbS platform** (WP5): This web viewer is intended to be an interactive guide that helps users to increase the understanding of NbS options and to select and prioritize potential solutions, while promoting stakeholder engagement, by visualizing the steps and background behind the selection of NBS options to address the WEF challenges. AirNbS provides a user-friendly interface to select potentially suitable NbS, through smart combinations of criteria defined by the users.

Table 8 | Activities performed in the REXUS project relevant to steps of the REXUS Framework

Step	Information provided by the REXUS project
STEP 2 Identify solutions to address the challenges.	• **The development of visions and pathways for Nexus sustainability and transformation pathways through sets of priority actions** (All WPs). A long-list of relevant solutions (including NbS) was identified based on the priority WEFE challenges, through desk-review and based on the findings from the CLD analysis. A stakeholder workshop was conducted where stakeholders selected the most appropriate and desirable solutions.
STEP 3 Evaluate solutions for how well they address the challenges.	• **Definition and analysis of Nexus indicators** (WP4): This was based on indicators identified through the scientific literature related to Nexus analyses and through interviews with stakeholders to identify key measurable quantities related to challenges in their sector/domain. This also included the identification of 'Nexus Resilience qualities based on evidence from the PSDM.
	• **Definition of Hazard indicators** (WP6): for water (floods and droughts), energy (electricity demand, renewable energy potential) and food (crop growth and stress), and related critical thresholds.
	• **Vulnerability indicators** (WP6) expressing predisposition and susceptibility of Nexus sectors to climate change impacts.
	• **Identification of indicators and procedures for assessing ecosystem services in Nexus systems** (WP3): The activity identified a list of ecosystem services to be considered for evaluating NbS in the Nexus context. It also identified the associated indicators to assess these. A procedure was developed to assess ecosystem service supply, ecosystem service demand and the economic value of ecosystem services in pilot areas.
	• **Identification of relevant criteria and indicators** (WP4, WP5): Identified criteria related to selected solutions (including NbS) and selected appropriate indicators.
	• **Performed evaluation of NbS in selected pilot areas** (WP5): This was done in selected pilot areas and based on their needs. For example, in the Nima pilot area, the biophysical and economic valuation of NbS was conducted as input to the final stakeholder workshop. Other pilots carried out qualitative evaluation of solutions as input into the PSDM.

Table 8 | Activities performed in the REXUS project relevant to steps of the REXUS Framework

Step	Information provided by the REXUS project
STEP 4 Select which solutions to include in a WEFE Nexus strategy.	• **Transition pathways for a resilient Nexus in pilot areas and developing an action plan** (WP2+ input from other WPs): Validated the selected priority actions with stakeholders and drafted an action plan in order to materialize the Nexus pathways and vision.
	• **PSDM analysis of impacts of different strategies** (WP4): PSDM incorporated quantitative and qualitative scenarios of implementing different suites of solutions.
	• **Coupled resource stock-flow model** (WP4): Showed changes to stocks and flows of resources at a strategic level. This approach was used to show changes to stocks and flows of resources under different scenarios of strategy implementation.
	• **Simulation game** (WP4): Provided a visualization of policy impacts for decision makers and wider stakeholders (WP4).

ANNEX 2
Example solutions card

This is an example of a solutions card (front and back) that can be used in workshops to identify viable solutions for the identified WEFE Nexus challenges.

FRONT SIDE

Solutions Card |Buffer Strips for water infiltration and slowing surface flow

Description
Strips of native vegetation (bushes or trees) at the margin of fields, arable land, roads and water courses provide good conditions for effective water infiltration. They can also slow surface flow and reduce theamount of suspended solids e.g. from agricultural runoff.

NEXUS Dimension	Water	Energy	Food Security	Ecosystems
Relevance (-/0/+/++)	++	0/+	+	+

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Buffer Strips for water infiltration and slowing surface flow

BACK SIDE

Solutions Card | Buffer Strips for water infiltration and slowing surface flow

Potential to address challenges			
Soil degradation & desertification	Unauthorized groundwater abstraction	Albufera wetland state	Jucar River baseflow
✓	✓	✓	✓

Ecosystem Services Enhanced													
Food provisioning	Water provisioning	Energy source	Material resource	Genetic Resources	Climate Regulation	Water flow regulation	Water purification	Moderation of extreme events	Erosion prevention	Biological control	Lifecycle maintenance	Recreation and tourism
					✓	✓	✓	✓	✓		✓	

Indicative Cost ($ to $$$)	Timeline (◷ to ◷◷◷)	Biodiversity Benefit (✲ to ✲✲✲)
$$	◷◷	✲

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PARTNER LOGO

REXUS

ANNEX 3
Template to help assess the enabling environment

Table 9 includes the recommended key dimensions, key criteria and indicators for assessing the enabling environment of NbS options and their proposed weights and evaluation scoring scale. Weights and the scoring scales can be modified based on discussions with stakeholders for specific cases.

Table 9

Recommended key dimensions, criteria and indicators and suggested weights for evaluating the enabling environment of NbS

			WEIGHT
CRITERION	1 Responsibilities for different aspects of NbS phases (planning, implementation and maintenance)		25%
INDICATOR	1 **Clearly defined structure and roles:** Dedicated actors have been identified for NbS planning, implementation, and maintenance	NbS specific	50%
SUB-INDICATOR	Planning, Implementation, Maintenance		
INDICATOR	2 NbS responsibilities: Well defined actors' responsibilities for each NbS phase have been identified	NbS specific	50%
SUB-INDICATOR	Planning, Implementation, Maintenance		
CRITERION	2 Coordination mechanisms (horizontal and vertical)		50%
INDICATOR	1 **Participation in all processes of the NbS intervention:** The use of participatory approaches in decision-making have been planned in all the phases of NbS intervention	NbS generic	20%
SUB-INDICATOR	Planning, Implementation, Maintenance		
INDICATOR	1.1 **Equity in participatory processes:** The participation is based on mutual respect and equity, regardless of gender, age or social status, and upholds the right of Indigenous Peoples to Free, Prior and Informed Consent (FPIC)	NbS generic	2%
SUB-INDICATOR	Gender, Age, Social status, Indigenous rights		
INDICATOR	1.2 **Represented stakeholders:** Identification and involvement of direct and indirect stakeholders affected by the NbS	NbS generic	3%
	2 **Represented interest of stakeholders:** The decision-making processes documents and responds to the rights and interests of all participating and affected stakeholders	NbS generic	25%

ANNEX 4
Criteria and indicators to assess the technical effectiveness of solutions against key WEFE Nexus challenges

Many indicators related to technical effectiveness have been used within the REXUS project (Table 10). These can be used as a reference to determine key criteria and indicators for evaluating the technical effectiveness of solutions according to the prioritized WEFE Nexus challenges. The WEFE Nexus challenges listed are those identified by the REXUS pilot cases areas (based on Pagano and Giordano 2022; Righetti et al. 2022; European Commission 2021). The challenges listed are not exhaustive and therefore some challenges may not be listed. This list does however cover a broad range of potential WEFE challenges and shows how to link challenges with the relevant criteria and indicators to assess technical effectiveness.

Table 10

Criteria and indicators to assess the technical effectiveness of solutions for WEFE Nexus challenges

WEFE Nexus challenges	Ecosystem services	Criteria	Example indicators
Ensuring water availability **Providing water for agriculture**	Water provisioning; Water flow regulation	Water availability	• Ground water level (depth, volume) • Number, capacity and density of water reservoirs • Number of potential beneficiaries/ groups • Surface water availability (level, volume) in reservoirs • Hydro-meteorological parameters: precipitation, temperature, rainfall intensity • River flow in different locations/ seasons • Water storage capacity per land use m^3/ha per year) • Ground water recharge rate (m^3/ha per year) • Water use (m^3/person per year; m^3/ primary and secondary sector per year

Table 10 | Criteria and indicators to assess the technical effectiveness of solutions for WEFE Nexus challenges

WEFE Nexus challenges	Ecosystem services	Criteria	Example indicators
		Water use	• Surface water/Ground water consumption (m^3/ person per year; m^3 /primary and secondary sector per year • Water demand • Number of users
		Use efficiency	• Water use efficiency • Water saving rate
		Water use for agriculture	• Quantity of pumped water per well/ user • Agricultural production per water volume pumped/used • Water efficiency in agriculture • Variation of cultivated area per crop over time • Water cost / total agricultural production cost
		Water overexploitation and management	• Groundwater level/ use vs. annual precipitation (or rate of yearly groundwater decline) • Temporal and spatial variation of groundwater and surface water • Water consumption • Water exploitation index
Dealing with poor water quality	Water purification	Ecological state	• Water quality parameters • Ecological status • Biological indicators: benthos, plant cover, fish and phytoplankton

Table 10 | Criteria and indicators to assess the technical effectiveness of solution for WEFE Nexus challenges

WEFE Nexus challenges	Ecosystem services	Criteria	Example indicators
		SW and GW deterioration	• Nitrogen concentration in surface and groundwater; Phosphorous concentration in surface and groundwater; Nitrogen to Phosphorous ratio • Dissolved Oxygen concentration in surface and groundwater • Electrical conductivity • Turbidity (Secchi disk depth) • Water temperature
Maintaining agricultural production	Food provisioning; life cycle maintenance; climate regulation	Agricultural productivity	• Agricultural production cost per unit area • Quality of agricultural products over time • Average production yield (kg/ha) • Crop consumption (kg/person per year) • Number of crop varieties and livestock breed species living in a region/ surface • Carbon sequestration rate per land use (tonnes CO_2/ha per year)
		Efficient and financially sustainable agriculture	• Energy consumption in agriculture (for irrigation) • Irrigation cost: energy • Irrigation cost: other (Maintenance, environmental fee) • Irrigation water cost/Agricultural production cost • Economic benefit per crop type vs. irrigation water needs

Table 10 | Criteria and indicators to assess the technical effectiveness of solution for WEFE Nexus challenges

WEFE Nexus challenges	Ecosystem services	Criteria	Example indicators
		Agricultural planning (crops)	• Temporal variation of cultivated area per crop over time • Economic benefit per crop type vs. irrigation water needs
		Sustainable practices	• Type, use and cost of pesticides • Use of green manure
Energy efficiency **Energy generation**	Energy source; climate regulation	Energy efficiency	• Energy cost (for irrigation) • Capacity of the energy system infrastructure • Energy consumption in agriculture (for irrigation) - unit production/ unit area • Converted energy (kWh/m^3 per year • Produced electricity (kWh/m^3 per year) • Energy use (kWh/m^3 per person per year)
		Renewable energy sources	• CO2 equivalent emissions savings • Cost of RES / Cost of conventional energy • RES density per region
		Water available for energy	• Hydropower plant production (MWh) • Number of potential beneficiaries/ groups

Table 10 | Criteria and indicators to assess the technical effectiveness of solution for WEFE Nexus challenges

WEFE Nexus challenges	Ecosystem services	Criteria	Example indicators
Dealing with erosion and sedimentation	Erosion regulation; water purification	Soil quality	• Cost-benefit of EU funding policies sectoral) • Soil quality parameters (change over time) • Kg pollutant removed from soil per soil type • Difference between current and desired pollutant concentration
		Soil degradation	• Type and use of pesticides • Loss by soil erosion (m^3/ha per year) • Amount of soil retained or sediment captured (m^3/ ha per year)
Ecosystem conservation and protection **Ecosystem restoration**	Life cycle maintenance; recreation and tourism	Environmen-tal protec-tion	• Protected areas • Illegal mining activities • Level of community awareness • Natural resources extracted (kg/ha per year) • Natural resources used (kg/industrial sector per year) • Social requests of habitat improvement or maintenance
		Biodiversity	• Aquatic vertebrates; insects • Species richness index • Biodiversity intactness index • Native vegetation or high value farmland
		Deforesta-tion	• Forested area • Deforestation rate

Table 10 | Criteria and indicators to assess the technical effectiveness of solution for WEFE Nexus challenges

WEFE Nexus challenges	Ecosystem services	Criteria	Example indicators
		Soil erosion	• Loss by soil erosion (m^3/ha per year) • Amount of soil retained or sediment captured (m^3/ ha per year) • Forested area
		Environmental flow requirement	Ecological flow requirement
Dealing with floods **Dealing with droughts**	Water flow regulation; Natural hazard protection	Water-related risks	• Frequency of extreme events • Hydro-meteorological parameters: precipitation, temperature, rainfall intensity, number of days with high low temperature • Carbon sequestration rate per land use (tonnes CO_2/ ha per year) • Population living/ economic activities situated in areas depending (directly) on ecosystem-based regulation (facing risks of flooding) • Flooded areas per year • Drought indices • Water storage capacity per land use m^3/ha per year) • Ground water recharge rate (m^3/ha per year)

ANNEX 5
Methodologies to assess technical effectiveness of NbS in relation to WEFE Nexus challenges

Table 11 provides example methodologies for assessing the key ecosystem services associated with NbS based on WEFE Nexus challenges. Methods are given according to the level of data needed and the detail of the analysis. Level 1 generally refers to methods that use expert judgement or global analysis. Level 2 generally uses global data but for the local context. Level 3 requires local data.

Table 11

Examples of methodologies to assess NbS ecosystem services and benefits

WEFE Nexus challenges	NbS benefits	Ecosystem services	Example methods
Ensuring water availability Ensuring resillience to droughts	Seasonal/ interannual variability of water availability is often an important factor in drought prone areas and important to understand service delivery. The effect of NbS on water availability is highly contextdependent and can be negative. The main impacts of NbS are changes to the evapotranspiration rate and the enhancement of the infiltration capacity of soils. E.g., *large-scale forest restoration in upper catchments; increased groundwater recharge, helping to maintain water supply* (Bassi et al. 2021).	Water provisioning Water flow regulation	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review **LEVEL 2: Ecosystem service modelling** e.g., InVEST annual water yield and seasonal water yield models **LEVEL 3: Water resources modelling** e.g., WEAP

Table 11 | Examples of methodologies to assess NbS ecosystem services and benefits

WEFE Nexus challenges	NbS benefits	Ecosystem services	Example methods
Ensuring resilience to floods	NbS can have flood risk reduction benefits due to the ability of the natural environment to retain and slow down the passage of water through its soil and vegetation. This decreases peak discharge, flood extent and flood volume. E.g., *Forest conservation/ restoration*: increases runoff retention, reduces peak discharge, flood volume and extent (Lallemant et al. 2021);	Water flow regulation Moderation of extreme events	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review
			LEVEL 2: Ecosystem service modelling e.g., TESSA (Toolkit for Ecosystem Service Site-based Assessment)
			LEVEL 3: Hydraulic and hydrological models e.g., HEC-HMS, SWAT, HECRAS
Dealing with poor water quality	NbS can trap sediment and pollutants through vegetation, soil and microorganisms. E.g., *Urban wetland: Artificial wetlands improve surface water and runoff from cities through filtering water through their soils, microorganisms and vegetation* (Iwaszuk et al. 2019).	Water purification	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review
			LEVEL 2: Ecosystem service modelling e.g., InVEST water purification model
			LEVEL 3: Water quality and primary production models for aquatic ecosystems e.g., D-Water Quality, PC-Lake, DYRESM-CAEDYM

Table 11 | Examples of methodologies to assess NbS ecosystem services and benefits

WEFE Nexus challenges	NbS benefits	Ecosystem services	Example methods
Dealing with erosion and sedimentation	NbS can stabilize riverbanks and slopes by trapping sediment to reduce bank erosion and sedimentation of waterways. E.g., *living fascines*[4]*: bundles of longliving woody stems that are established along riverbanks. They decrease erosion by stabilisation riverbanks, dissipating waves, and reducing water velocity.*	**Erosion prevention**	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review **LEVEL 2: Ecosystem service modelling** e.g., InVEST Sediment Retention Model **LEVEL 3:** SWAT
Ensuring energy efficiency	NbS can be used to increase energy efficiency. For example, by reducing the energy needed for water supply to agriculture. E.g., *agroecological practices: using ecological principles to ensure the productivity of the food production system. Various techniques improve soil water holding capacity, increasing water availability and reducing the need for irrigation* (Abdallah et al. 2021).	**Water provisioning** **Water flow regulation**	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review **LEVEL 2: Water resources modelling** e.g., WEAP

4 https://directives.sc.egov.usda.gov/17791.wba

Table 11 | Examples of methodologies to assess NbS ecosystem services and benefits

WEFE Nexus challenges	NbS benefits	Ecosystem services	Example methods
Ensuring energy generation	NbS can help to regulate water flows and maintain water availability. They can also prevent erosion and sedimentation of water infrastructure, reducing the energy needed to remove sediment (for example from reservoirs) and restore function. They can reduce energy needed for wastewater treatment/ pollutant removal. E.g., *Forest conservation and restoration: forests regulate water flows influencing water volume and timing of delivery through processes such as inception and infiltration. Increased water flow regulation can maintain hydropower production by providing a constant water supply. Forest vegetation reduces erosion and sediment export that may impact hydropower production infrastructure downstream* (Conservation International and The Nature Conservancy, n.d.).	Water provisioning Water flow regulation	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review **LEVEL 2: Ecosystem service modelling** e.g., InVEST annual water yield & Sediment Retention Models **LEVEL 3: Water resources modelling** e.g., WEAP

Table 11 | Examples of methodologies to assess NbS ecosystem services and benefits

WEFE Nexus challenges	NbS benefits	Ecosystem services	Example methods
Providing water for agriculture	The effect of NbS on water availability is highly context dependent and can be negative. The main impacts of NbS are changes to evapotranspiration rate and enhancement of the infiltration capacity of soils. For agricultural water supply, NbS like agroecology can reduce the amount of water needed. E.g., *Mulching to conserve moisture and improve soil fertility: This uses organic material to cover the surface of the soil. This practice can dramatically improve the capacity of soil to store water by reducing evapotranspiration and conserving soil moisture. This reduces the agricultural water demand* (Raffa et al., 2021).	**Water provisioning**	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review **LEVEL 2:** InVEST crop production model **LEVEL 3: Water resources modelling** e.g., WEAP
Maintaining agricultural production	NbS can Improve soil fertility, increase infiltration capacity of soils. E.g., *Intercropping: this involves rowing two or more crops in proximity. This helps to make more efficient use of resources due to the different requirements between plants to use resources. This reduces competition between plants and improves soil quality, enhancing soil organic carbon, nitrogen content and increasing soil microbial diversity* (Žalac et al. 2022).	**Food provisioning**	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review **LEVEL 2:** InVEST crop production model

Table 11 | Examples of methodologies to assess NbS ecosystem services and benefits

WEFE Nexus challenges	NbS benefits	Ecosystem services	Example methods
Conserving and protecting ecosystems	Maintaining and conserving biodiversity, ecosystems and key ecosystem functioning. This enhances the ecosystem services provided. E.g., *Maintaining and enhancing natural wetlands: Wetlands are biodiversity hotspots and conserving the conditions that maintain ecosystem functions supports biodiversity and the array of other ecosystem services they provide.*	**Life cycle maintenance**	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review **LEVEL 2: Habitat Suitability models** e.g., HABITAT, CASiMiR
Restoring ecosystems	Restoring the functioning of key ecosystems increases biodiversity and restores key ecosystem services. E.g., *Wetland restoration and management to improve the hydrological regime and enhance habitat quality: Wetlands are often areas of high biodiversity and offer many other benefits, such as water provision and flow regulation. Restoring the hydrological regimes that supports the ecosystem helps to restore these ecosystems and the habitat to support biodiversity* (Ralston et al. 2017).	**Life cycle maintenance**	**LEVEL 1: Qualitative assessment** based on expert judgement and literature review **LEVEL 2: Habitat Suitability models** such as HABITAT, CASiMiR

ANNEX 6
Methodologies to estimate the economic costs and benefits of solutions

Table 12 provides criteria and approaches to evaluate the economic costs and benefits of solutions.

Table 12
Criteria and approaches to evaluate the economic costs and benefits of solutions

Criteria description	Approach
ECONOMIC COSTS	
• **Up-front investment costs** include initial capital and materials expenses and labour costs needed to implement grey and NbS options, covering all aspects of design and construction.	This requires the collection of unit cost data per expense (e.g., EUR/ha) (e.g., for securing permits, design and planning, site preparation and construction). For example, NbS schemes may need large areas of land, which could incur purchase, transaction, or governance costs (Bridges et al. 2021).
• **Recurring operation and maintenance (O&M) costs** include recurring costs to ensure that components of grey and NbS options survive over the project life cycle.	This requires the collection of information on O&M expenditures on a unit cost basis by solution component throughout the expected lifespan of the solution. For example, for NbS O&M costs could include ecosystem management costs, such as pest control, landowner payments and enforcement. This information can be estimated from secondary data and from consultation with stakeholders to establish local costs of activities.
• **Transaction costs** associated with the time, effort and resources to search out, initiate, negotiate and complete an agreement and get investment in a solution (Gray et al. 2019). This also includes feasibility studies and stakeholder engagement costs (IADB 2020).	This requires estimates of the activities and time involved in this process. NbS can require a high economic investment in awareness raising, participatory planning and engagement to ensure the sustainability of the solutions proposed. More information about transaction costs of NbS projects can be found in Gray et al. (2019).

Table 12 | Criteria and approaches to evaluate the economic costs and benefits of solutions

Criteria description	Approach
ECONOMIC COSTS	
• **Opportunity costs** are defined as forgone value from implementing the options. For example, watershed restoration and protection efforts can take land out of production, or other foregone income (e.g., from land used for implementing solutions, as opposed to an alternative option). They reflect what the landowner/ user is "giving up" (i.e., net revenues from competing land uses). These are the indirect costs of the solution.	This requires the estimation of the net revenues from competing land uses as a result of implementing a solution. For example, this could be the loss of agricultural land. It is important to identify the relevant stakeholder groups and to capture all the relevant economic activities that could be affected by the solution.
ECONOMIC BENEFITS	
• **Valuing the ecosystem services provided by solutions**. The economic value of resources that can be traded in markets. This is particularly relevant to food provision and energy provision.	The economic value of ecosystem services starts with estimating changes in biophysical processes as a result of solution implementation (compared to a 'baseline' or 'without solution' scenario) that support the provision of ecosystem services. Then the benefits that this has on society (i.e., the ecosystem service supply) can be estimated. From this, the economic value of ecosystem services can be estimated. See Table 13 for biophysical indicators to estimate ecosystem function and ecosystem service supply and how these translate into economic valuation indicators to convert results into monetary terms. See Righetti et al (2022) for more information of the methodology developed to assess the economic benefits of ecosystem services. Estimates of ecosystem services can be done using various methodologies and tools, including modelling tools specifically developed to map and value ecosystem services, such as InVEST, TESSA, Aries etc. See Table 11 in Annex 5 for more information on these methods.

Table 12 | Criteria and approaches to evaluate the economic costs and benefits of solutions

Criteria description	Approach
ECONOMIC BENEFITS	
• **Avoided damage cost**: The economic value of the risk reduction benefits derived from solutions, including in climate change mitigation and adaptation.	This uses an approach that is similar to that explained above related to valuing the ecosystem services provided by solutions. Risk is a function of hazard (likely frequency and intensity of a destructive event), exposure (the location of the event in relation to people and assets) and vulnerability (how likely people and assets will be negatively impacted by an event). Hazard frequency and intensity can be simulated (for example flood depth). This is then converted into economic losses result from the hazard by estimating impacts on people and infrastructure. This includes estimating changes to biophysical processes as a result of the solution related to climate change mitigation (e.g., carbon sequestration) and adaptation (e.g.. flood damage reduction). It involves 1) estimating the hazard intensity for the 'baseline' or 'without solution' scenario; then 2) estimating the impact of solution implementation on the hazard intensity (with project scenario) (van Zanten et al. 2023). From this the expected economic impacts of the solution can be calculated by comparing the baseline and solution scenarios. For modelling resources related to different hazards see Table 11 in Annex 5 and other disaster risk modelling resources (e.g., GFDRR, 2014).
• **Replacement cost**: Relevant only to NbS, the replacement cost method estimates the value of an ecosystem service as the cost of replacing the service with human-built infrastructure/ similar asset at the current market price.	Cost estimates for alternatives can be derived from secondary data. For example, in GFDRR/ World Bank (2018) they estimate the replacement costs of the ecosystem service 'regulation of water flows' as a result of wetland restoration using data on water users, required water-related infrastructure, and costs from National census and statistics data and data published by the National Water Supply and Drainage Board. This can sometimes overestimate the value of ecosystem services. To ensure this is not the case, the least cost alternative for infrastructure should be used (van Zanten et al. 2023).

Table 12 | Criteria and approaches to evaluate the economic costs and benefits of solutions

Criteria description	Approach
ECONOMIC BENEFITS	
• **Net factor income**: The economic value of ecosystem inputs into the production of marketed goods and services. Since ecosystem inputs are often not priced, this method tries to calculate a monetary value for these inputs by subtracting the other input price from the final good or service.	To estimate the value of ecosystem input to production of goods and services, the production of the good or service needs to be modelled to estimate the contribution of an ecosystem to a product in monetary terms. For example, mangroves provide habitat for fish. Using data on ecosystem extent and diversity, and costs of other inputs to fish (e.g., fishing effort), and the quantity and price of fish caught it is possible to estimate the relationship between mangroves and fish productivity (van Zanten et al. 2023).

ANNEX 7
Economic indicators for valuing Ecosystem Services provided by NbS when addressing WEFE Nexus challenges

Table 13 provides indicators for the economic valuation of Nexus-related ecosystem services produced by NbS. It matches the biophysical indicators related to ecosystem function and ecosystem service supply, with economic indicators related to ecosystem service demand. It is based on a review of the main ecosystem services frameworks of the Millennium Ecosystem Assessment (MEA) (2005), The Economics of Ecosystems and Biodiversity initiative (TEEB) (2008) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Diaz et al. 2015). See Righetti et al. 2022 for details on the methodology developed through the REXUS project.

Table 13

Economic indicators for valuing the benefits provided by solutions in monetary terms

(Adapted from Righetti et al. 2022). (*) Benefits typically generated only by NbS projects.

REQUIRED TO

WEFE Nexus challenges	Benefits	Economic indicators	Bio-physical indicators
To maintain the agricultural production and seek food security	**Food provisioning**	Economic value of food provisioning based on market price (€)	Average production yield (kg/ha)
To maintain the water supply for multiple uses (e.g., agriculture, domestic)	**Water provisioning**	Economic value of water provisioning based on market price per sector: water (€)	Fresh and/or processed water availability per water use (m^3/ha per year)
Achieving energy security through different sources (e.g., hydropower, wind)	**Energy source**	Economic value of energy provisioning based on market price (€)	Converted energy (kWh/m^3 per year); Produced electricity (kWh/m^3 per year)
To ensure availability of raw materials	**Material resource**	Economic value of resources extraction based on market price (€)	Natural resources extracted (kg/ha per year)

Table 13 | Economic indicators for valuing the benefits provided by solutions in monetary terms (Adapted from Righetti et al. 2022). (*) Benefits typically generated only by NbS projects.

REQUIRED TO

WEFE Nexus challenges	Benefits	Economic indicators	Bio-physical indicators
To maintain the genetic potential for climate resilient crop varieties	**Genetic resources***	Restoration costs based on €/ha per year	Number of crop varieties and livestock breed species living in a region/surface
To reduce and capture GHG emissions to mitigate global climate change	**Climate regulation**	Economic value of carbon sequestration based on market price (€)	Carbon sequestration rate per land use (tons CO_2/ha per year)
To regulate water flows to ensure availability for multiple uses (e.g., agriculture, domestic)	**Water flow regulation**	Replacement costs based on €/m³ of construction material	Water storage capacity per land use (m³/ha per year); groundwater recharge rate (m³/ha per year)
To control water pollution due to agricultural inputs and other pollutants	**Water purification**	Replacement costs based on €/ton of pollutant removed	kg of pollutant retained from soil per soil type
To mitigate and adapt to water cycle extreme events (e.g., droughts, floods)	**Moderation of extreme events (flood protection)**	Replacement costs based on €/m³ of construction material	Water storage capacity per land use (m³/ha per year); groundwater recharge rate (mm/ha per year)
To mitigate soil erosion and loss that can put food and ecosystem security at risk	**Erosion prevention**	Replacement costs based on €/ton of soil retained	Amount of soil retained, or sediment captured (m³/ha per year)
To replace chemical inputs by biological agents for fertilizing and pest controlt	**Biological control***	Replacement costs based on €/l of pesticides	Populations of pest control agents (n/ha)

Table 13 | Economic indicators for valuing the benefits provided by solutions in monetary terms (Adapted from Righetti et al. 2022). (*) Benefits typically generated only by NbS projects.

REQUIRED TO

WEFE Nexus challenges	Benefits	Economic indicators	Bio-physical indicators
To protect biodiversity and minimize the impacts of agriculture, water provision and energy production on ecosystemst	**Lifecycle maintenance***	Restoration costs based on €/ha of habitat restored	Native vegetation or high nature value farmland; pollination associated to biodiversity; structural changes in habitats and other ecosystem characteristics
To create opportunities for tourism based on ecosystem conservation	**Opportunities for recreation and tourism**	Visitors' total expenditure (€)	Number of facilities (e.g., hotels, restaurants, hiking paths, parking lots; n/ha); results from questionnaires on nature and leisure preferences (wildlife-viewing, hiking, fishing, sports)

ANNEX 8
Methodologies to assess non-monetary values of solutions

The sections below give a few examples of the many qualitative methods that can be applied to identify and assess socio-cultural values associated with ecosystem services. Any selected method to perform non-material values assessment should have a participatory approach as its main feature.

Although there is no universal technique to assess non-material values, as these need to be context-based, there are some suggested steps that can help assess these values (adapted from Chan et. al. 2012):

1. **Determine the decision context**: Set the objective of the analysis. Identify who will be making the final decision of choosing and implementing the solution and explain the reasons. Identify what motivates the assessment of non-material values and what can be negotiable or non-negotiable in relation to the solutions' objective.

2. **Characterize the socioecological context**: Identify the spatial and temporal scales of the solution, its degree of intervention and the scale of benefits. Understand the social, cultural, and political aspects by identifying stakeholders involved or impacted. Consider including stakeholders from various sectors, administrative levels, and demographic groups. Understand power dynamics and historical conflicts among them. The goal is to ensure equitable participation of stakeholders in decision-making processes.

3. **Assess the ecosystem services, benefits and values**: Evaluate ecosystem services, benefits, and values using the qualitative tools like the ones outlined in Annex 7. Select a suitable tool that enables decision-makers to recognize current ecosystem services within the intervention area, along with the associated benefits and non-material values. Encourage stakeholders to consider socio-cultural benefits and values. This assessment should also provide insights into both positive and negative impacts of the solution on the evaluated ecosystem services, benefits, and non-material values, emphasizing the significance of these impacts. Clearly identify any potential trade-offs.

4. **Present information**: Develop visual representations and scenarios that illustrate the ecosystem services and their associated benefits and non-material values identified in the previous step. Give priority to benefits and non-material values that are expected to change significantly due to the intervention and are highly valued by stakeholders, such as those contributing to people's well-being. Collaborate with stakeholders in the creation of these graphics and scenarios. Take into consideration the diverse perceptions among stakeholders when prioritizing non-material values.

The data obtained from conducting these steps should guide the decision-making process. Created data should highlight the ecosystem services, benefits, and non-material values that stakeholders deem most significant, thereby focusing the solution on enhancing these benefits. If scenarios or decisions are likely to adversely affect ecosystem services, benefits and socio-cultural values, efforts should be made to mitigate or compensate for these trade-offs. Running an assessment of non-material values will complement the monetary analysis of a solution and contribute to a more comprehensive understanding of its economic and socio-cultural implications.

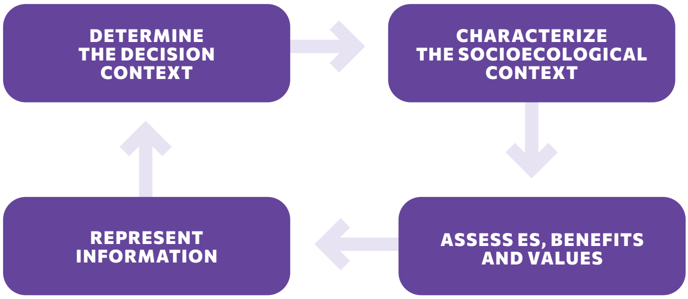

Table 14

Qualitative methods to assess the outcomes of solutions

Qualitative tool	Description
Narrative analysis	These methods are usually applied at the fine level, mostly at the individual level. They are especially helpful for identifying people's values attributed to ecosystem services and their benefits based on a specific local context. Gathered qualitative data helps identify and understand place/heritage and spiritual values (Chan et. al., 2012).
Interviews	There are three types of interviews: structured, semi-structured, and unstructured interviews. Depending on each type, interviews can be applied at a fine or coarse level. Collected data informs about information about personal experiences and values attributed to ecosystem services and can allow comparison between answers (Kvale 1996).

Table 14 | Qualitative methods to assess the outcomes of solutions

Qualitative tool	Description
Cultural or mental mapping	This method is usually applied at a fine scale. It helps understand local cause-effects logics between ecosystem services, benefits and attributed values in a multicultural context. Cultural or mental mapping can be used for identifying values attributed to specific sites, landscapes and natural particularities (Duxbury et al. 2015).
Preference surveys	Surveys can be applied at the fine or coarse levels and provide insights into the personal preferences of ecosystem services. The gathered information will inform about personal information on behaviours, preferences of ecosystem services, values attributed to ecosystem services, or demand distribution for non-material services (Hernández-Morcillo et al. 2013, Palomo et al. 2013).
Paired comparisons	These methods can be applied at the fine or coarse level, as long as the number of ecosystem services and benefits analyzed are no more than 10. Comparison tools aim to create rankings of prioritized values of ecosystem services. Rankings result from value weights inferred from people's preferences for certain ecosystem services and benefits (Chan et. al. 2012).
Focus groups	This method can be applied mostly at the fine level, with small groups or people. Focus groups could inform about people's opinions, experiences, and perceptions related non-material values. This method promotes discussion between people and develops group ideas (Morgan 2015).

The methodologies are not universally applicable. Identifying non-material values of ecosystem services requires a local and context-based approach that recognizes different interests, values, conflicts and other socioecological aspects that influence decision-making processes. More information about sociocultural valuation can be found in Hernández-Morcillo et al. (2013), Palomo et al. (2013), Felipe-Lucia et al. (2015), Chan et al. (2012) and IPBES (2022).

ANNEX 9

An example score card that can be used to facilitative comparison of solutions and strategies

Scorecards such as the example below, can facilitate comparison between different solutions and help to prioritise solutions into strategies.

	CRITERIA	INDICATORS	BASE CASE	REFERENCE CASE		STRATEGY 1		STRATEGY 2	
			2020	2030	2050	2030	2050	2030	2050
TECHNICAL EFFECTIVENESS	Flood risk reduction (Primary objective)	Peak flow rate (*m^3/s*)							
		Peak flood volume (*m^3*)							
		Risk to critical infrastructure (*%*)							
		Area exposed to flood risk (*ha*)							
		Local population exposed to flood risk (*No./ha*)							
		Agriculture land exposed to flood risk (*ha*)							
	Aquifer recharge & surface water availability	Net surface water availability (*m^3/year*)							
		Level of groundwater table (*m below ground surface*)							
	Tourism	Increase in tourism (*Mean no. visitors/day per year*)							
		Green space accessibility (*%*)							
	Biodiversity	Number of native species (*number*)							
		Extent of habitat for native pollinator species (*ha*)							
		Proportion of protected areas (*%*)							
SOCIO-CONOMIC ASSESSMENT	Economic costs	Up-front investment costs (€)							
		Recurring operation and maintenance (O&M) costs (€)							
		Transaction costs (€)							
		Opportunity costs (€)							
	Economic benefits	Mean annual direct and indirect economic losses due to flooding (€)							
		Replacement costs to mitigate and adapt to ensure water availability (*€/m^3 of construction material*)							
		Replacement costs to regulate flows (*€/m^3 of construction material*)							
		Visitors' total expenditure (€)							
		NbS cost/benefit analysis: avoided costs (€)							
	Social values	General wellbeing and happiness (*Number 1-5*)							
		Visual acces to green space (*Number 1-5*)							
	Cultural values	Historical and cultural meaning and identity (*Number 1-5*)							
		Cultural value of blue-green spaces (*Number 1-5*)							
	Cost/ benefit analysis	Reduced/avoided damage costs from flood risk reduction (*€/year*)							
		Return of investment (*%*)							

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