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MERLIN

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Scaling up freshwater restoration and Nature-based Solutions in Europe: an evidence-informed workflow

Index

Publishing information

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MERLIN key messages

1. Freshwater ecosystems are critical for Europe. They underpin biodiversity, water security, flood protection, climate mitigation and public wellbeing, yet are among the most degraded ecosystems in the EU.

2. Upscaling restoration is essential to deliver EU priorities. Strategic freshwater restoration is needed to meet obligations under the Biodiversity Strategy for 2030, the Water Framework Directive, the Nature Restoration Regulation and the EU Water Resilience Strategy, while addressing rising societal demands for clean water and flood resilience.

3. Restoration must be strategic and fit for purpose. Context-sensitive approaches that prioritise Nature-based Solutions, complemented by engineered measures where necessary, deliver the greatest ecological and societal returns.

4. Policymakers need decision-ready tools. The MERLIN Upscaling Workflow provides an evidence-based framework to prioritise action, quantify benefits, and guide planning and financing. It is directly applicable for regional authorities, river basin managers and water boards.

5. Targeting the right places maximises success. MERLIN analyses highlight where protected freshwater habitats, including Natura 2000 sites, can be restored most effectively, supporting the effective implementation of the Nature Restoration Regulation.

6. Financing must reflect the real value of ecosystems. Delivering restoration at scale requires more ambitious financing of restoration, creating conditions for large scale mobilisation of public and private funding.

7. Ambition on biodiversity is essential. Restoration must aim to realise full biodiversity potential and explicitly manage synergies and trade-offs, especially where multiple policy objectives and legal protections intersect.

Executive summary

Freshwater ecosystems across Europe including rivers, lakes, wetlands and floodplains face **increasing pressures** from pollution, fragmentation, over-extraction and climate change, with most **failing to meet ecological targets** despite existing EU policy frameworks.

This report presents a **strategic, evidence-based approach** to support the **upscaling of freshwater restoration** and **implementation** of **Nature-based Solutions** across Europe. Central to the approach is the **MERLIN Upscaling Workflow**, a flexible decision-support tool that uses Europe-wide datasets to **identify high-impact restoration areas**.

The MERLIN Upscaling Workflow can be applied across Europe to **simulate ecological and societal benefits of restoration** initiatives and **develop cost-effective implementation** strategies. The workflow can be used by administrations, agencies and experts contributing to the development of restoration actions, for instance under the Nature Restoration Regulation. It can also be used by authorities involved in nature conservation and river basin management to plan synergistic actions delivering on the Nature Directives and the EU Water Framework Directive.

The Upscaling Workflow has been **applied in five selected case studies** to demonstrate its applicability and usefulness in **quantifying ecosystem service benefits** and valuing these benefits through **Cost-Benefit-Analysis**, highlighting outcomes such as nutrient retention, flood risk mitigation and climate regulation.

Biodiversity benefits cannot be modelled in the same way as ecosystems service outcomes, the MERLIN framework therefore applies a different approach for assessing the biodiversity restoration potential. Using a data-driven modelling based on site conditions, land use, hydrology and connectivity, the **restoration potential** for freshwater habitats was estimated, focusing specifically on lake and stream habitats **within Natura 2000 sites**.

The report also explores **funding pathways**, emphasising more effective use of EU instruments, national schemes and private finance.

Overall, the report hopes to **support EU institutions** and **Member States** in translating restoration commitments into **operational actions** and **funding arrangements** that deliver **measurable ecological**, **economic** and **societal outcomes**. We recommend the MERLIN Upscaling Workflow as an evidence-based tool to prioritise and scale up freshwater restoration across Europe. By identifying context-specific opportunities and quantifying ecosystem service benefits **early in the planning** and design process, the workflow enables **strategic**, **cost-effective restoration** at regional and local scales.

In light of the severity of the current biodiversity crisis, we recommend that restoration efforts aim to **realise the full biodiversity potential** of ecosystems. These efforts should explicitly **address synergies** and **trade-offs** where multiple policy objectives and legal protections intersect, in order to **ensure** the **effective conservation** of threatened and protected species, habitats and ecosystems.

Introduction

Europe's freshwater ecosystems, including rivers, lakes, wetlands, floodplains and groundwater-dependent habitats, are central to achieving the European Union's environmental, climate and societal objectives. They sustain biodiversity, secure clean water, regulate floods and droughts, store carbon, and support livelihoods and human well-being. Freshwater ecosystems are essential for building resilience and maintaining competitiveness in the face of the increasingly intense and destructive impacts of climate change. Yet, despite decades of policy action, degradation continues at alarming rates. Fragmentation, pollution, over-extraction and land-use pressures have left most freshwater bodies far from the "good ecological status" required by the EU Water Framework Directive (WFD), while many freshwater habitats and species protected under the Habitats Directive remain in unfavourable condition.

This report responds to this challenge by outlining how implementing NbS or restoration of freshwater ecosystems can be scaled up strategically across Europe. **Upscaling is understood in this document as the strategic replication and integration of measures across sites and regions to expand ecosystem services, engage diverse actors and maximise ecological and societal benefits.** It should be acknowledged that the different benefits for e.g., biodiversity can necessarily be maximised everywhere, and depending on site characteristics, the priority can be given to e.g., climate mitigation, water purification or biodiversity goals.

Within Natura 2000 sites, restoration of protected habitats should be prioritised in line with the ambitions of the EU Biodiversity Strategy for 2030 and the Nature Restoration Regulation (2024/1991) (NRR). The restoration potential of 14 protected freshwater habitats, both standing and running waters, has been assessed in MERLIN to support evidence-based decision-making. Thereby, this report serves as a practical reference for EU institutions, national authorities and regional planners, helping translate the EU's commitment under the NRR to restore at least 20% of degraded ecosystems by 2030, and all those in need of restoration by 2050.

This document presents the following:

- → A broad-scale assessment of the current state of freshwater biodiversity across Europe, highlighting regions where restoration is most urgently needed, and clarifying the potential role of restoration and Nature-based Solutions (NbS) approaches in biodiversity recovery, climate adaptation and water resilience.
- → An assessment of restoration potential under the NRR for protected lake and stream habitats within the Natura 2000 network.
- → High level methodological guidance and analytical tools that enable authorities to identify priority areas for restoration, set biodiversity and ecosystem service targets, quantify expected benefits and outcomes, and compare alternative restoration scenarios in spatial and economic terms.
- → Financing pathways that can make large-scale freshwater restoration both feasible and sustainable, through improved use of EU funds, innovative national schemes and engagement with private finance.

In particular, the document presents the MERLIN Upscaling Workflow designed to support strategic planning and decision-making in freshwater restoration and NbS projects (**Box 1**). Outcomes of the workflow's practical implementation are presented based on its testing in five large-scale MERLIN case study areas, each representing diverse ecological and socio-economic conditions across Europe.

The present document focuses on the benefits delivered by restoration and its funding. Successful upscaling is however dependent on other factors, such as thorough stakeholder engagement, enabling regulations and planning rules, and mainstreaming of restoration into the daily operations of economic sectors. These broader social and institutional drivers of upscaling are presented in the MERLIN European Cross-Sectoral Routemap (Blackstock et al., 2025).

Box 1. What can the MERLIN Upscaling Workflow be used for?

The workflow can be used to support strategic planning to maximise the benefits of NbS and restoration projects by providing evidence on the ecosystem services, economic value and financial returns that can be unlocked by the projects. It can be used at different spatial and temporal scales. At European and national level, the workflow can be used by authorities and experts implementing the Nature Restoration Regulation (EU 2024/1991)[1], Nature Directives and the Water Framework Directive (2000/60/EC)[2] to identify restoration potential, prioritise and enable restoration at scales that maximise benefits.

At river basin and catchment levels, water managers can use the workflow

- → to target NbS and restoration actions strategically in their respective areas;
- → to quantify the benefits of large-scale projects;
- → to guide investment decisions;
- → and to engage stakeholders with evidence of added value.

Users can simulate short-, medium- and long-term effects of the projects and assess the relative benefits of phasing-in restoration over different timeframes. The workflow allows for exploring the potential of different funding arrangements to enable the implementation of projects.

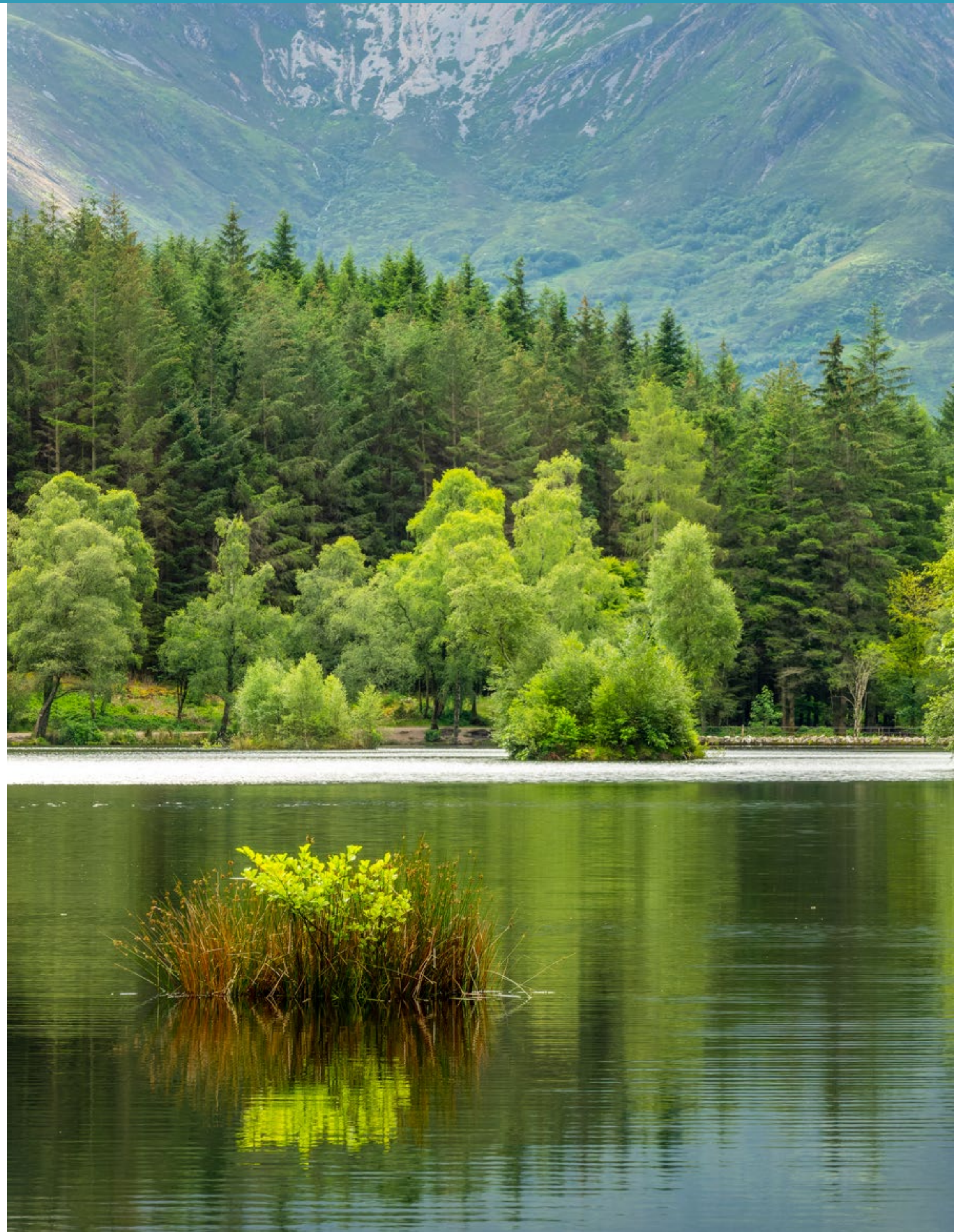
1 https://eur-lex.europa.eu/eli/reg/2024/1991/oj/eng
2 https://eur-lex.europa.eu/eli/dir/2000/60/oj/eng

Why do we need to scale up restoration of freshwater ecosystems across Europe?

Freshwater ecosystems are amongst the most biologically diverse on Earth, while at the same time playing a fundamental role in supporting human well-being. Diverse communities of aquatic plants, animals and microorganisms drive key ecological processes that regulate the flow of energy, nutrients and organic matter within freshwater systems. These processes underpin a wide range of ecosystem services being the direct and indirect contributions of ecosystems to human well-being (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). Freshwater ecosystem services include different categories of services such as provisioning (e.g., supply of clean water, food and biomass), regulating (e.g., water purification, nutrient cycling, climate regulation and disease control) and cultural services (recreational, educational or spiritual) (Garcia et al., 2017) that are essential for society.

However, freshwater ecosystems are under immense stress across Europe. In 2022, only 38% of surface waters were in good ecological status and 30% in good chemical status, due to a mix of pollution, abstraction and physical pressures from agriculture and industry, urban areas and sectors like energy and navigation (EEA, 2024). Water-scarcity conditions are documented in 34% of the EU's land area (EEA, 2025), affecting river basins across much of Europe. Over the past decade, droughts have become more frequent and severe, disrupting seasonal water availability. With climate change projected to further increase the frequency, intensity and impacts of drought events, it appears unlikely that water scarcity will decrease by 2030 without substantial intervention (EEA, 2021; EEA, 2025).

The combined pressures of pollution, habitat degradation, water abstraction and the spread of invasive species have contributed to significant declines in freshwater biodiversity across Europe, along with the deterioration of essential ecosystem services that support human well-being (Cardinale et al., 2012; Díaz et al., 2018). A coordinated and large-scale restoration strategy is therefore essential to reverse biodiversity loss and restore the capacity of freshwater ecosystems to deliver essential services.



What is the EU already doing?

In recent decades, the EU has increasingly recognised the critical importance of freshwater biodiversity and ecosystem services and the alarming rate of its decline across the continent. In response the EU has developed a comprehensive suite of policy frameworks and legal instruments aimed at protecting and restoring freshwater habitats and the species they support. Central among these is the **EU Water Fremework Directive (2000/60/EC)**[1], which provides the legal basis for achieving good ecological status in all water bodies; the **Habitats Directive (92/43/EEC)**[2], which underpins the Natura 2000 network and protects key freshwater species and habitats; the **EU Biodiversity Strategy for 2030**[3], which sets ambitious restoration and protection goals; and the newly adopted **Nature Restoration Regulation (NRR; EU 2024/1991)**[4], which introduces legally binding targets to reverse ecosystem degradation across Member States. Together, these instruments reflect a strong political commitment to halting biodiversity loss and ensuring the long-term sustainability of Europe's freshwater resources (see Table 1). In addition, several other policies, such as **EU Water Resilience Strategy**[5], the **Nitrates Directive (91/676/ECC)**[6], the **EU Strategy on Adaptation to Climate Change**[7], and sectoral policies such as the **Common Agriculture Policy**[8], are of relevance to addressing declines in freshwater biodiversity (see the Blackstock et al., 2025).

1 https://eur-lex.europa.eu/eli/dir/2000/60/oj/eng
2 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01992L0043-20130701
3 https://eur-lex.europa.eu/EN/legal-content/summary/eu-biodiversity-strategy-for-2030.html
4 https://eur-lex.europa.eu/eli/reg/2024/1991/oj/eng
5 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52025DC0280
6 https://eur-lex.europa.eu/eli/dir/1991/676/oj/eng
7 https://eur-lex.europa.eu/legal-content/DA/PIN/?uri=celex:52021DC0082
8 https://agriculture.ec.europa.eu/common-agricultural-policy_en

Table 1. Overview of key policy frameworks and legislative tools in Europe developed in response to freshwater biodiversity decline.

European Policy	Objective and scope
EU Water Framework Directive (WFD)	The EU Water Framework Directive (WFD) was adopted in 2000 (Directive 2000/60/EC) and is the cornerstone of European water policy. The main aim of the WFD is to ensure the protection and sustainable management of all water bodies across the EU, including rivers, lakes, wetlands, coastal waters and groundwater. The directive aims to achieve “good ecological and chemical status” for all waters by 2027 at the latest, while preventing further deterioration and promoting sustainable use. A key feature of the WFD is its integrated river basin management approach, which organises water governance according to natural hydrological boundaries rather than administrative borders. Member States are required to assess the status of their water bodies, develop and update River Basin Management Plans (RBMPs) every six years, and implement programmes of measures to improve water quality and ecosystem health.
EU Habitats Directive (HD)	The EU Habitats Directive (Council Directive 92/43/EEC) was adopted in 1992, and is one of the cornerstones of nature conservation policy in the European Union. Its primary aim is to ensure the long-term conservation of Europe’s most valuable and threatened habitats and species. Together with the Birds Directive, it forms the legal basis for the Natura 2000 network – the largest coordinated network of protected areas in the world. The directive requires Member States to designate Special Areas of Conservation (SACs) for habitats and species listed in its annexes, covering both terrestrial and freshwater environments.
EU Birds Directive (BD)	The EU Birds Directive (Directive 2009/147/EC) was originally adopted in 1979 and later codified in 2009. Its primary aim is to protect all wild bird species naturally occurring in the European Union, along with their habitats. Together with the Habitats Directive, it provides the legal foundation for the Natura 2000 network, through the designation of Special Protection Areas (SPAs) for the most threatened and migratory bird species.
EU Nitrates Directive	The EU Nitrates Directive (91/676/EEC) was developed to protect water quality across Europe by preventing pollution from agricultural sources, particularly nitrates from fertilisers and manure.
EU Biodiversity Strategy for 2030	The EU Biodiversity Strategy for 2030 is a central element of the European Green Deal and outlines the European Union’s long-term vision to halt biodiversity loss and restore natural ecosystems. Adopted in May 2020, the strategy aims to make Europe’s biodiversity “on the path to recovery” by 2030, contributing to global biodiversity targets and the UN Sustainable Development Goals.
Nature Restoration Regulation (NRR)	The EU Nature Restoration Regulation, formally adopted in 2024, is the first legally binding EU-wide framework dedicated to the large-scale restoration of degraded ecosystems, including terrestrial, coastal, freshwater and marine environments. It is a central pillar of the EU Biodiversity Strategy for 2030 and contributes directly to the EU’s climate goals under the European Green Deal. The regulation sets out quantified, time-bound restoration targets for all Member States, with a focus on restoring at least 20% of the EU’s land and sea areas by 2030 and all ecosystems in need of restoration by 2050. Specific obligations include: → Restoring at least 20% of degraded habitats listed under the Habitats Directive to good condition by 2030, increasing to 60% by 2040 and 90% by 2050. → Reversing the decline of pollinators by 2030. → Restoring 25,000 km of rivers to free-flowing state by removing barriers and reestablishing natural connectivity. → Rewetting drained peatlands, restoring forests, improving urban green space and enhancing agricultural ecosystems. Member States must develop National Restoration Plans, detailing how they will meet these targets, supported by monitoring, reporting and public participation mechanisms. The regulation emphasises synergies between biodiversity and climate adaptation, especially through Nature-based Solutions.

Despite these policy frameworks and legal instruments, most regions in EU are falling short of reaching the objectives of the WFD and HD[9]. **Figure 1** shows the current state of European freshwater habitats and freshwater-related species, ultimately determining in which regions restoration measures are required. While the resolution of the map is too coarse to support restoration planning at the regional and local scale, it illustrates the extent of degradation of freshwater habitats and related species thereby highlighting that restoration efforts are needed across Europe to meet environmental targets. European-wide maps are available in the MERLIN web app[10] (Baattrup-Pedersen et al., 2025).

9 To get more detailed information on the current state of European freshwater-related habitats, a full report can be accessed here: https://project-merlin.eu/deliverables/articles/deliverable-d3-1.html
10 https://www.waterwebtools.com/merlin

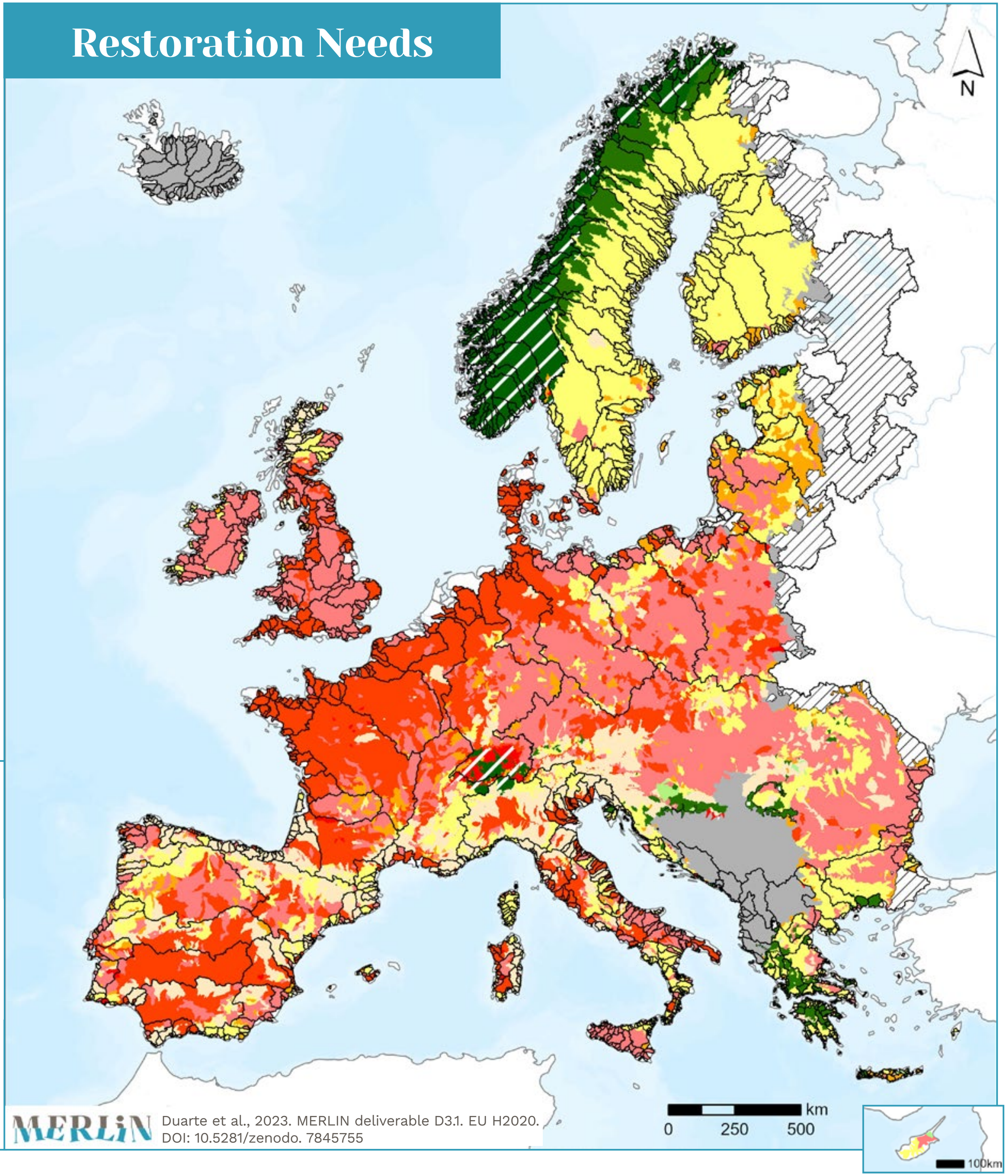
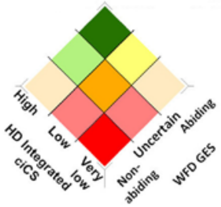


Figure 1. A Europe-wide map showing the combined results of an analysis of compliance with both the Habitats Directive and the Water Framework Directive.

The map was created by integrating combined indicators for protected freshwater habitats and species (from the Habitats Directive) within river restoration units with indicators of ecological status (from the Water Framework Directive) and visualised these using a bivariate choropleth map (Duarte et al., 2025).

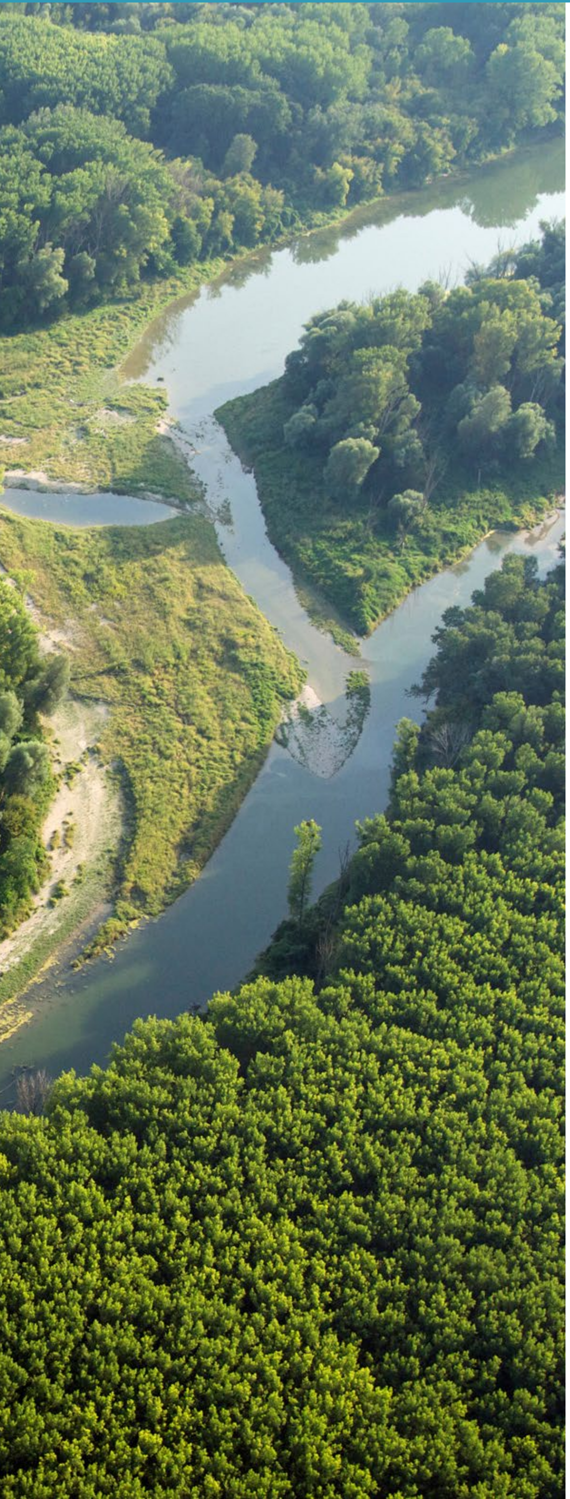
The average area of a river restoration unit was app. 400 km²



Area of RUs out of EU
Basins
No data / Unclassified
No data / Unclassified Biodiversity
No data / Unclassified WFD

Unfav. = Unfavorable
Fav. = Favorable
CS = Conservation Status
GES = Good Ecological Status
WFD = Water Framework Directive

Data source: Vigiak et al., 2021.
European Commission, JRC Dataset.
Habitats Directive Article 17 Database



What do we mean by freshwater ecosystem restoration?

There is a clear and urgent need to restore Europe's freshwater ecosystems in order to meet the targets set out in the EU Biodiversity Strategy and the NRR. While such restoration can be and historically has been carried out with a focus on biodiversity, there is growing recognition of the potential to simultaneously address other pressing societal challenges, such as climate change adaptation, water security and flood risk without compromising the core objective of ecosystem restoration. The following sections explore such synergies between freshwater ecosystem restoration and other policy priorities. In this context, however, it is essential to acknowledge that synergies cannot be achieved everywhere, and that many restoration actions that can address important societal challenges do not automatically support or improve, let alone maximise, existing biodiversity. In some cases, actions for e.g., climate change mitigation may even involve trade-offs that can undermine biodiversity objectives. This section therefore emphasises the importance of clearly identifying, from the outset, which opportunities exist and which compromises may be necessary. It is equally important to ensure that newly introduced measures do not conflict with, or prevent the fulfilment of, targets laid down in existing legislation.

The concept of ecosystem restoration was introduced in the 1980s when scientists, land managers and practitioners began to frame ecological restoration as a scientific discipline, not just a land management activity. Since then, interest and investment in ecosystem restoration have grown, driven by escalating environmental degradation and biodiversity loss, advances in restoration science and stronger global policy frameworks. Restoration encompasses a wide range of practices aimed at halting and reversing the negative impacts on ecosystems, ultimately contributing to sustainable development and the well-being of both people and nature. However, despite the growing attention, the need for large-scale restoration persists, as illustrated in **Figure 1**, and implementation at the scale and speed needed to reverse biodiversity and ecosystem loss remains a significant challenge.

Ecosystem restoration refers to "the process of actively managing the recovery of an ecosystem that has been degraded, damaged or destroyed."

(Clewell et al., 2005)

In the late 2000s, the concept of Nature-based Solutions (NbS) came to light (MacKinnon et al., 2008). Unlike ecosystem restoration, NbS goes beyond ecological recovery by explicitly integrating societal dimensions such as human well-being, poverty alleviation, socio-economic development and inclusive governance. It positions nature as a core component of solutions to societal challenges, and can involve both (1) conservation measures in natural/protected areas to e.g., limit risks associated with extreme weather conditions, (2) management measures that develop sustainable and multifunctional landscapes to improve the delivery of selected ecosystem services e.g., biofiltration solutions like constructed wetlands used to purify polluted water in agricultural landscapes and (3) design and management of new ecosystems e.g., the creation of green roofs and walls to mitigate city warming and clean polluted environments (Eggermont et al., 2015).

While there is an overall agreement that the concept of NbS builds on nature or nature-inspired processes, different definitions put emphasis on different aspects. The definition of the European Commission is practical and policy-oriented, with an emphasis on resilience through cost-effective, nature-inspired solutions. The IUCN's framework is more far-reaching, prioritising ecological systems, measurable biodiversity outcomes and adaptive, inclusive governance. Further discussions of NbS for freshwater restoration can be found in MERLIN outputs on mainstreaming aquatic restoration using Nature-based Solutions, that can be accessed through the MERLIN website[1].

The concepts of ecosystem restoration and NbS are mutually reinforcing, yet differ in their primary objectives: while restoration typically aims to recover the structure, function and integrity of ecosystems, NbS are explicitly designed to deliver societal benefits by leveraging nature's processes and functions (Waylen et al., 2024). Central to NbS is the delivery of ecosystem services, such as clean water, flood regulation, carbon storage and recreational opportunities, which are essential for human well-being and

1 https://project-merlin.eu/deliverables/articles/deliverable-d4-1.html

climate resilience. Although both approaches can yield biodiversity benefits, NbS are primarily assessed in terms of their service provision and contributions to societal goals, meaning their outcomes for biodiversity conservation can be more variable and context-dependent than those of restoration efforts that directly target ecological recovery.

In freshwater systems, this distinction is especially important: while some NbS (e.g., wetland restoration, riparian buffer zones) can enhance freshwater biodiversity, others may prioritise services like flood protection or water purification, with indirect or uncertain benefits for nature. As such, the potential for biodiversity enhancement through NbS depends not only on the type of intervention, but also on the ecological and social context in which it is applied (**Figure 3**). Nonetheless, when carefully designed and implemented, NbS can offer a powerful means of aligning ecological and societal objectives, making them a key mechanism for scaling up ecosystem service delivery while contributing to long-term ecosystem health.

While NbS may be beneficial for a certain level of service provisioning, they might not be the solution or holy grail in all situations. Some societal challenges, such as those related to flooding, may require engineered measures alongside NbS. For example, this means that natural water retention measures such as reforestation, floodplain restoration and wetland creation can reduce peak flows and retain water upstream in a catchment that may prevent flooding further downstream. In urbanised zones, grey infrastructure can complement these efforts, with interventions like engineered drainage systems or flood barriers. In combination, these measures may offer robust and resilient flood risk management across the entire catchment. Given the increasing frequency of climatic extremes in Europe, the buffering role of hydro-ecological systems is more important than ever; however, their capacity may be exceeded under severe conditions, underscoring the need for integrated strategies that effectively align nature-based and engineered solutions across the landscape.

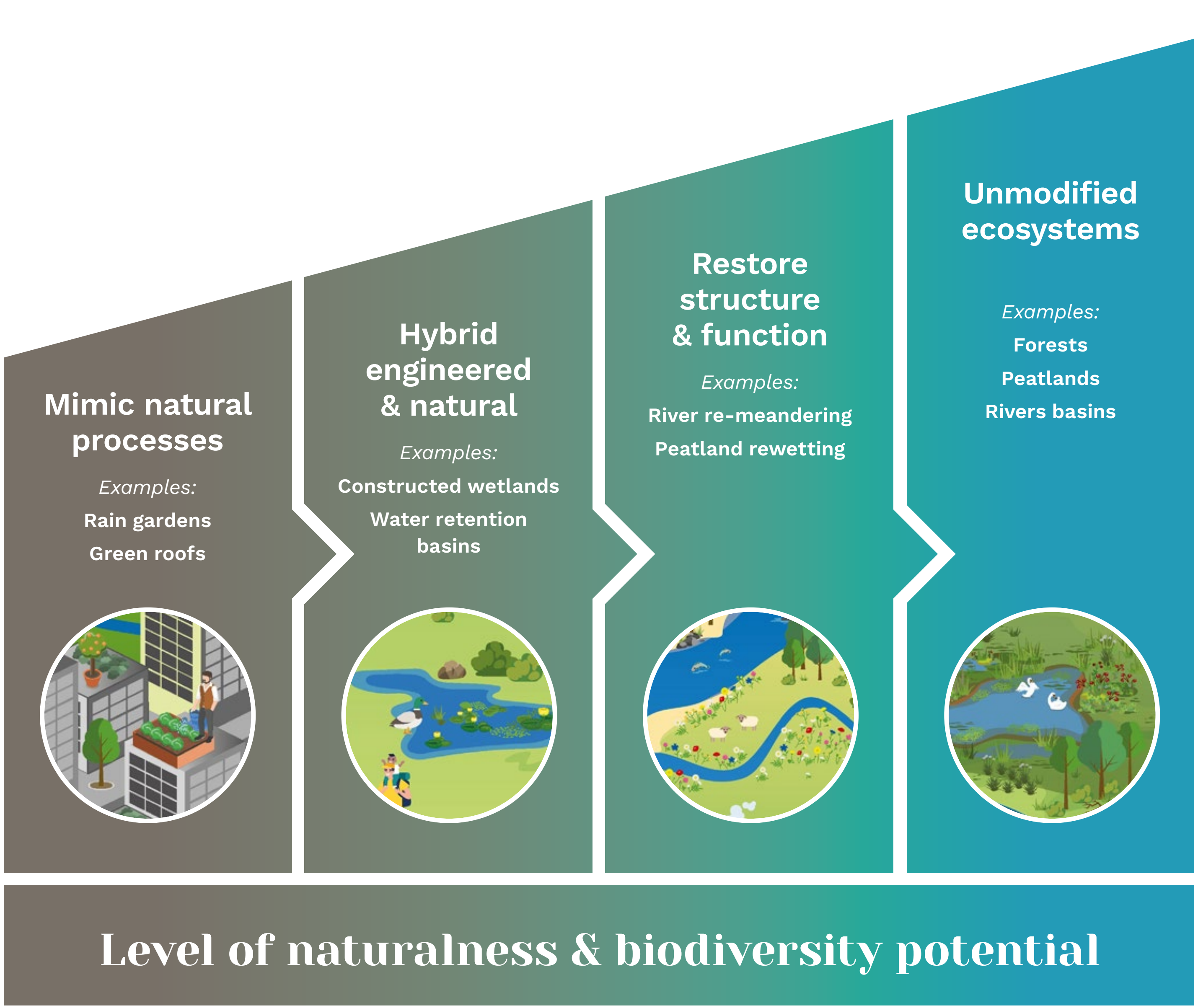


Figure 2. A conceptual framework displaying different types of NbS and potentials for biodiversity enhancement.

Note: Different settings, whether protected natural areas, agricultural catchments or urban environments offer different opportunities and constraints for achieving biodiversity enhancements through restoration. To contribute to halt freshwater biodiversity loss, targets for biodiversity should thrive to fully realise the biodiversity potential in the settings the NbS is applied. This implies that the targets should reflect the environmental settings.

What are the benefits of freshwater restoration?

Although EU legislation (**Table 1**) sets ambitious targets for large-scale ecosystem protection and recovery, NbS/restoration can only be implemented effectively at smaller, operational scales at which local and regional authorities operate and where land ownership, management, and planning decisions are made. Implementing NbS and restoration measures at these scales, while having a clear vision during the planning phase of how they can be coordinated to compound their expected benefits, is therefore essential to enable the broader upscaling of restoration efforts across Europe. The emphasis here is on planning for scalability at an early stage, when design features and implementation actions can still be coordinated more efficiently (e.g., avoiding barriers from sunken investments) and when a wider landscape/territorial perspective can be instrumental in identifying opportunities (e.g., to secure clear ownership of the initiatives and to engage key stakeholders).

The MERLIN case studies are best-practice examples of restoration efforts at the local scale and can serve as a basis for a strategic replication and integration of restoration measures across EU. The case-studies have generally been designed to restore ecosystem processes that support the conservation of freshwater biodiversity while simultaneously delivering ecosystem service benefits. Consequently, these projects are scoped and implemented in ways that align with broader societal goals, contributing to multiple objectives of the European Green Deal.

An overview of the MERLIN case studies, including the NbS and restoration measures applied, their anticipated benefits in relation to climate regulation, flood and drought resilience, zero pollution, human health and wellbeing, sustainable food systems, sustainable energy, transport and many more can be found via the case study portal[1] and via the MERLIN web app[2] (Baattrup-Pedersen et al., 2025).

The expected ecosystem service benefits in the MERLIN cases include provisioning service benefits, such as biomass for energy production (e.g., Danish Kvorning case study), regulating service benefits, such as flood and drought mitigation (e.g., the Hungarian Tisza and Israeli Tzipori case studies), water purification nutrient cycling (e.g., the Flemish Scheldt and the Portuguese Lima case studies), climate regulation (e.g., the Finnish case study) and cultural services (e.g., the German Emscher case study) that are essential for society while at the same time creating more space for freshwater biodiversity to develop (**Figure 3**).

1 https://project-merlin.eu/cs-portal.html
2 https://www.waterwebtools.com/merlin

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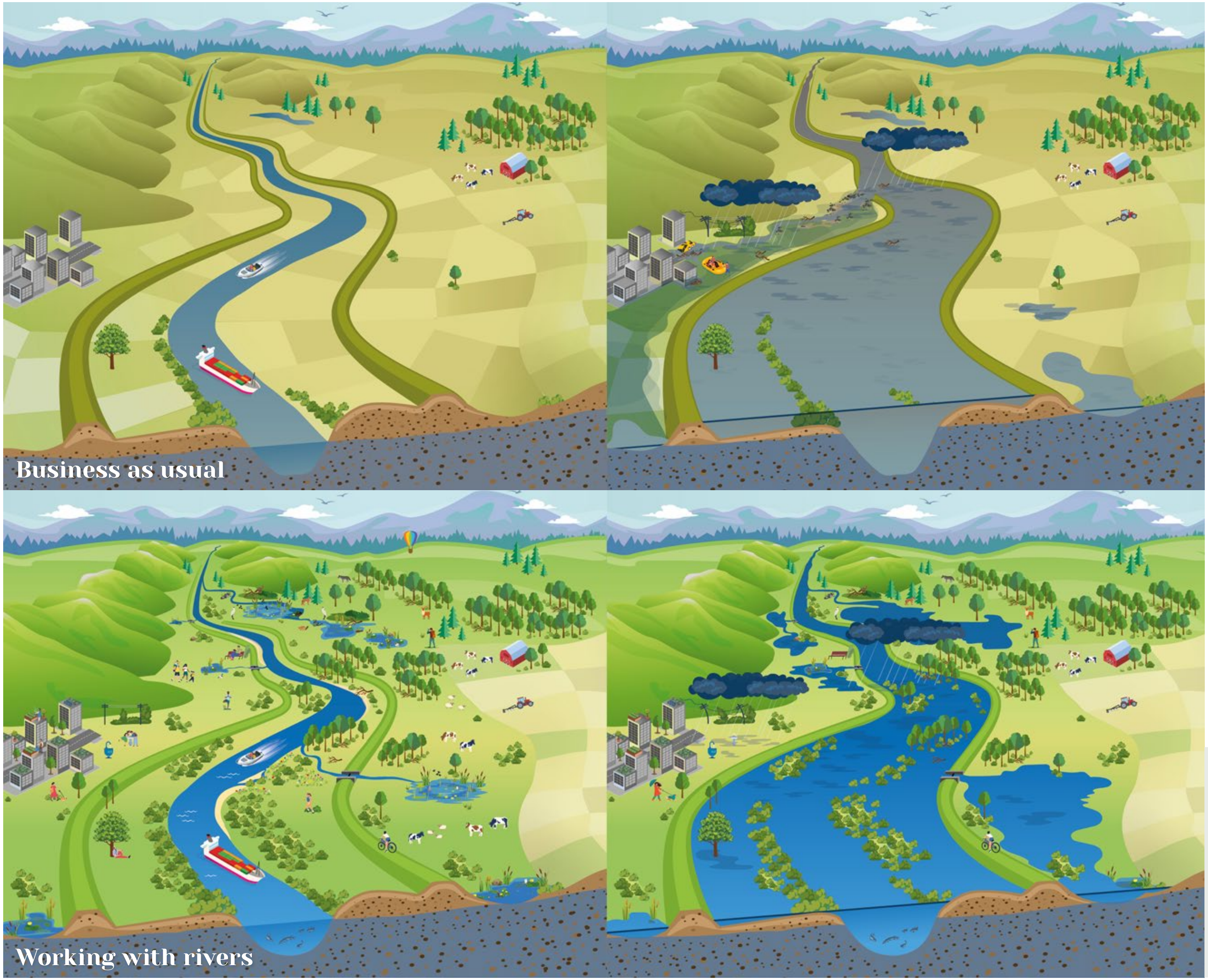


Figure 3 - Infographic illustrating the many ecosystem service benefits that can be achieved by applying NbS in large rivers.[1]

1 https://project-merlin.eu/outcomes/infographics.html

Benefits for both people and nature

- minimised flood risk
- improved navigability
- drought resilience & carbon storage
- recreation & fisheries
- wetland habitats
- biodiversity

Supporting evidence-based restoration upscaling

While the potential benefits of restoration and NbS are well recognised, determining quantifiable restoration targets and the scale of intervention required to achieve them remains a complex challenge. It is often unclear whether NbS or restoration alone is sufficient or if it needs to be complemented by, e.g., engineered/grey measures. For example, how many hectares of peatland must be restored to achieve a certain reduction in greenhouse gas emissions? Or how many kilometres of stream need to be remeandered to significantly lower flood risk?

Such questions highlight the need for robust system understanding and the use of modelling tools and decision-support frameworks that can link ecological processes with desired outcomes for society. Taking a data-driven, evidence-based approach to setting desired outcomes from the outset offers a clear advantage. Goal-oriented planning informed by evidence allows practitioners to determine the scale of intervention needed to achieve specific targets, ensures that enough areas are included in the plan to meet these targets, and enables prioritisation of sites that can contribute most effectively to the intended societal and ecological outcomes. It also ensures that the anticipated returns, both societal and ecological, are transparent from the beginning, which can be critical for engaging landowners and other stakeholders who must provide access to land or other resources.

Three aspects are further developed below:

1. **Setting robust restoration targets for nature and biodiversity** (see page 15)
2. **Quantifying the ecosystem services and benefits delivered by restoration** (see page 17)
3. **Funding the upscaling** (see page 26)

1. Setting robust restoration targets for nature and biodiversity

Achieving measurable improvements in biodiversity remains one of the most complex and least successful aspects of restoration actions, with most Member States being off track in meeting biodiversity targets (**Figure 1**). Therefore, this section places particular emphasis on how to define robust biodiversity enhancement targets, recognising that biodiversity objectives are often the most challenging to realise in restoration projects and therefore require dedicated attention in planning and implementation.

Restoring biodiversity involves more than improving physical habitat conditions (Birk et al., 2025) or enhancing ecosystem functions. It requires a deeper understanding of the primary barriers to recovery faced by species or habitat types targeted in the implementation site. This implies that it is essential to identify and address the underlying pressures that result in the degradation, damage or destruction of the ecosystem, e.g., lack of water, alterations in the hydrological regime, pollution, barriers to connectivity and species migration (IPBES, 2024). Equally important, targets should be set that are carefully tailored to the specific type of restoration measure or NbS being implemented and to the landscape setting surrounding the implementation site. Additionally, it is important to ensure that introduced measures do not conflict with, or prevent the fulfilment of, targets laid down in existing legislation.

To succeed, two key aspects should be considered. First, it should be ensured that the intervention in the implementation site targets the main pressures of biodiversity decline. Thus, it is generally most effective to address the primary stressor first, as doing so creates the most favourable conditions for biodiversity recovery and allows subsequent measures to have a greater impact. By prioritising the most significant pressures, restoration efforts are also more likely to succeed and support long-term ecosystem resilience. These might include reducing nutrient pollution and other chemical emissions from sectors like agriculture and industries in order to improve water quality; tackling overuse of water, dams and channelisation of rivers in order to restore natural water flows; and ensuring that critical habitats are protected and restored in alignment against main drivers of freshwater biodiversity decline.

Second, targets for biodiversity outcomes should be made explicit, measurable and wherever possible aligned with central policy frameworks and legal instruments in Europe. Doing so also facilitates more transparent evaluation of progress and enhances the credibility of restoration and NbS as a tool for biodiversity enhancement in freshwater systems. It should be recognised that setting targets for biodiversity outcomes is complex and requires understanding of the ecological mechanisms that the selected action promotes and how these mechanisms align with the ecological requirements of target species and habitats. Therefore, this process demands the involvement of skilled professionals with strong ecological expertise.

A number of targets for biodiversity is given in Carvalho et al. (2022; **Table 2**), that are related to the status – and trend in the conservation status – of protected species and habitat types under the HD and to the ecological status of waterbodies.

Table 2. **Examples of biodiversity enhancement indicators in accordance with central policy frameworks and legal instruments in Europe i.e., HD and WFD.**

Status of habitat (condition)
Trend in habitat condition
Status of HD Annex II and Annex IV listed species (peatland, wetland and freshwater species in case study area)
Trend in HD Annex II and Annex IV listed species (peatland, wetland and freshwater species in case study area)
Status of Annex I listed species in the Birds Directive (focus on peatland, wetland and freshwater species in case study area or nearby landscape)
Trend in Annex I listed species in the Birds Directive (focus on peatland, wetland and freshwater species in case study area or nearby landscape)
Total area protected (Natura 2000 or nationally protected) (ha)
Length of river re-connected without transversal barriers (km)
Area of functioning floodplain re-connected to river (ha)
Ecological status of rivers and lakes in the case study area
Ecological status of each WFD Biological Quality Element
Normalised Ecological Quality Ratio (EQR) of Biological Quality Elements (BQE) for the waterbody (WFD)
Presence of invasive non-native species
Control measures for invasive non-native species
Pollinator service (species richness)
Pollinator service (abundance)

To ensure that biodiversity outcomes are measurable and clearly trackable, it is a clear advantage to define project-specific targets in more detailed and specific terms. Table 3 provides some examples of concrete and measurable biodiversity indicators and targets that can be set for these. Formulating targets that are specific, time-bound and linked to ecological processes makes it easier to assess progress and demonstrate tangible outcomes. At the same time, it should be acknowledged that ecological change takes time. Many biodiversity-related outcomes, such as securing habitats for endangered or keystone species, expanding priority habitat types or increasing the presence of IUCN or Habitats Directive-listed species may only become visible over longer timeframes. In this context, having long-term monitoring in place is highly beneficial, as it allows for gradual changes to be documented and restoration efforts to be adjusted over time if needed.

In contrast, NbS in more heavily modified or urban landscapes have limited or no potential to meet conservation-focused targets for biodiversity. This includes for instance the implementation of constructed wetlands to treat polluted agricultural runoff or the installation of green roofs and walls to mitigate urban heat and air pollution. In these more functional or engineered settings, biodiversity targets should be context-appropriate and realistic. To take an example, a target might be to filter a specific volume of water (e.g., x m^3/day) to reduce pollutant concentrations by a measurable percentage (e.g., y%). Similarly, in urban settings, a biodiversity-related goal might be to introduce a minimum of three native plant species that are known to support local pollinators, thereby enhancing small-scale ecological connectivity and supporting urban biodiversity within the limits of space and system.

Table 3. Relevant measurable indicators to effectively monitor progress on biodiversity enhancement.

Biodiversity indicators	Target
Increase in native species	E.g., increase native species richness by x species over y years in the intervention area, based on a baseline biodiversity survey.
Improved ecosystem connectivity	E.g., enhance longitudinal or lateral connectivity by removing or modifying x barriers (e.g., weirs, culverts) to reconnect y km of stream or river length. E.g., x% increase in number of migrating fish species.
Securing habitat for endangered or keystone species	E.g., restore hydrological function in x hectares of peatland or wetland habitats within z km^2 of protected areas, focusing on areas with known or potential habitat for [target species].
Increase coverage of priority habitats	E.g., expand the potential coverage of IUCN Red-Listed habitats E.g., expand the potential coverage of HD Annex I habitats by x% through restoration of y km of degraded river containing remnants or potential for such habitats.
Increase in IUCN or Habitats Directive-listed species	E.g., improve conditions for Annex II or IV species (HD) or IUCN Red List species by restoring x km of buffer zones and y number of stepping-stone habitats adjacent to existing populations, facilitating dispersal and population expansion. E.g., increase IUCN or Habitats Directive-listed species richness by x species over y years in the intervention area.

2. Quantifying the ecosystem services and benefits delivered by restoration

To support strategic planning and decision-making in freshwater restoration and NbS projects, the MERLIN Upscaling Workflow was developed. The workflow provides a structured approach to simulate restoration scenarios, assess ecosystem service outcomes and evaluate the socioeconomic benefits of restoration to inform planning and decision-making in freshwater restoration and NbS projects. The workflow thus provides a foundation for a strategic replication and integration of restoration measures across sites and regions in Europe. By offering an evidence-based approach for prioritising actions, it can help deliver the greatest societal benefits. The proposed workflow further enables the translation of high-level policy goals into spatially explicit and quantifiable restoration or NbS actions.

The first step in any restoration or NbS project is to define the desired goals, as these guide the initial identification of suitable candidate areas (**Figure 4**). If the goal is limited to restoring ecosystems within, for example, a Natura 2000 site, where the focus is on improving the conservation status of freshwater habitats, the most promising locations for successful restoration can be identified directly in the MERLIN web app[1] (Baattrup-Pedersen et al., 2025; see page 19).

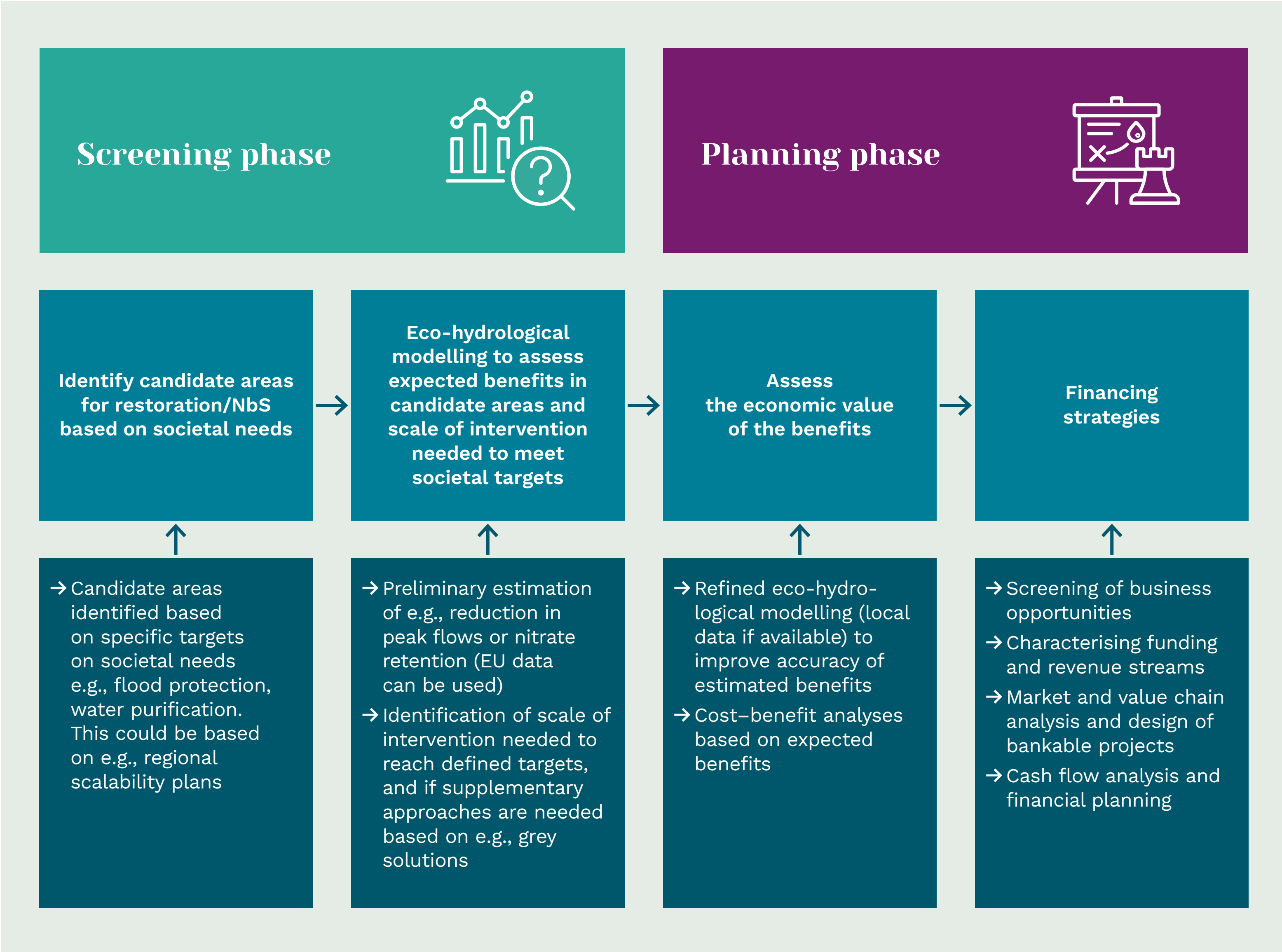


Figure 4. The MERLIN Upscaling Workflow: an evidence-based framework for upscaling NbS for ecosystem service benefits.

1 https://www.waterwebtools.com/merlin

In cases where multiple benefits are targeted, candidate areas should be identified through a screening phase, during which a preliminary estimation of potential benefits is made. In the screening phase, the specific and measurable targets for the project should be outlined, e.g., reduce downstream flood peak by 20% or improve nitrate retention by 50 tons. These targets serve as the basis for identifying candidate areas for restoration/NbS. Candidate areas are areas where interventions are ecologically feasible, the delivery of targeted benefits likely, with a potential for restoration or land use change and/or compatible with existing land uses. Additionally, the areas must be well-positioned within the landscape to deliver the desired service, e.g., for flood protection it should be floodplains, upstream catchments to areas that are sensitive to flooding or wetland buffer zones to hold back water. In this initial screening phase, Europe-wide datasets can be used to generate a rough but quantitative estimate of the benefits, supporting the selection of areas with the greatest potential impact as detailed in Garcia et al. (2025).

Once the candidate areas have been identified, their potential to deliver on the project's ecosystem service targets should be assessed using a refined eco-hydrological modelling approach. This modelling step provides a more quantitative basis for comparing options and estimating the expected benefits of the interventions. At this stage, it is preferable to use high-resolution local data if available and involve skilled analysts to improve the accuracy and reliability of the results. The modelling output serves as a key input for evaluating the economic value and net societal benefits of restoration, which can help prioritise areas and scale of action. To ensure that the prioritisation is embedded in financial realities, the assessment should also be informed by a screening of financing options, including the potential to mobilise both public and private sources of funding to support restoration efforts. Specialist knowledge on economics and finance is essential here to implement relevant methodologies like Cost-Benefit Analysis, natural capital accounting, market analysis, Value Chain Analysis and financial planning.

Applying the two-phase framework presented in **Figure 4** provides the necessary basis for prioritising and operationalising restoration and NbS at scale. Crucially, it allows decision-makers to select combinations of areas that collectively meet defined ecosystem-service goals and maximise benefits in an evidence-based and transparent manner. This creates a replicable pathway for upscaling NbS and restoration initiatives across broader landscapes and regions (**Box 2**).

Box 2. MERLIN Upscaling Workflow and guidance to identify restoration areas and quantify benefits.

To enable a rapid screening of restoration opportunities, the MERLIN project developed a MERLIN Upscaling Workflow which enables managers and planners to evaluate and compare the ecosystem service outcomes of restoring or applying NbS in different potential project areas. The tool has been applied in five European river basins as a demonstration and the results are presented in the MERLIN web app[1] (Baattrup-Pedersen et al., 2025).

Thorough descriptions and guidelines are provided in Garcia et al. (2025) that may serve as a technical tool for analysts and a strategic resource for decision-makers, allowing users to explore the opportunities of different restoration approaches in a spatially explicit and evidence-based manner. Additionally, by enabling data-driven assessments of restoration outcomes, it strengthens the scientific foundation for investment in NbS/restoration and supports the mainstreaming of ecological restoration across sectors.

1 https://www.waterwebtools.com/merlin

Identifying best opportunities for implementing restoration within Natura 2000 areas in alignment with NRR

Since biodiversity benefits cannot be modelled in the same way as ecosystems service outcomes related to societal needs like e.g., water purification (**Figure 4**), a different approach for selecting sites for biodiversity restoration was used in the MERLIN framework. The chosen approach is closely linked to the NRR Article 4 that underscores the importance of prioritising restoration efforts within the Natura 2000 network prioritising habitats that are currently degraded and therefore require restoration.

To facilitate the identification of areas with protected freshwater habitats and species and their conservation status, we developed a web-based tool. The tool allows users to get an overview of protected freshwater habitats in the Natura 2000 network, to zoom in on specific areas to explore individual species and habitat types and to extract data behind. More details are included in Baattrup-Pedersen et al. (2026)[1].

Figure 5 gives an overview of sites within the Natura 2000 network that require restoration to meet the targets set by the NRR and can be viewed in more detail in the MERLIN web app[2] (Baattrup-Pedersen et al., 2025).

As a means to guide restoration efforts in line with the NRR, the freshwater habitat restoration potential was modelled for all lake and stream habitats[3] that were in good and average or reduced conservation status in all Natura 2000 sites across Europe. The approach used to calculate the restoration potential was based on an understanding that the ecological and spatial context of sites in excellent conservation status (A) can effectively guide the identification of sites where restoration efforts of habitats in good (B) or average/reduced (C) conservation status have the highest probability of successfully enhancing freshwater biodiversity (Baumane et al., in review, see **Box 3**).

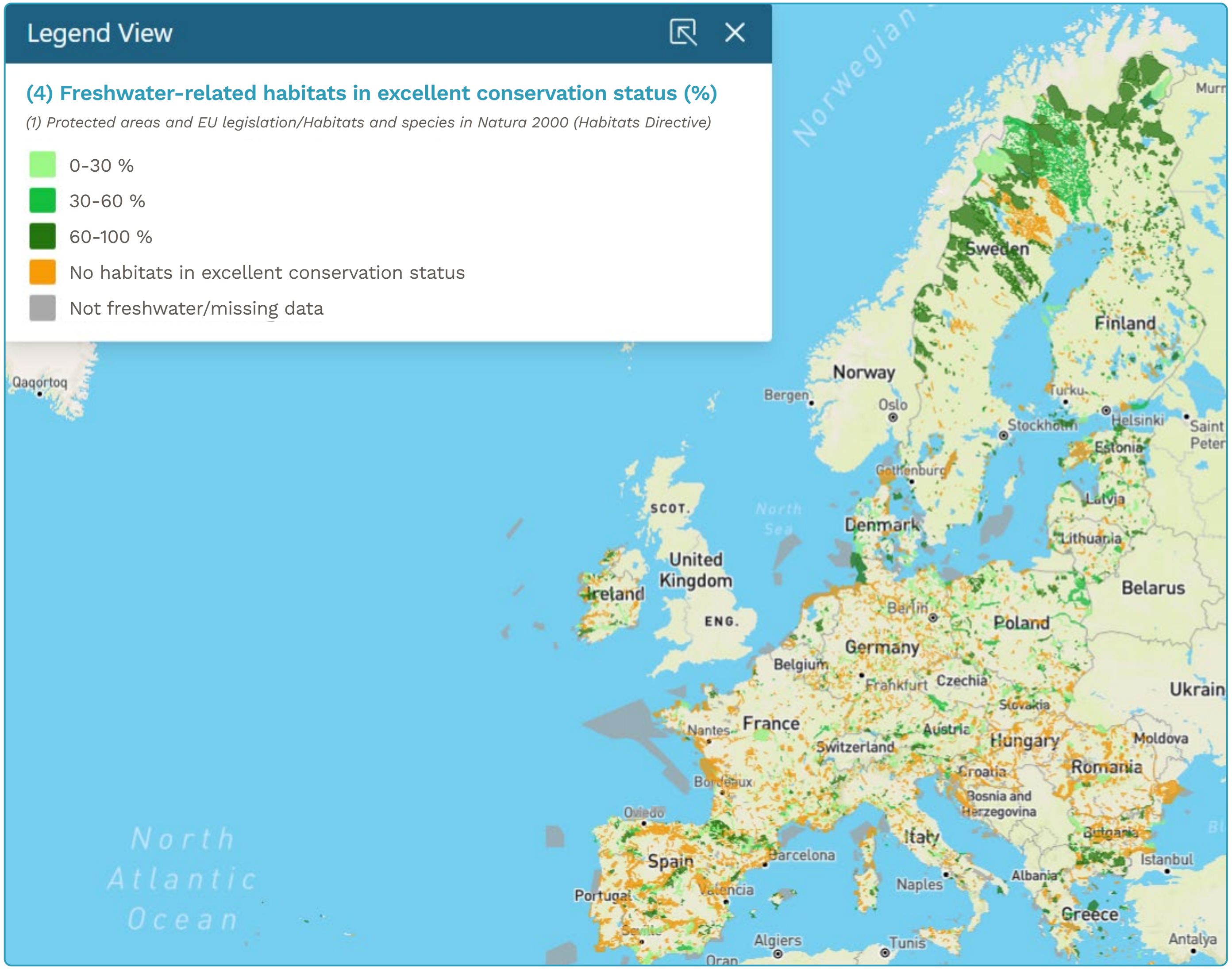


Figure 5. Conservation status of freshwater-related habitats within the Natura 2000 sites.

Note: Increasing intensity of green display an increasing percentage of freshwater-related habitats in excellent status, whereas orange colour display that no freshwater-related habitats are in excellent status within a site. Freshwater-related habitats are broadly defined including both freshwater habitats in the strict sense (codes 3xxx in the HD Annex I) but also groundwater-dependent ecosystems, whose water requirements are protected by the WFD Article 1 implying that bog, mire, fen, wet forest, certain types of scrub, natural and semi-natural grassland habitats were included as freshwater habitats.

1 Baattrup-Pedersen, A., Baumane, M., Nielsen, A., Trolle, D., Branco, P., Borgwardt, F., Hering, D., Birk, S. (under revision). Freshwater habitats within the Natura 2000 network. Ecological Applications.
2 https://www.waterwebtools.com/merlin
3 Habitat codes 31xx and 32xx according to HD Annex 1

Funded by
the European Union

Box 3. Modelling approach to assess restoration potential for lake and stream habitats in Natura 2000 sites.

A comprehensive list of context-dependent variables was derived from open-access, EU-wide datasets and grouped into four main categories: Natura 2000 site characteristics, Natura 2000 habitat characteristics, land use characteristics, nutrients and hydrology (**Figure 6**).

Site characteristics included total site area and the distance to the nearest Natura 2000 site, reflecting spatial scale and connectivity. Habitat characteristics focused on the area and cover of target habitats, total freshwater habitat cover and the proportion of freshwater habitats in excellent conservation status. Land use variables accounted for the surrounding landscape composition, including the extent of agricultural areas, forests and seminatural areas, wetlands and waterbodies. Nutrient and hydrological variables included levels of nutrient and organic pollution, the probability of failing to meet ecological status and hydrological connectivity metrics such as the number of nodes and barriers per hectare, as well as the presence of permanent or temporary water bodies. More details on the modelling approach and results can be found in Baumane et al. (in review)[1].

1 Baumane, M., Nielsen, A., Trolle, D., Branco, P., Borgwardt, F., Hering, D., Birk, S., Baattrup-Pedersen, A. (2025). Restoration potential of protected freshwater habitats in Natura 2000 network (in review.).

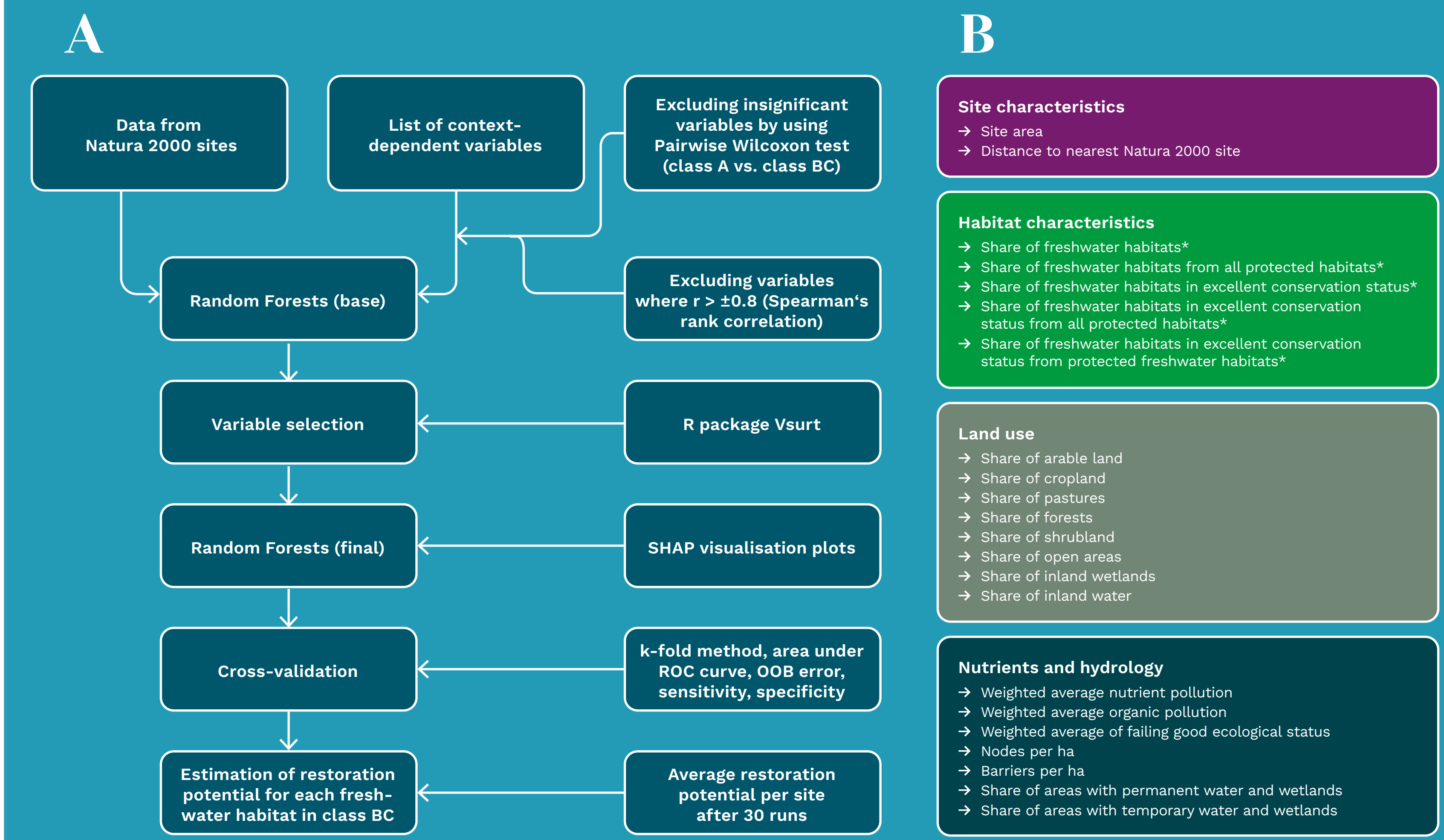


Figure 6. Overview of approach used to estimate habitat restoration potential (A) and context-dependent variables included in the data analysis (B). Abbreviations: Shapley Additive Explanations (SHAP), Receiver Operating Characteristic (ROC), Out-Of-Bag Error (OOB), habitats in excellent conservation status (A), habitats in good and average or reduced conservation status (BC).

**target habitat (e.g., 3260) is excluded.*

The freshwater restoration potential for lakes and streams can be seen on the MERLIN web app[4] (Baattrup-Pedersen et al., 2025) adding the layer 'Restoration in Natura 2000 – lakes and streams (Nature Restoration Potential)' and then specific habitat types can be selected. **Figure 7** gives an overview of the restoration potential for one of the protected habitat types, habitat type 3130, which is a small oligotrophic to mesotrophic lake habitat type that is highly vulnerable to pollution. The restoration potential is scaled into five classes based on the context-dependent settings within the areas (explained in more detail in the box above).

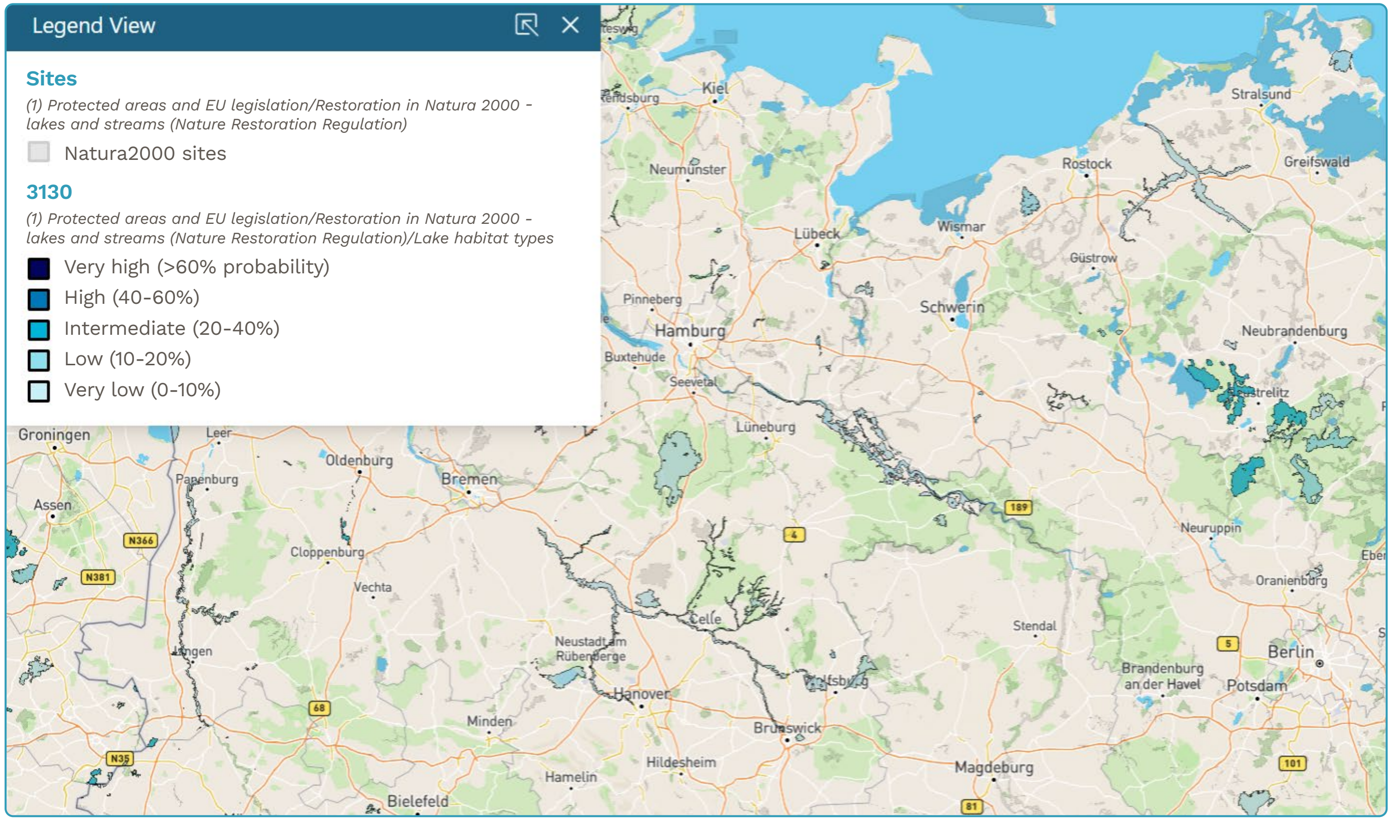


Figure 7. Restoration potential of lake habitat type 3130, i.e., oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoeto-Nanojuncetea within the Natura 2000 sites.

Note: Increasing intensity of blue display an increasing probability of successful restoration. Restoration potential for other lake and stream habitats can be found in the MERLIN web app[5] (Baattrup-Pedersen et al., 2025).

A photo showing species of *Lobelia dortmanna*, *Plantago uniflora* and *Myriophyllum alterniflorum*, that are species typical of this lake type.

The restoration potential, currently calculated for lake and stream habitats within the Natura 2000 network and visualised in the MERLIN web app[5] (Baattrup-Pedersen et al., 2025), can also be calculated for other freshwater-related habitats. The approach used demonstrates how a data-driven method can be used to prioritise actions that contribute to the NRR targets, including the restoration of at least 20% of the EU's land and sea areas by 2030 within the Natura 2000 network.

4 https://www.waterwebtools.com/merlin

Catchment-scale modelling of freshwater ecosystem services & cost-benefits

The MERLIN Upscaling Workflow as depicted in **Figure 4** has been applied to five MERLIN case studies to estimate ecosystem service benefits of freshwater ecosystem restoration. **Table 4** shows an overview of the results, which are presented in detail in Kok et al. (2025). It is important to note that, given the limited number of cases presented, it is not possible (nor intended) to draw general conclusions about the magnitude of freshwater restoration benefits from these results, but to showcase how the modelling approach can be used to quantify the net societal benefits of restoration, which in turn informs the development of financing strategies for implementation. **Box 4** presents detailed results of the modelling in the Forth Catchment. Hereunder, the main outcomes of the co-benefits modelling and the potential of the MERLIN Upscaling Workflow to support restoration upscaling, are briefly discussed.

Nutrients retention benefits were quantified in terms of additional mass of nutrients retained and degraded by ecosystems thanks to restoration and resulting changes in nutrients concentration in water flows reaching rivers. The estimated effect of restoration was small in Kampinos, Forth and Sorraia: the nutrients mass retained by ecosystems represented a reduction of about 1 to 2% of total nutrients mass exported from the catchment. The estimated nutrients retention was larger in Komppasuo, with a reduction of about 7% of total nutrients mass exported, but an increase in nutrients concentration in water flows reaching rivers. This can be explained by the significant increase in evapotranspiration in restored peatlands, which leaves less water to dilute the nutrient load still present. However, this is not a concern, as nutrient concentrations in the Komppasuo catchment are already low and not critical for achieving the water quality objectives in this watershed.

Flood risks mitigation benefits were quantified in terms of a reduction of peak flow percentage and resulting avoided flood damage costs. Benefits were substantial in the Forth (peatland rewetting scenario) and in Kampinos and small in Forth (channel remeandering scenario). There was no flood risk mitigation benefit in Komppasuo, because the catchment is not located in a region vulnerable to floods. Flood risk mitigation benefits were not estimated in Sorraia, because effects of riparian buffers on flood risk could not be modelled with the MERLIN Upscaling Workflow. These effects are likely to be very small.

Global climate regulation benefits were by far the largest benefits in all case studies. This is not surprising, as enhancing carbon sequestration and reducing greenhouse gas emissions were among the main objectives of the restoration projects. It is worth noting that we used social costs of carbon to value tons of CO_2e. Current tons of CO_2e prices on the carbon markets are much lower than social costs of carbon. For instance, the average price of carbon credits purchased from Peatland Code projects in the UK in 2022 was € 28.1 per ton of CO_2e (UK Carbon Price Index | IUCN UK Peatland Programme, n.d.), whereas we used a social cost of carbon of € 179 per ton of CO_2e for the year 2022 to quantify global climate regulation benefits in the Forth case study. This difference is important when considering carbon markets as potential private funding sources for the restoration.

Further developments of the MERLIN Upscaling Workflow could enhance its usefulness to support restoration upscaling. First, though the MERLIN Upscaling Workflow provides relevant biophysical metrics with respect to drought risk mitigation, this co-benefit could not be monetised in the timeframe of MERLIN. Drought risk mitigation co-benefits may take multiple forms, depending on the restoration context and potential uses of water (e.g., farming, hydropower, navigation, recreation). Monetary valuation approaches adapted to those different use cases are needed to monetise the drought risk mitigation benefits. Second, our modelling results should be updated with scenarios that do account for the future effects of climate change. Freshwater ecosystems restoration is expected to increase resilience to future climate change extreme events, but climate change may also threaten the effectiveness of restoration.

Modelling the effects of future climate change on restoration effects is needed to strengthen evidence on the benefits of restoration for water resilience. Lastly, the MERLIN Upscaling Workflow could also support cost-effectiveness assessment of freshwater ecosystem restoration in comparison to grey measures, to determine the optimal mix of NbS and grey infrastructure to enhance resilience to future climate change.

Table 4. **Overview of nutrient retention, flood risk mitigation and global climate regulation benefits of freshwater ecosystems restoration estimated by the MERLIN Upscaling Workflow in in five MERLIN case studies**

Case Study	Nutrient retention benefits		Flood risk mitigation benefits		Global climate regulation benefits	
Restoration measure	Biophysical	Monetary[1]	Biophysical	Monetary[1]	Biophysical	Monetary[1]
CS05 – Kampinos Wetlands Floodplain rewetting – 18,673 ha	14 tons N & 5 tons P retained Mean N & P concentration reduced by 1.15%	2.7 €m	Flood risk reduced by 6%	6 €m	2,898 t CO_2e	37 €m
CS13 – Sorraia floodplain Riparian buffers – 509 ha	0.28 tons N & 0.04 tons P retained Mean N & P concentration reduced by 0.1% and 2.1% respectively	1 €m	n.a.	n.a.	987 t CO_2e	10.8 €m
CS14 – Komppasuo peat extractiona area Peat extraction area rewetting – 3,509 ha	5 tons N & 3 tons P retained Mean N & P concentration increased by 9.2% and 8.1% respectively	-2.2 €m	n.a.	n.a.	40,817 t CO_2e	1,132 €m
CS17 – Forth catchment – peatland rewetting Drained peatlands rewetting – 1,657 ha	88 tons N & 11 tons P retained Mean N & P concentration decreased by 0.9% and 0.7% respectively	13 €m	Flood risk reduced by 8.8%	3.9 €m	7,380 t CO_2e	39.4 €m
CS17 – Forth catchment – Channel remeandering River channel remeandering – 154 km	45 tons N & 8 tons P retained Mean N & P concentration decreased by 1% and 1.1% respectively	7 €m	Flood risk reduced by 0.9%	0.34 €m	n.a.	n.a.

1 Present value of benefits discounted over 100 years

Box 4. Benefit assessment in the Forth catchment (Scotland).

In the Forth catchment (MERLIN case study 17, **Figure 8**), the MERLIN Upscaling Workflow was applied to model the benefits from rewetting drained peatlands with a mid-upscaling scenario (829 ha of rewetted peatlands) and a high-upscaling scenario (1657 ha of rewetted peatlands). Benefits of restoration were assessed for three ecosystem services: nutrient retention, climate regulation and flood risk mitigation.

Flood risk mitigation benefits were valued as flood damage costs avoided thanks to restoration. Benefits result from the reduction of peak flow probabilities in rivers (**Figure 9**) and the value of assets exposed to river flooding (Kok et al., 2025). The high-upscaling scenario resulted in a decrease of flood probability of 8.5% and monetary benefits of 1.28 million euros, while the mid-upscaling restoration scenario resulted in a decrease of probability of 8.5% and monetary benefits of 3.87 million euros (**Figure 9**). Those results indicate that peatland areas located closer to the downstream parts of the catchment (in yellow in **Fig. 8**) are the most beneficial and to be prioritised for flood risk mitigation.

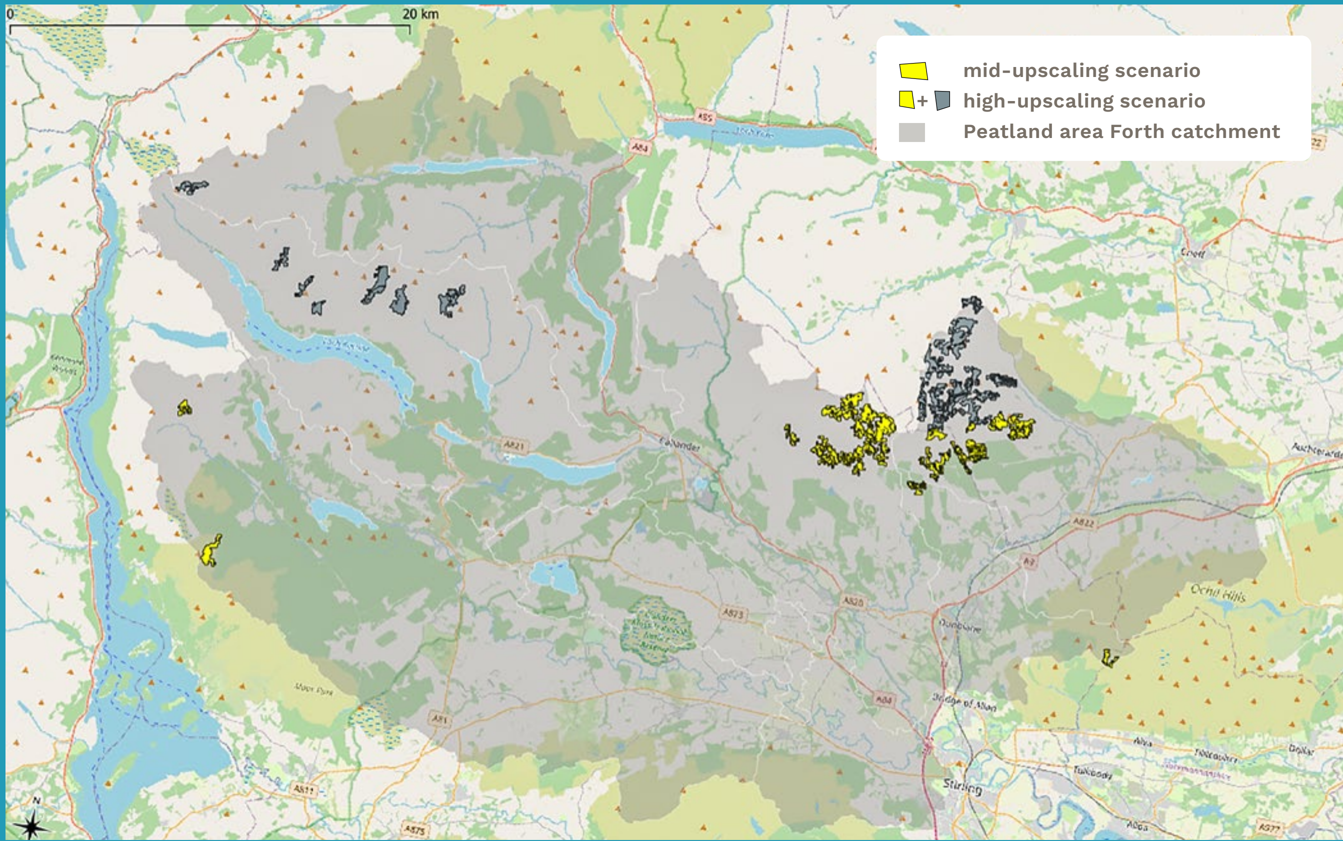


Figure 8. The Forth catchment and its peatlands.

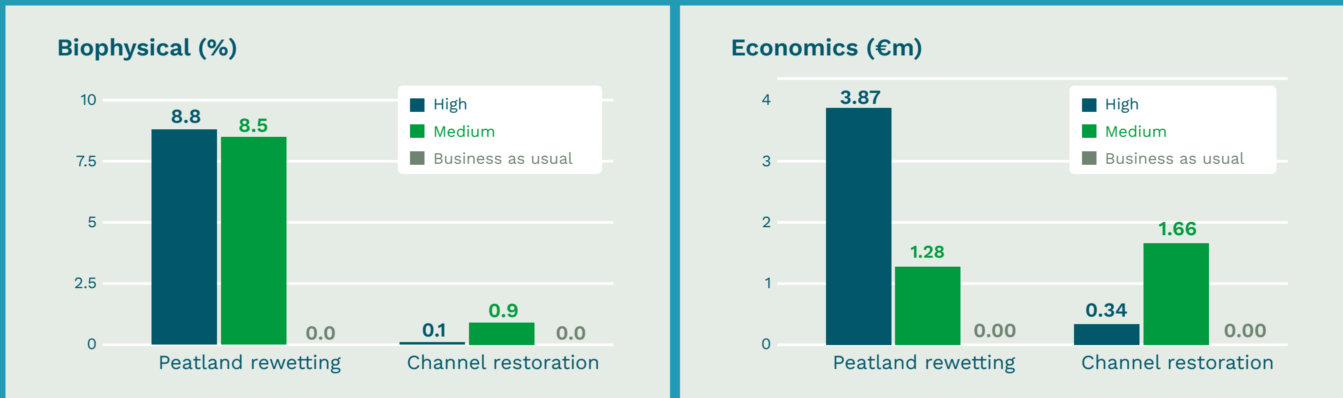


Figure 9. Flood mitigation benefits.

Biophysical: reduction of river peak flow probability in %.

Economics: present value of avoided flood damage costs over 100 years in million euros.

Box 4. Benefit assessment in the Forth catchment (Scotland) (continued).

In the high-upscaling scenario, 88 tons of Nitrogen and 11 tons of Phosphorus are retained thanks to restoration, but these amounts represent less than 1% of total nutrients exports. Therefore, the restoration effect on nutrient concentration in streams of the catchment is limited. Average N concentration is reduced by 0.9% and averaged P concentration is reduced by 0.7%. To optimise the planning of restoration measures for this benefit, additional spatial data on the demand for the nutrient retention service (e.g., water quality status, drinking water extraction points) should be combined with the model outputs. In the case of the Forth catchment, **Figure 10** indicates that rewetted peat areas are located in the north-eastern parts of the catchment where the water quality status is already good or high. Increasing nutrient retention in the south-western parts of the catchment would be more beneficial. This is not captured by the outputs of the model, as benefits are modelled based on a replacement cost approach which does not take into account the demand for the service (Kok et al., 2025).

Global climate regulation benefits increased twice from the mid-upscaling to the full-upscaling restoration scenarios, from 3.7 ktons CO_2e/year to 7.4 Ktons/year (**Figure 11**). Global climate benefits were estimated by calculating reduction in greenhouse gas emissions emissions associated to restoration-induced changes in peat condition and use, applying specific emission factors per peat condition and use class. Avoided GHG emissions were valued using social costs of carbon (Kok et al., 2025).

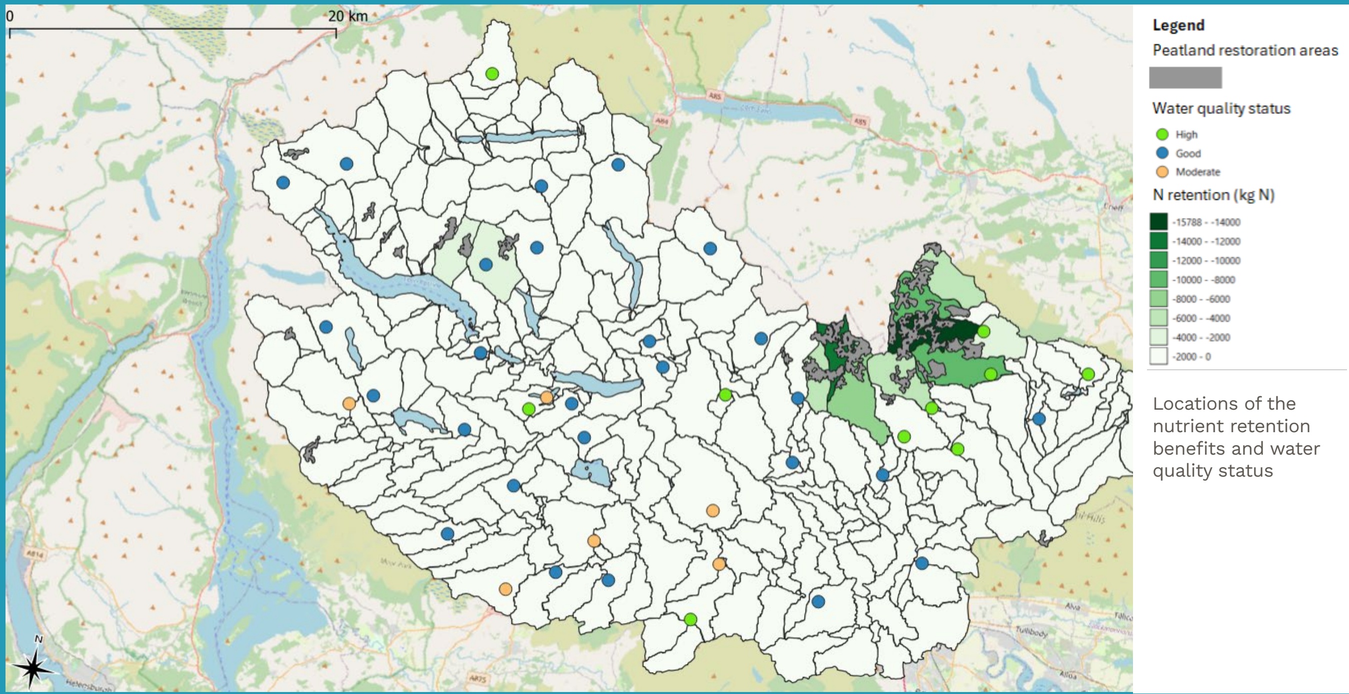


Figure 10. Nutrient retention benefits.

Figure 11. Global climate regulation benefits.

More information can be found at MERLIN web app (Baattrup-Pedersen et al., 2025) for the Forth catchment as well as for other catchments in Europe: https://www.waterwebtools.com/merlin

3. Funding the upscaling

The MERLIN Upscaling Workflow includes an additional component focusing on financial planning (**Figure 12**), which provides restoration managers with a structured, adaptive approach to design financially viable strategies for implementing the identified measures at scale. It is articulated around four iterative and interdependent pillars: project planning, benefits and cost assessment, funding diversification, and financing strategy. These pillars guide restoration teams through the process of aligning restoration objectives with fitting sources of funding and finance.

Importantly, financial planning should not be treated as a linear or isolated exercise. Rather, emerging knowledge about the restoration context must evolve in tandem with stakeholder engagement, ecological-economic modelling, commercial know-how and understanding of funding and finance opportunities. Central is the early engagement of restoration managers with local communities, stakeholders and business actors to identify restoration needs and potential benefits, prioritise ecosystem services to be delivered, and take stock of business opportunities arising from restoration. Building relationships takes time and requires fully integrating a broad set of perspectives in the design phase of the restoration plan.

Financing is embedded in the earlier steps of the MERLIN Upscaling Workflow, in particular the quantification of ecosystem services, costs and benefits of restoration (see page 22). These assessments enable a clear articulation of societal value, supporting the development of credible arguments for drawing in financial support.

Financial planning within the MERLIN Upscaling Workflow encourages restoration managers to consider a diversity of funding sources and revenue streams, from public subsidies and philanthropic donations to ecosystem service payments and sales of nature credits. It also recognises the important role of in-kind contributions in reducing capital and operational expenditures. While a Cost-Benefit Analysis will not quantify private benefits, the process of identifying costs and benefits in the restoration area can be designed in such way so to help uncover excludable private sector benefits and business opportunities linked to environmental outcomes.

Financial planning within the MERLIN Upscaling Workflow supports the formulation of an integrated financing strategy, including a detailed cash flow analysis and the identification of suitable financing mechanisms to close funding gaps. The four pillars presented in Figure 12 serve as a guide, highlighting the key building blocks practitioners need to operationalise large-scale NbS in a strategic, cost-effective, transparent and adaptive manner, ensuring that restoration efforts are not only ecologically sound but also financially sustainable and investment-ready.

The next, final section of this report presents lessons learned on the application of the financing part of the MERLIN Upscaling Workflow.

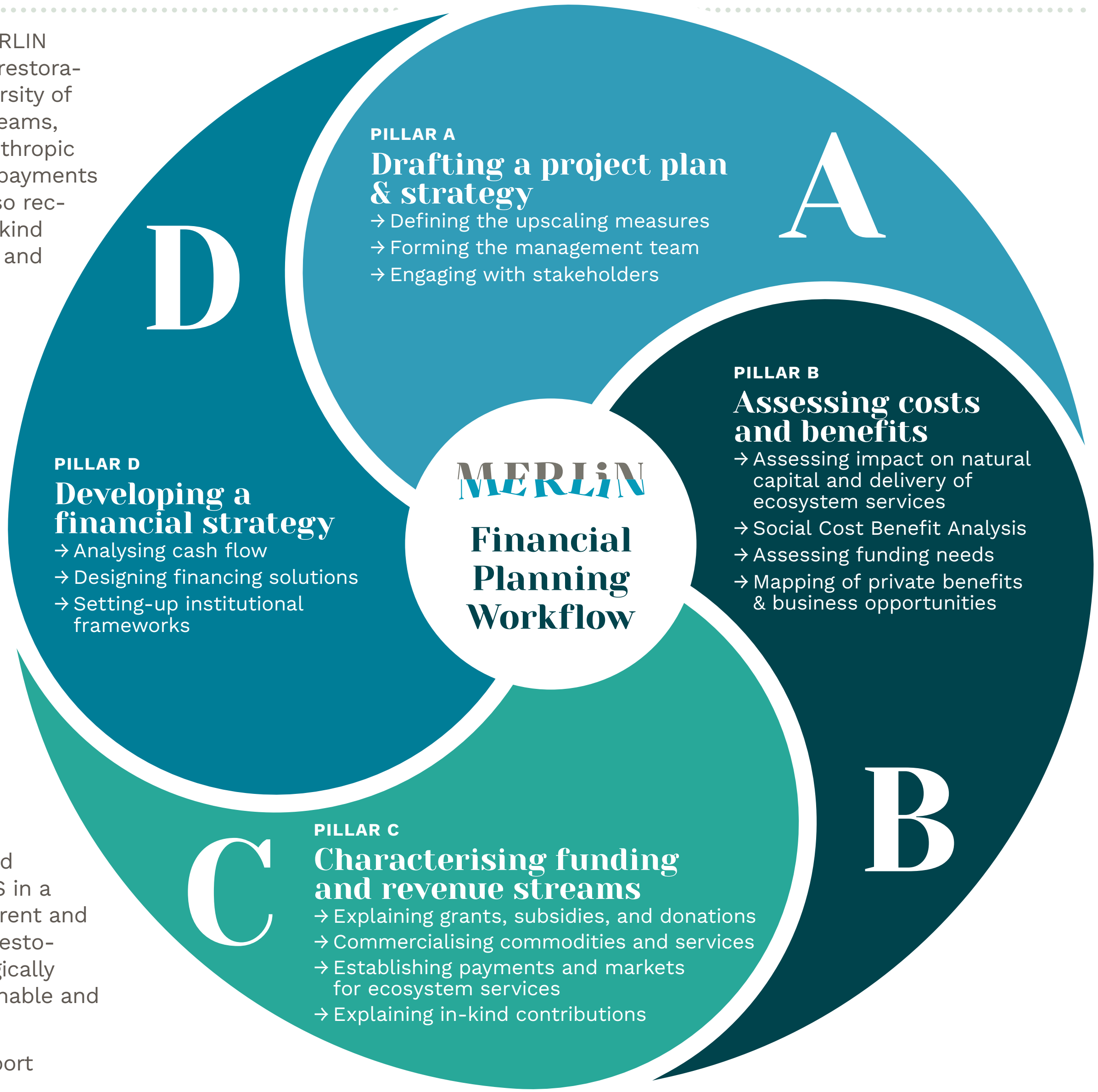


Figure 12. Overview of key building blocks or "pillars" of the MERLIN Upscaling Workflow focused on financing (Rouillard et al., 2025).

What funding is needed to upscale freshwater restoration and NbS?

The need to align public funding with restoration targets

Public funding remains the primary financial support for freshwater restoration and NbS across Europe and plays a crucial role in driving progress and ensuring long-term sustainability. Several EU funding instruments are relevant, but their impact varies. Programmes like LIFE[1] provide dedicated and targeted support for nature restoration, environment and climate actions.

However, the majority of funding potentially relevant for environment and climate currently lies within other instruments of the Multi-annual Funding Framework (MFF) 2021-2027 (**Figure 13**). These instruments support primarily particular sector development, such as agriculture through the Common Agricultural Policy (CAP) or rural areas and regional development through Cohesion Funds (e.g., EAFRD, ERDF). In practice, high-ambition restoration is often difficult to achieve through these channels due to competing priorities, complex rules and limited targeting. Unlocking the full potential of these funds requires better alignment with EU biodiversity and climate commitments and removing incentives that may run counter environmental and climate objectives. The upcoming negotiation over the next EU Multi-annual Financing Framework is an opportunity to increase funds dedicated to restoration, to match the ambition of the EU WFD, Biodiversity Strategy 2030 and the NRR and to ensure sectoral aid supports the transition to a nature positive economy (**Box 5**).

As the largest source of EU funding impacting on rural land use, the CAP has a pivotal role to play in upscaling freshwater restoration and the use of NbS across Europe. Currently agriculture represents a major source of pressure on freshwater biodiversity. Better alignment of CAP payments with sustainable land use and management, river basin management and restoration plans is critical to make EU's food production more sustainable and resilient (Blackstock et al., 2025; Meier et al., 2025; Pereira Dos Santos et al., 2025; Rouillard et al., 2026).

While Member States fund several interventions beneficial for biodiversity, freshwater restoration and NbS in their CAP Strategic Plans (see e.g., ENPLC, 2025), they have not harnessed the full potential that CAP regulations offer (Rouillard et al., forthcoming) and current proposals of the future CAP are unlikely to support the needed upscaling of restoration measures by the agricultural sector (Hart & Baldwin, 2025; Meier et al., 2025). Future CAP payments should remain conditional on high environmental standards, consistent with societal expectations and necessary to safeguard wetlands, peatlands, riparian buffers and other biodiverse waterscape features. At the same time, care must be taken to avoid subsidising practices that risk further degradation, such as high pollution loads through intensive use of fertilisers and pesticides, erosion, drainage, irrigation or reservoirs in already water-stressed landscapes (Pe'er et al., 2020). By ensuring such safeguards and incentives, the CAP can become a powerful enabler of freshwater restoration and NbS at the scale and coordination level needed to address Europe's water and climate challenges.

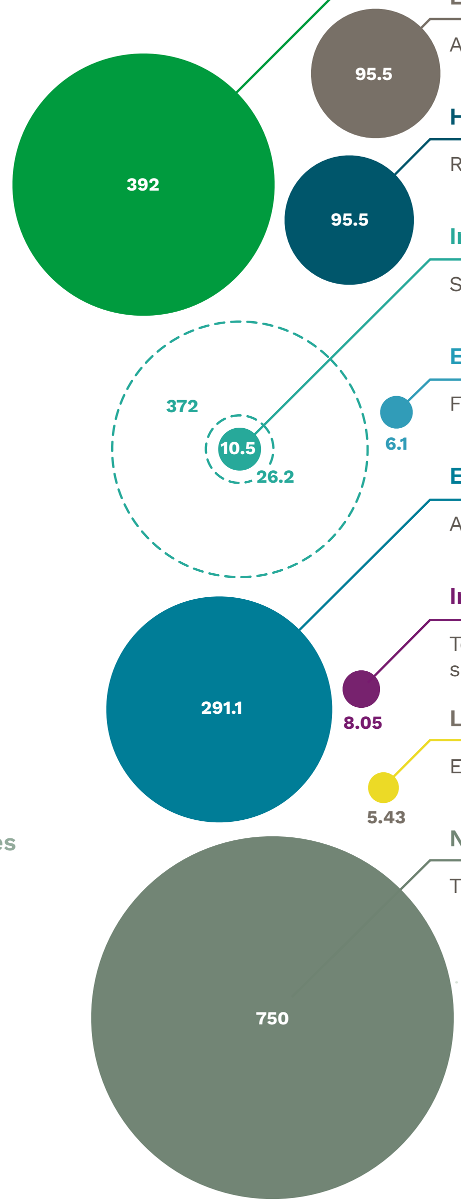
A shift towards a more performance-based framework would further help ensure that payments reflect meaningful outcomes, allowing for more effective targeting of resources and a more robust evaluation of their impact on freshwater ecosystems. Equally, investments in farmer training and advisory services are essential to build capacity for water-resilient farming and to encourage collaborative approaches that deliver coordinated outcomes at the catchment and landscape scale (Le Clech et al., 2025; Meier et al., 2025). One such example is Ireland's adoption of a performance-based, collaborative payment scheme which illustrates how the CAP can be designed to deliver freshwater restoration and NbS (see **Box 6**).

Box 5. The next Multi-annual Funding Framework (MFF) of the European Union 2028-2034.

As the end of the current MFF nears, attention is given to the next MFF 2028-2034. Proposals on the next MFF released by the EU Commission in July 2025 promote fewer funds, consolidated primarily around three funds. The largest fund is **1)** the European Economic, Territorial, Social, Rural and Maritime Sustainable Prosperity and Security Fund, which will integrate several important EU funds for environment and climate, including CAP and Cohesion Funds. Member States will need to draw National and Regional Partnership Plans (NRPP) to show how EU funds will be used. Other funds include the **2)** European Competitiveness Fund (for research and innovation, defense, digital sector, health, biotech, but also clean transition, agriculture and bioeconomy); and **3)** the Global Europe Fund (including development assistance and foreign policy).

A first analysis of these funds (e.g., Hart & Baldwin, 2025) indicates a stronger focus on current priorities (i.e. security, defense, improved competitiveness and significantly greater flexibility to adapt to unforeseen events) and less so on environment and climate. More critically, funding for environmental and climate objectives are likely to be diluted into multiple funds dedicated to support specific sector and regional development objectives. As Member States are planned to have greater flexibility on how to use EU funds, ensuring adequate support to freshwater restoration would require preserving an ambitious environment and climate dedicated fund, increasing the profile of environment and climate objectives in the new consolidated funds, using ring-fencing requirements to ensure sector incentives are nature-positive, and reinforcing the governance for approval and monitoring of funds, including to ensure alignment of fund use according to the Do No Significant Harm Principle.

1 https://cinea.ec.europa.eu/programmes/life_en



Cohesion Fund & European Regional Development Fund

Cross-sectoral, but including regional infrastructure, industry, energy, environment, employment, social cohesion

European Agricultural Fund for Rural Development

Agriculture, forestry, rural development

Horizon Europe

Research and innovation across sectors

InvestEU Fund[1]

Several thematic area, including infrastructure, innovation & digitalisation, SMEs, social investment, etc.

European Maritime and Fisheries and Aquaculture Fund

Fisheries, aquaculture, blue economy

European Agricultural Guarantee Fund

Agriculture

Interreg

Territorial, cross-sectoral into regional development, cross-border, transport and connectivity, social cohesion, environment, climate, innovation

LIFE programme

Environment, climate action, biodiversity

NextGeneration EU[2]

Transversal, but some earmarked shares for climate, digital, health, resilience of economies

Figure 13. Main EU funds, including sectors that will benefit most, directly relevant to natural resources and the environment in the 2021-2027 Multi-annual Funding Framework.

1 Budget from the EU is 10,5 billion €, but this allows for 26 billion € in guarantees, leveraging a total of 372 billion € of public and private investments.

2 The fund was established as a recovery instrument after the Covid Pandemic. It is composed of a mix of grants and loans for investments in many areas, but some earmarked shares exists for climate, digital, health, and increasing economic resilience. Allocation: 672 billion € under the Recovery and Resilience Facility, 48 billion € under REAC-EU, 2 billion EU RescEU, 10 billion € for Just Transition Fund and 28 billion € for existing programmes including European Agricultural Fund for Rural Development, Invest EU, and Horizon.

Freshwater restoration and NbS also largely depend on standalone national and subnational public funding sources. Examples of large public investment initiatives by Member States exist. Compelling examples are illustrated by e.g., the “Room for the River” in the Netherlands (see Blackstock et al., 2025 and Box 7) and the “Agreement on a Green Denmark” (see Box 8). These are driven by national priorities, for instance, flood risk management for the former and climate mitigation from greenhouse gas emissions from agriculture and water purification for the latter. These examples showcase the transformative potential of public funding when ecological restoration at scale becomes a priority on strategic policy agendas.

Box 6. Ireland’s ENVCLIM intervention with cooperation option.

Ireland is directing CAP funds to support coordinated freshwater restoration at both catchment and landscape scales. It directs nicentives to landowners, especially farmers, to achieve tangible environmental outcomes at landscape scale. Funding is directly tied to ecological improvements, with payments partially based on performance. Progress is assessed using site-level scorecards to ensure measurable results. Crucially, the “cooperation option” scales the intervention from individual farms to coordinated, landscape-level efforts, as groups of farmers collaborate with locally based project teams to develop integrated sustainability plans. By defining shared goals for biodiversity, water and climate, this collective framework enables CAP funds to support joint action and drive systemic restoration across entire catchments.

While new and innovative funding sources are welcome, existing funding mechanisms should be better exploited and strategically aligned. For instance, several economic principles are embedded in the EU Water Framework Directive (through its Article 9) such as the polluter-pays principle and the recovery of the costs of using and polluting water resources, including environmental and resource costs (e.g., through charges for water abstraction or pollution emissions). However, these principles are poorly implemented by Member States. More rigorous enforcement of the provisions included in existing regulation would internalise environmental externalities and incentivise economic behaviour towards more efficient and nature-positive sectoral activities, while it would provide public authorities with additional funding resources. These could be earmarked or channelled into funds that support large scale, long-term catchment restoration activities and NbS.

To upscale public investment in freshwater ecosystem restoration, broader political and societal support for restoration must be strengthened. Strategic communication, framing restoration around clean water, flood safety, recreation and health, can make its relevance more tangible. A narrative of nature as an infrastructure critical to the continuous and competitive operation of the European economy could be developed. Ultimately, the full range of benefits including ecological and socio-economic outcomes, costs and trade-offs must be made more visible and credible to policymakers (Rouillard et al., 2025). Long-term commitment depends also on confidence in restoration’s effectiveness and value for money. This requires participatory planning, inclusive engagement, robust monitoring and evaluation as well as adaptive management (Blackstock et al., 2025).

Box 7. The "Room for the River".

In response to extreme river flooding in the 1990s, the Dutch government initiated the "Room for the River" programme in 2007 to increase flood safety while enhancing the ecological quality of the riverine corridor. Instead of only focussing on fortifying dikes, the strategy emphasised the restored natural floodplains in less vulnerable areas and allowing rivers more space during high flows. Implemented across over 30 locations with a coordinated national approach, the programme had a total budget of EUR 2.3 billion, jointly financed by central and regional governments, and was completed by 2015.

Box 8. Agreement on a "Green Denmark".

As part of its broader climate and biodiversity agenda, Denmark signed the Agreement on a Green Denmark in June 2024 – a landmark consensus among the government, farmers, environmental groups and industry. The goal of the agreement is to reduce greenhouse gas emissions and losses of nitrate to coastal areas as well as improve biodiversity. The agreement commits to restoring 140,000 hectares of lowland agriculture by 2030 into natural areas such as wetlands and meadows, create 250,000 hectares of new forest, and establish 21 new national parks. A Green Acreage Fund of DKK 43 billion (EUR 5.76 billion) supports the large-scale land management initiatives such as afforestation, land conversion, and strategic land acquisitions.

Engaging with the private sector

The EU increasingly recognises the need to expand and diversify sources of funding to enable restoration at the scale required to meet environmental targets. For example, Member States' Nature Restoration Plans under the NRR must explicitly outline "the means of intended financing, public or private, including financing or co-financing" (Article 15.3(u)).

Diversifying funding requires reaching out to a larger group of funders with more diverse expectations and needs, several of which will look not only at biodiversity benefits but also social and economic ones (**Box 9**). MERLIN has shown how restoration teams across Europe are beginning to explore collaborations with private donors, lenders, and investors (Rouillard et al., 2025). Yet, case studies reveal persistent barriers with mobilising private sources: limited business and financial expertise; hesitation about engaging with financial markets; difficulties in quantifying and communicating economic and social restoration benefits (rather than just biodiversity benefits); and concerns around greenwashing. These constraints are compounded by limited knowledge (e.g., of funding opportunities), skills (to engage and collaborate with the private sector), time and actionable guidance, which are critical ingredients for building trust and aligning goals with private partners (Altamirano et al., 2021; Hüsken et al., 2025; Rouillard et al., 2025).

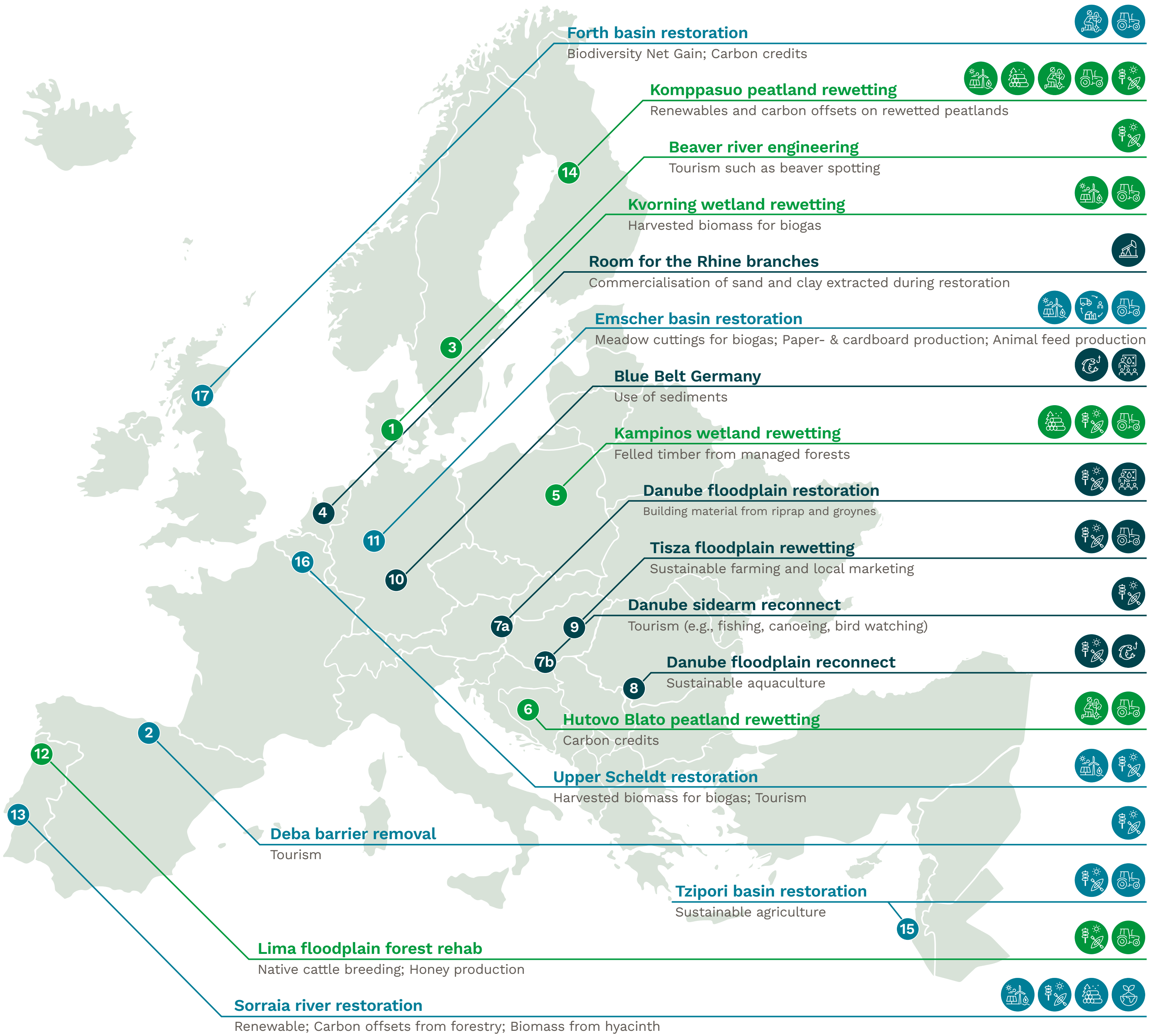
To meet these demands, restoration teams need to build capacities to engage and collaborate with companies and investors. This includes better understanding investor requirements around project size, return rates and timelines, as wll as risk appetite, alongside practical skills in economic assessment and financial planning, ranging from Cost–Benefit Analysis and natural capital accounting to cash flow projections and financial risk assessment. Dedicated public funding and support programmes to lay the groundwork to approach the private sector with concrete proposals, together with appropriate training and advisory support can play a catalytic role. For example, the Scottish Facility for Investment Ready Nature in Scotland[1] provides restoration teams with financial and capacity-building assistance to explore new funding streams, while WWF and the European Investment Bank are collaborating to mobilise €0.5 billion in green investments and develop a pipeline of large-scale NbS initiatives across agriculture, energy and urban resilience (EIB, 2024).

In spite of the many recent efforts at EU and global level to raise the weight of environmental, social and governance aspects in corporate decision-making, structural barriers continue to limit private sector engagement in restoration. Many restoration benefits are public goods, shared, non-excludable and intangible, which means they are often overlooked in conventional metrics and markets. Businesses and investors have thus limited incentive to contribute voluntarily, as restoration outcomes rarely translate into direct financial returns in the short term. Overcoming this requires deliberate policy intervention, including enforcing regulation that corrects market failures (e.g., cost recovery provisions in the EU Water Framework Directive) and developing new standards, metrics and "nature-positive" economic models that capture the full value of restoration.

Nonetheless, some opportunities exist to align ecological goals with private interests (**Table 5**). The continuity and stability of operations in several economic sectors, including water utilities, insurers, tourism operators and agriculture, are directly dependent on well-functioning freshwater ecosystems and thus stand to benefit from enhanced ecosystem health and reduced environmental risks. Other activities such as those linked to eco-tourism, carbon markets and the harvesting of biomass and inorganic materials can also unlock additional resources, as direct income can be generated from ecological restoration. Targeted partnerships with willing private actors, those with matching interests or Environment, Social and Governance (ESG) commitments, offer a practical entry point to build collaboration and test the scalability of particular funding and finance arrangements (EIB, 2023). **Table 5** presents some opportunities from ecological restoration identified in the case studies of the MERLIN project. Opportunities across sectors are elaborated in the MERLIN EU Cross-Sectoral Routemap (Blackstock et al., 2025).

1 https://www.nature.scot/funding-and-projects/firns-facility-investment-ready-nature-scotland

Table 5. Ecosystem Services delivered by restoration and link to business opportunities in examples from MERLIN.



Box 9. Funding and financing instruments available for restoring freshwater ecosystems.

Figure 13 presents a non-exhaustive overview of the types of funding (funds provided for restoration without an expected return), revenues (from the commercialisation of goods and services unlocked by restoration) and financing mechanisms (funds provided with an expected rate of return) available to form a financing strategy for restoration upscaling initiatives. Within the MERLIN project, a suite of Off-the-Shelf Instruments[1] were also developed to provide restoration managers with practical insights on setting up, managing and using diverse types of funding and financing instruments to pay for their restoration activities. Instruments covered include corporate donations and branding, crowdfunding campaigns, debt instruments and climate bonds, among others.

1 https://project-merlin.eu/outcomes/off-the-shelf-instruments.html

Purpose	Instrument	Size (€)	Partnerships	Complexity	Policy requirements	Project requirements
Funding	Corporate Donations	€ – €€€	private sector businesses	↓	✕	✓
Funding	Donation-based crowd-funding	€ – €€	private donors	↘	✕	✓
Funding	In-kind contribution	€ – €€	private sector businesses, private donors	↓	✕	✓
Revenues	Corporate branding	€ – €€	private sector businesses, private donors	↘	✕	✓
Revenues	Tourism & agriculture activities	€ – €€€	private sector businesses, verification, certification & auditing services	↗	+	✓✓✓
Revenues	Carbon offsets	€€ – €€€€	project development consultant, verification, certification & auditing services, credit retailer	↑	+	✓✓✓✓
Revenues	Biodiversity offsets	€€ – €€€€	project development consultant, verification, certification & auditing services, credit retailer	↑	++	✓✓✓✓
Financing	Debt (loans)	€ – €€€€€	$	↘	+	✓✓✓
Financing	Climate bonds	€€€€€	$, legal services, government entity	↑	++	✓✓
Financing	Mutual Guarantees	€€ – €€€€€	$, legal services, government entity	↑	+	✓✓

€ => 15.000 | €€ = 50.000
€€€ = 100.000 | €€€€ = 1.000.000
€€€€€ > 5.000.000

(private sector icon) = private sector businesses
(donor icon) = private donors
(award icon) = verification, certification & auditing services
(lightbulb icon) = project development consultant
(cart icon) = credit retailer
$ = financial services
(scales icon) = legal services
(building icon) = government entity

↓ = low: requiring little to none efforts and financial expertise
↘ = low-medium: requiring some effort and financial expertise
↗ = medium-high: requiring considerable effort and financial expertise
↑ = medium: requiring substantial effort and financial expertise

x = Instrument does not depend on policies
+ = Local policies might be supportive
++ = Instrument depends on local policies

✓ = minor: project should satisfy some voluntary conditions
✓✓ = basic: project must satisfy some basic contractual conditions
✓✓✓ = elaborated: project outcome must meet specific requirements
✓✓✓✓ = extensive: project design must follow a given protocol

Figure 13.
Types of funding, revenues and financing instruments relevant for freshwater restoration.

Private sector participation in restoration financing can bring much-needed capital and innovation, but it also introduces significant reputational risks that must be carefully managed. Partnerships perceived as greenwashing, where companies overstate the environmental benefits of their investments or use restoration projects primarily for marketing or scandals involving partner companies and multinationals can undermine public trust in the restoration initiative.

EU and national policymakers can create enabling conditions to guide how investments are mobilised and structured to deliver high-quality, context-aware outcomes. Key actions include:

- → Providing clear definitions and criteria for responsible restoration finance
- → Establishing EU and national-level funds that blend public and private capital and specialise on nature restoration
- → Setting standards and safeguards to reduce reputational risks due to participation in private partnerships, including when benefiting from ESG initiatives or when participating in emerging carbon and biodiversity markets
- → Creating intermediary institutions and governance structures such as limited companies or associations to align stakeholder interests, pool resources and manage revenues at scale

Innovative approaches, such as Landscape Enterprise Networks (LENs)[2], already demonstrate how cross-sectoral investment can be mobilised through collaborative, place-based processes. Cooperative structures such as the Emscher Genossenschaft in Germany, which pools contributions from public and private members alongside loans and green financing, illustrate how blended finance can sustain ambitious restoration programmes over decades (**Box 10**).

Box 10. Restoration of the Emscher catchment in Germany.

For the restoration of the Emscher, the Emschergenossenschaft (EG) and the neighbouring Lippe Verband (LV) formed the Emscher Genossenschaft-Lippe Verband (EGLV), a legal cooperative partnership uniting public and private members in the catchment. This cooperative structure pools resources and coordinates action for watershed management. Funding combines member contributions based on the polluter-pays principle, long-term loans from the European Investment Bank, green financing from NRW.BANK and public grants. This blended finance approach has enabled the long-term, large-scale restoration of the Emscher system and modernisation of water infrastructure.

Only clear, coordinated policy signals and long-term commitment can play a significant role in reducing investment risks and incentivising private engagement while keeping environmental and social integrity in check. Continuity in policy programmes (and their ambition) and regulatory frameworks are therefore essential. Regulatory initiatives – such as the EU Taxonomy, Corporate Sustainability Reporting Directive and sustainable finance standards – are contributing to mainstream nature into corporate decision-making (see also Blackstock et al., 2025). Strengthening these mechanisms for nature restoration is needed, rather than weakening them as currently proposed under the "Omnibus Package"[3].

Ultimately, scaling private sector contributions will require more than upskilling, better communication, and supportive policy, it calls for a genuinely transformative change towards a nature-positive economy. New socio-economic models are needed in which investment and spending prioritise balanced initiatives that integrate environmental, social and economic gains, while addressing and compensating for the negative impacts of transition. This shift begins with recognising that a healthy natural system is not an optional asset but a fundamental precondition for a resilient, competitive economy. More importantly, it requires EU and national policy makers and the private sector to act consistently on this understanding, embedding it in financial choices, business strategies and public policy alike.

2 https://landscapeenterprisenetworks.com/

3 https://finance.ec.europa.eu/news/omnibus-package-2025-04-01_en

Conclusion

Europe's **freshwater ecosystems** support **rich biodiversity** and provide **essential benefits** such as clean water, flood protection, carbon storage and recreation. **Restoring** these ecosystems is therefore an **urgent priority** for achieving Europe's environmental, social and climate goals. This requires restoration at scale, combining Nature-based Solutions with engineered measures where appropriate, to meet societal needs and **deliver EU commitments** under the **Water Framework Directive**, the **Biodiversity Strategy for 2030** and the **Nature Restoration Regulation**.

The **MERLIN Upscaling Workflow** offers an evidence-based and practical tool for authorities and practitioners to **plan** and **prioritise restoration**. It helps identify where restoration is most likely to succeed, including in Natura 2000 sites, and allows ecosystem service benefits to be quantified. By demonstrating co-benefits such as increased carbon sequestration, improved water resilience and reduced flood and drought risks, MERLIN strengthens the case for investment and stakeholder support. **Financing approaches** should therefore **combine public** and **private sources** and reflect the full value of ecosystem services.

Overall, the MERLIN Upscaling Workflow enables **targeted**, **cost-effective freshwater restoration** that supports Europe's **long-term ecological integrity**, **climate resilience**, and **policy objectives** under the European Green Deal and the Biodiversity Strategy for 2030. We recommend its use to **prioritise** and **upscale restoration across Europe**, while ensuring that projects maximise biodiversity benefits and explicitly consider potential synergies and trade-offs, particularly where existing legislation protects natural species and habitats.

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