DELIVERABLE 4.1

NBS strategy and implementation plans for front-running regions

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Land4Climate

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Abbreviations

AT	Austria
CAP	Common Agricultural Policy
CRA	Climate Risk Assessment
CZ	Czech Republic
DE	Germany
DX.Y	Deliverable X.Y
EU	European Union
FRR	Front Running Region
IT	Italy
LAND4CLIMATE	Utilization of private land for mainstreaming nature-based solution in the systemic transformation towards a climate-resilient Europe
MEL	Monitoring, Evaluation and Learning
M&E	Monitoring and Evaluation
NBS	Nature-Based Solution
NGO	Non-Governmental Organization
PES	Payments for Ecosystem Services
RCP 4.5	Representative Concentration Pathway
RO	Romania
SK	Slovakia
SMA	Soil Moisture Anomaly Index
SPI	Standardized Precipitation Index
UNFCCC	United Nations Framework Convention on Climate Change
UTCI	Universal Thermal Climate Index
WP	Work Package
WRF	Weather Research and Forecasting

Executive Summary

Deliverable 4.1 sets out strategies and implementation plans for Nature-Based Solutions (NBS) in six European Front-Running Regions: Euskirchen (Germany), Lafnitz (Austria), Upper Timiș (Romania), Krásná Lípa/ Bohemian Switzerland (Czech Republic), Roňava River (Slovakia) and the Delta Po (Italy). The objective of this work is to demonstrate how NBS can be strategically designed, adapted to local conditions and implemented in practice, with a particular focus on the integration of private land into systemic climate adaptation efforts.

The analysis shows that each region faces distinct climate risks, from floods, droughts and heat-waves to biodiversity loss, soil erosion and coastal hazards. In response, context-specific "no-regret" measures are considered and developed like tiny forests in urban Germany, agroforestry measures in Austria, reforestation in Romania, small retention ponds in the Czech Republic, water retention ponds in Slovakia and dune restoration in Italy. These interventions are selected not only for climate hazard-reduction potential but also for their multifunctionality, delivering co-benefits such as biodiversity enhancement, carbon sequestration, soil fertility, recreational opportunities and improved community well-being.

The main framework across all regions is the central role of private land. While public land offers opportunities for pilots and demonstration sites, systemic resilience cannot be achieved without the active involvement of private landowners, who own the majority of land in Europe. However, engaging them remains a challenge due to fragmented ownership, opportunity costs, competing economic interests and complex regulatory environments. Lessons from the strategies highlight that trust-building, voluntary agreements and co-design processes are essential to overcome resistance. Clear demonstration of benefits for landowners, alignment with agricultural subsidy schemes and adaptation policies and transparent, participatory governance frameworks all proved decisive for legitimacy and long-term success.

The deliverable also emphasizes the importance of embedding monitoring, evaluation and learning into implementation planning, even in projects with limited budget. By tracking both ecological and socio-economic indicators, regions can adaptively manage interventions, strengthen legitimacy and build an evidence base for replication. Cross-regional learning and knowledge exchange are equally vital, ensuring that approaches developed in front-running regions can inspire and guide replicating regions across Europe.

Overall, Deliverable 4.1 demonstrates that NBS are not isolated technical interventions but comprehensive, systemic approaches that integrate ecological restoration, social engagement and governance innovation. Through inclusive participation, policy alignment and strategic investment in capacity-building, NBS can progress from small-scale pilots to transformative, landscape-scale solutions. In doing so, they contribute not only to climate resilience but also to long-term ecological sustainability and the creation of stronger, more resilient communities across Europe.

Keywords

NBS, private land, landowner engagement, climate resilience, implementation strategies

1. Introduction

Climate change is one of the main global challenges. It manifests by e.g. increasing frequency and severity of extreme weather events and associated floods and droughts. These impacts present significant risks for ecosystems, communities and economies. Climate change disproportionately affects vulnerable populations and undermines the efforts for the sustainable development of our society. Considering these impacts, it is essential to develop resilience and adaptation to climate change.

Climate resilience requires close and effective collaboration between governments, communities, businesses and NGOs to implement adaptation and mitigation measures (UNFCCC, 2020). The UNFCCC presents a series of six pillars of climate resilience: raising awareness, assessing systemic risks, strategic implementation, mobilizing resources, monitoring progress and sharing knowledge. In Europe, changes in continental climates have caused extreme events with long-lasting effects (Dolejs et al., 2022). The EU Climate Change Adaptation Mission has prioritized systemic approaches, such as nature-based solutions (NBS). NBS leverage natural systems to reduce climate risks and support adaptation, while providing co-benefits (e.g. biodiversity conservation, ecosystem health etc.) (Raska et al., 2022).

Although NBS are multifunctional, these measures are slowly adopted due to limited impact assessments, a focus on public lands and ineffective land policy instruments that discourage the participation of private landowners. However, private lands have significant untapped potential for implementing NBS and delivering ecosystem services (Hartmann et al., 2019). Thus, land use policy reform is essential for promoting climate resilience.

To effectively mainstream NBS for climate resilience, real-life experiences of implementation need to be showcased. LAND4CLIMATE project aims to not only mitigate and strengthen the resilience of various European regions to climate change, through strategically implemented NBS, but also to set up a framework for widely spread and sustainable adaptation practices across Europe. To achieve this, large NBS projects will be co-designed, co-developed and implemented across the European continental biogeographical area. Deliverable 4.1 reports on the NBS strategy and implementation plans developed in six front-running regions (FRR): the County of Euskirchen in Germany (DE), the Lafnitz River catchment in Austria (AT), the city of Krasna Lipa and the nature reserve of Bohemian Switzerland in the Czech Republic (CZ), the region of East Emilia in Italy (IT), the upper Timiş River in Romania (RO)and the Rovana River basin in Slovakia (SK). These FRRs serve as living laboratories to draw lessons learned for successful NBS replication and upscaling in other regions such as the seven Replicating Regions involved in LAND4CLIMATE.

The NBS projects developed in LAND4CLIMATE aim to increase resilience of rural and urban landscapes in continental Europe to climate-related risks such as floods, droughts, forest fires, biodiversity loss and soil degradation. These risks are intensified by weather, seasonal changes and significant temperature changes characteristic of a continental climate, emphasizing the urgent need for efficient adaptation strategies.

The document is structured to provide a comprehensive analysis of the implementation strategies for NBS in six European FRRs, highlighting their role in increasing climate resilience. This approach is essential to capture the diverse ecological, social, economic and governance contexts of each region. This will ensure that these strategies are not only technically sound, but also locally relevant and socially acceptable. By examining a range of experiences and practices, the analysis will help to find transferable lessons, identify common challenges and effective solutions that can inform broader policies and practices.

Section 1 (Chapter 2) – Strategy and Planning for Implementing NBS presents both the conceptual foundation and practical steps for implementing NBS in developing regions. This section emphasizes planning-action-learning relationships. In this approach, strategic prioritization and stakeholder engagement are essential. The section shows how LAND4CLIMATE approach is to design non-regret NBS that respond to identified local challenges, are implemented in a collaborative manner and can be used as learning opportunities not only to inform broader policy integration and future adaptation strategies but also to serve as validated models for replicating regions

Section 2 (Chapter 3) – NBS strategies and implementation plans in FRR – provides detailed strategies adapted for some regions, presenting the challenges, solutions and operations strategies specific for each region. For each FRR, the document discusses:

- the environmental context and challenges (key climatic risks like floods, drought, biodiversity loss and urban heat)
- the vision and objectives (long term objectives for achieving resilience through NBS)
- implementation plans (detailed plans for NBS implementation)
- stakeholder engagement (approaches for involving local communities, landowners and policymakers to ensure the success of the initiatives)
- monitoring and evaluation (frameworks for assessing the performance and effectiveness of NBS interventions).

These elements are included for each FRR in order to provide context-specific NBS, addressing the specific environmental challenges and socio-economic conditions of each area. The environmental context and challenges sub-sections contribute to grounding the strategies in local realities, while the vision and goals provide direction and long-term ambition.

The implementation strategies translate these goals into actionable measures/ activities, supported by stakeholder engagement to foster local ownership and collaboration. Monitoring and evaluation ensure that the effectiveness of interventions can be measured, allowing for learning and adaptation over time.

The sets of measures/activities proposed in this section will serve as guides for FRRs, who can select and/or adapt various measures for implementation depending on the dynamics of local conditions.

The Conclusions section provides key messages and practical recommendations for decision-makers, practitioners and other stakeholders to improve NBS implementation and upscaling in building climate resilience.

2. Strategy and planning NBS implementation

An NBS implementation strategy is a structured approach that clearly emphasizes the steps, objectives and necessary resources to identify, design, implement and monitor NBS to address different specific issues of climate resilience. This involves an evaluation of local climate challenges, prioritizing interventions based on their efficiency, effectiveness and feasibility, stakeholders' engagement, strengthening stakeholder capacity to manage this type of project, securing necessary funding, monitoring the progress and implementing corrective adaptive measures according to necessity. An NBS strategy for climate resilience aims to maximize the benefits of natural ecosystems for enhancing the communities' and ecosystems' well-being while minimizing trade-offs.

In turn, an NBS implementation plan for climate resilience can be defined as a comprehensive roadmap that details measures for building resilience against climate change impacts. This plan defines the steps, objectives and resources needed to identify, design, implement and monitor NBS. This involves an evaluation of climate vulnerabilities, identifying the hotspot affected areas, selecting appropriate NBS, stakeholder engagement, securing financing, an efficient implementation of NBS projects, monitoring NBS efficiency and effectiveness and adjusting these measures based on ongoing evaluations. A plan aims to make operational and to leverage the strategy of natural assets to increase the resilience to climate change impacts, while promoting ecological sustainability and community well-being.

The main difference between a strategy and a plan lies in their scope and focus. A strategy is a broader framework or approach developed to reach long-term aims or objectives. A strategy involves developing plans and decisions at a high level aimed at guiding different activities towards a future state. The strategies are more general and conceptual, focusing on main directions and on principles that guide decision-making and resource allocation.

In contrast, a plan is a detailed description of the specific measures, tasks and steps needed to achieve a specific goal or objective. It provides a roadmap for implementation, clearly defining who will do what, whenand how. Plans focus on the tasks' execution for achieving defined results.

On the short term, while a plan defines specific activities and tasks for achieving short-term objectives, a strategy will establish the main direction and general principles for reaching long-term objectives.

The plans are more detailed and operational, while the strategies are more conceptual and provide guidance for decision making.

2.1 NBS implementation – from public to private land

2.1.1 Introduction

NBS have increasingly been recognized as essential instruments for tackling climate change impacts, biodiversity loss and urban resilience challenges (European Commission, 2015). Over the last decade, numerous EU-funded projects have advanced methodologies for planning, designing, financing and monitoring NBS. However, the majority of these experiences have been concentrated on public land and municipally managed areas. In contrast, Land4Climate project directly and explicitly addresses the crucial and underexplored dimension of NBS implementation on private lands. Thus, Land4Climate aims to bridge the gap between public-sector innovation and the fragmented, multi-owner landscapes.

This chapter provides a brief analysis on the transition from NBS implementation in public spaces to the more complex (and difficult to approach) reality of private lands.

2.1.2 Lessons from public land implementation

Horizon projects such as CLEVER Cities and URBAN GreenUP demonstrate how NBS can be embedded in urban regeneration strategies led by municipalities. In CLEVER Cities project, action labs in cities like London, Milan and Hamburg created co-designed public green spaces (like green roofs, noise barriers, lakeside regeneration) that were implemented with strong municipal leadership and co-financing. Similarly, URBAN GreenUP project developed NBS interventions catalogues for urban green spaces (e.g. public parks, squares and riverfronts), thus providing for decision-makers several practical references for selection and monitoring (URBAN GreenUP, 2022).

These initiatives highlight the relative advantages of public land:

- Legal authority for municipalities to act directly;
- Availability of public budgets or EU co-financing;
- Visibility and symbolic value of interventions in urban centers;
- Easier integration into urban planning frameworks.

However, these initiatives also underline several limitations in terms of scalability (which is restricted when interventions remain confined to public land) and opportunities (which for systemic landscape-scale adaptation are often missed).

2.1.3 Extending the focus to private land

NBS are increasingly promoted as sustainable and ecologically viable alternatives to conventional grey infrastructure. Yet, in contrast to engineered measures, NBS generally require larger areas to operate effectively (Bogdzevič, 2023; Hartmann, Slavíková and McCarthy, 2019). Consequently, questions of land availability, ownership and governance emerge as decisive key factors shaping their feasibility given that this land is often controlled by private actors rather than public authorities.

In many cases, the most appropriate sites for NBS (e.g. floodplains, wetlands, riparian corridors, or degraded areas like disused gravel pit) are located on privately owned land (Hartmann, Slavíková and McCarthy, 2019).

This creates governance and policy challenges. From a legal perspective, private property is protected from direct state intervention, thus preventing the authorities from imposing NBS measures without the private landowners' agreement. At the same time, policy instruments, financial incentives and collaborative mechanisms that would encourage voluntary participation by landowners are often missing, particularly in the context of flood risk management and climate adaptation. As Bogdzevič (2023) notices, “approaches for collaborating with private land users to realize risk reduction and adaptation measures on private land are lacking in theory and practice.” Moreover, much of the current NBS research is concentrated on urban or public contexts (e.g. green infrastructure for stormwater management or city greening projects) while the complexities of applying NBS in privately owned rural landscapes remain insufficiently studied (McPhearson et al., 2025; Pinto, Russo and Sudoso, 2025; Lavigne et al., 2024). In these contexts, landowners are frequently treated as passive recipients of regulation rather than as active partners in shaping sustainable landscapes. This gap reflects wider shortcomings in environmental governance, where policies rarely provide clear structures for co-design, co-management, or shared stewardship between landowners and public institutions.

Against this background, advancing NBS on private land is not only a practical imperative for addressing climate and water risks but also a governance challenge requiring new approaches to collaboration, legitimacy and long-term maintenance.

Achieving large-scale resilience therefore requires integrating private landowners into NBS strategies, even though this shift poses several challenges:

- Fragmented ownership and diverse interests of landowners;
- Unclear incentives for landowners to allow or maintain NBS;
- Regulatory gaps in integrating NBS into private land use;
- Long-term stewardship uncertainties, particularly once project-based funding ends.

Unlike public land interventions, NBS on private land require negotiation, compensation and hybrid governance mechanisms.

2.1.4 Frameworks for implementation

Several EU projects developed and provided transferable frameworks that can be adapted/ adjusted for private land contexts:

- Connecting nature framework: distinguishes three phases (planning, delivery, stewardship) each requiring attention to governance, finance, co-production and monitoring. For private lands, stewardship is particularly relevant, as ongoing maintenance must be co-organized with landowners.
- proGIreg implementation plans: developed "Living Lab" roadmaps in Dortmund, Turin, Zagreb and Ningbo that integrated technical realization, community involvement and business models. Based on this approach, private land NBS can be embedded into concepts and initiatives like landowner cooperatives or stewardship contracts.
- GrowGreen adaptation pathways: applied flexible roadmaps that sequence measures over time in Manchester, Valencia and Modena. This approach allows private land strategies to quickly balance land productivity with NBS gradual adoption.
- REGREEN de-paving and renaturing guidelines: this project emphasizes re-greening sealed land and achieving "net zero land take". These guidelines can inspire solutions for transforming underused or degraded private lands.

An effective private land integration also requires effective adapted governance and financing tools. Insights from several EU funded projects show that:

- Quadruple helix governance (government, academia, private sector, civil society) can be an effective tool but must be recalibrated to place landowners at the center (proGIreg, CLEVER Cities).
- Financing models should combine CAP subsidies, LIFE or cohesion funds, local tax rebates and payments for ecosystem services (PES), thus ensuring that the landowners are compensated for the public benefits of flood protection and biodiversity (GrowGreen, URBAN GreenUP).
- New business models (urban farming, agroforestry, ecotourism) can make NBS attractive to private landholders by providing direct income streams.

2.1.5 Key insights

The move from NBS on public land to NBS on private land represents a paradigm shift for European adaptation strategies. While public land interventions are easier to initiate and symbolically important, the transformative potential of NBS lies in engaging private landowners across fragmented landscapes. Land4Climate contributes to this frontier by bridging this gap and building on the methodological foundations of earlier EU projects and innovating around different regional challenges.

2.2 Strategic planning overview

NBS strategic planning is a crucial element of wider NBS implementation strategies. Its main aim aligns environmental resilience with sustainable development objectives. This planning process uses a systematic approach for selecting, designing and integrating NBS into different landscapes to approach the specific ecological, social and economic challenges. There is a need for a very good understanding of local context, careful allocation of available resources and active stakeholder engagement to ensure that the solutions are both efficient and sustainable.

The first phase of NBS strategy development implies a detailed evaluation of environmental conditions and specific vulnerabilities of the targeted area. This evaluation:

- includes an analysis of climatic data, biodiversity indicators, socio-economic factors and actual pressures on the environment;
- helps in identifying the most urgent environmental challenges;
- identifies NBS measures that can efficiently approach these problems.

In the second phase, strategic planning will prioritize stakeholder involvement and inter-sectoral cooperation. By involving relevant stakeholders, their different views and perspectives will be considered and the sense of ownership and engagement towards NBS measures will be promoted. Collaborative events (e.g. planning sessions, public consultations, workshops etc.) may facilitate this engagement and can act as platforms for interested parties to express their concerns, suggest changes and share local expertise that can further enhance NBS effectiveness.

In addition, integrating NBS into existing urban and regional planning policies is considered highly essential. This integration ensures that these are not isolated efforts but part of a cohesive approach for land-use planning, infrastructure development and environment conservation. Strategic planners will need to work closely with all relevant decision-makers to incorporate NBS in the legal and regulatory framework, thus securing long-term support and sustainability for these initiatives.

Finally, NBS strategic planning must include solid systems of evaluation and monitoring. These mechanisms are essential for monitoring the performance of implemented solutions, understanding their effectiveness and making data-driven adjustments in due time. By establishing some clear success metrics and by regularly evaluating processes against these benchmarks, the planners can ensure that NBS will continue to achieve their objectives and adapt to changing environmental, social and economic conditions.

Through a careful strategic planning process, NBS can be efficiently implemented to increase ecological resilience, offer significant environmental, economic and social benefits and contribute to more sustainable and viable communities.

2.3 Development of strategic planning

LAND4CLIMATE foresees a resilient European landscape where private landowners can play a significant role in stimulating climate resilience by a systemic implementation on multifunctional NBS. The project aims to change the approach of climate adaptation by integrating NBS innovative practices on private lands, ensuring that these measures are both efficient and sustainable, creating a resilient ecological network in European regions. This aim will be achieved by following the implementation strategy presented in Figure 1.

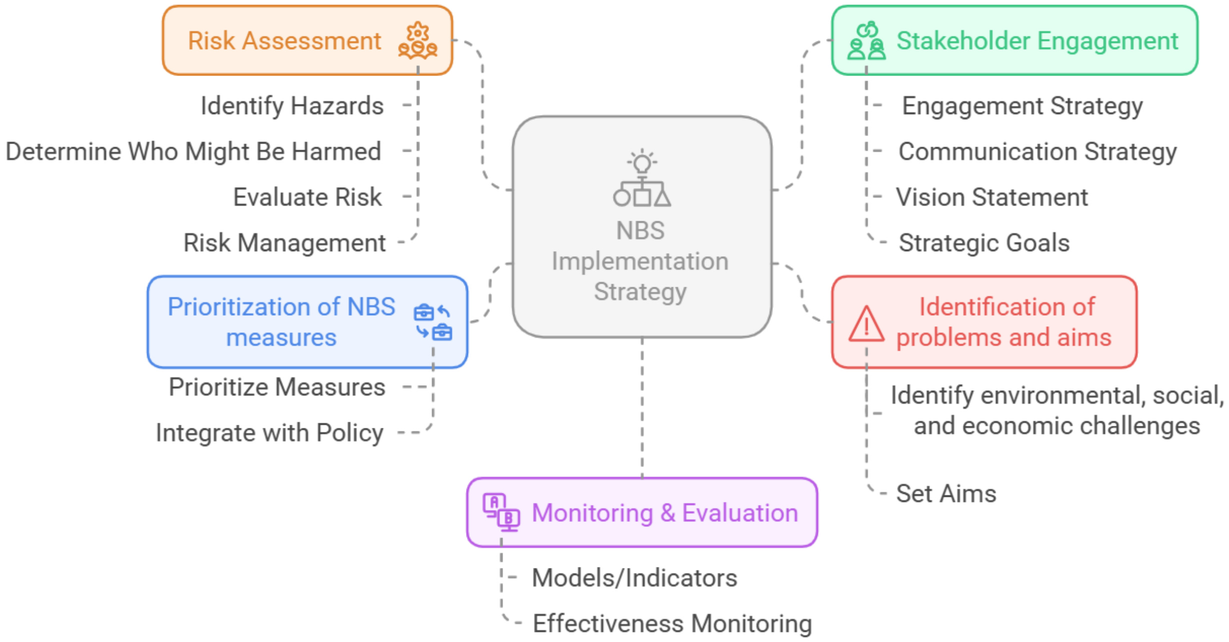


Figure 1 LAND4CLIMATE conceptual framework that outlines a five-step iterative process for the strategic planning of NBS implementation

2.3.1 Identification of the problem(s) and aims

The process of NBS development strategy starts with a detailed identification of the most pressing environmental, social and economic challenges in the targeted regions. This initial evaluation, closely aligned with the project results presented in *D1.3 – Climate risk analysis – front-running regions,* allows the identification of areas where NBS may have a significant impact, ensuring that the initiatives are strongly aligned with the local needs and opportunities (explored in *D1.1 – Future-oriented local climate adaptation scenarios – front-running regions, and D1.5 – Visualization of cause-effect relations and potential systemic effects – front-running regions*). The priority domains for NBS interventions are determined through a comprehensive evaluation of factors like environmental degradation, social vulnerability and economic potential. The findings from this evaluation and the stakeholder inputs are documented in D1.7 – *Report on stakeholder workshops on cause-effect relations and potential systemic effects – front-running regions*, and in D1.9 – *List of stakeholders' preferred no-regret NBS measures – front-running regions*.

The regions that are confronted with severe climate risks, such as floods and droughts, as well as the communities that are relying on natural resources, are of top priority. This targeted approach ensures that the efforts are sustainable and support the most vulnerable communities and ecosystems.

By finalizing the process of defining priority domains, the strategy establishes clear and specific, measurable, achievable, relevant and timely (SMART) objectives. Objectives include enhancing climate resilience through ecosystem restoration, promoting biodiversity, improving community wellbeing and fostering economic development through sustainable practices. These goals are crafted to encourage a holistic approach that integrates community input and scientific research, resulting in multifaceted benefits. Then objectives as well as the goals are discussed and detailed in *D1.2 – Knowledge exchange on future-oriented local climate adaptation scenario development for replicating regions, D1.6 – Knowledge exchange workshop on cause-effect relations and potential systemic effects for replicating regions, D1.8 – Knowledge exchange on stakeholder analysis in* *regard to cause-effect relations and potential systemic effects in replicating regions, and D1.10 – Knowledge exchange workshop on stakeholder-led no-regret NBS measures identification and evaluation for replicating regions.*

In LAND4CLIMATE project, academic partners will support the practice partners from each FRR in the identification of the key problem(s) and defining the resilience goal(s) for their respective regions. This strategic framework ensures that NBS initiatives are effectively tailored to address the identified challenges, promoting a sustainable and resilient future. By emphasizing local knowledge and targeting systemic changes, the strategy aims to develop robust ecological networks and vibrant communities that are well-prepared to deal with present and future climate challenges.

2.3.2 Risk assessment

The process of developing a strategy for NBS implementation requires first identification and understanding of the specific problems that the strategy must address or mitigate. This is critical for both the adaptation of NBS to local conditions but also to ensure that the proposed solutions are effectively aligned with both environmental challenges and community needs.

One of the most important reasons for both NBS development and implementation is the growing frequency and intensity of extreme weather events (e.g. floods, droughts and heatwaves) exacerbated by climate change. Urban areas, for instance, are projected to experience the effects of heat islands and flash floods due to increased impervious surfaces and insufficient green spaces. In rural regions, e.g. severe erosion and biodiversity loss threaten land productivity and ecological stability. Identifying these challenges requires a combination of data analysis, community consultation and expert input to evaluate levels of risk and vulnerability. In LAND4CLIMATE project, academic partners have deeply investigated the hazards associated with the problems identified for each FRR.

Deliverable 1.3 *Climate risk analysis - front-runner regions* (Holtkötter, et al., 2024) is focused on finding the potential impacts of climate-related hazards for different future scenarios in each FRR. The main objective of D1.3 is to identify and visualize climate risk hotspots within these FRRs and communicate the findings to project partners. D1.3 also provides a detailed overview of the data and methodologies that have been used to ensure transparency and traceability (Figure 2).

Figure 2 Systematic approach developed in D1.3 to understand and mitigate climate-related risks by focusing on hazard identification, exposure analysis and vulnerability integration (based on outcomes of D1.1)

The research process begins by approaching inherent uncertainties from the climatic projections as well as the socio-economic dynamics. Assessing these aspects involves a modeling approach to integrating actual and future climatic hazards scenarios with socio-economic and infrastructure changes. This approach creates a comprehensive area of opportunities for risk evaluations under different scenarios.

The methodology of risk assessment is structured around 3 main components: climate hazard, exposure and vulnerability. In LAND4CLIMATE, climate hazards involve the analysis of heavy rain, floods, heatwaves and drought, using specific indicators and scenarios. For heavy rain and floods, hazard assessments involve modelling scenarios with medium and low probabilities of occurrence, based on hydrological models and local maps for flood risk. Heatwave hazards are evaluated using temperature statistics, the number of heatwave days and the Universal Thermal Climate Index (UTCI), resulting from reanalysis and climate projections data. Drought hazards are evaluated using indicators like the Standardized Precipitation Index (SPI), Soil Moisture Anomaly Index (SMA) and potential evapotranspiration, including the diverse dimensions of water scarcity.

The risk component focused on exposure is addressing aspects related to land use and critical infrastructures. It involves the evaluation of different combinations of hazards and land uses (e.g. residential, agricultural, industrial areas etc.). Infrastructure is incorporated through spatial analysis using tools like ArcGIS Pro. The baseline and future land use scenarios are modeled using CORINE Land Cover data and planning documents, while infrastructure data are processed with standardized grids and buffers.

Vulnerability is analyzed by considering the sensitivity of exposed systems. Indicators include building density, population density and infrastructure capacity, with a focus on particularly vulnerable age groups like children and the elderly. Data are compiled and harmonized across regions to enable consistent assessments. Exposure and vulnerability data are spatially processed to generate a uniform grid, necessary to ensure comparability.

The climate risk is finally determined by combining hazard, exposure and vulnerability indicators. This methodological framework is thus able to provide a robust and transferable process for identifying climate risk hotspots in the FRRs. Through a spatially visualization of these risks, the assessment will define the foundation for targeted climate adaptation actions using NBS.

The full report about methodological approach of the climate risk assessment (CRA) in LAND4 CLIMATE including the future-oriented climate adaptation scenarios that are considered is included in Holtkötter et al (2024). Future-oriented local climate adaptation scenarios – front running regions (LAND4CLIMATE Deliverable 1.1).

By carefully identifying climate risk, we can design and implement NBS strategies efficiently and effectively. To plan the implementation of NBS to enhance resilience to climate change, evaluating the groups that may be affected by these interventions and the nature of those impacts is a crucial and mandatory step. This process not only helps identify vulnerable populations but also aids in adapting solutions to ensure they benefit all community segments without causing unintended negative consequences.

Vulnerable groups (e.g. low-income communities, the elderly, children, individuals with health issues) are the most exposed and face the greatest risks from climate change impacts. They also may suffer disproportionately from well-meaning interventions but poorly executed. As an example, new green or blue spaces development can increase property values and taxes in that area, finally having the potential to displace long-term residents who can no longer afford to live in those neighborhoods. Similarly, land-use changes aimed at enhancing biodiversity or reducing flood risks may lead to an access limitation to vital natural resources (e.g. farmland, forests) that local communities rely on for their livelihoods.

An assessment of the climate risks as they relate to the NBS interventions is a key component of the implementation strategy for how NBS will effectively strengthen climate resilience without doing more harm than good. The climate risks assessment maps, focusing on four key hazards (heavy rain, floods, heat and drought), provide details based on local conditions. The modelling process integrates many sources of information — such as official hazard maps, climate simulations, land use plans and infrastructure datasets — to understand the complex inter-relations of hazards such as heavy rainfall, floods, heat and drought. After performing CRA and identifying the climate risk hotspots, the next step consists in selecting appropriate no-regret NBS to address these risks. No-regret NBS are defined as measures that provide tangible benefits for ecosystems and local communities regardless of future climate scenarios or socio-economic developments. This process was initiated through collaborative and interactive workshops with local stakeholders. The workshops were structured into three main parts to ensure a systematic and participatory approach to NBS selection (Figure 3).

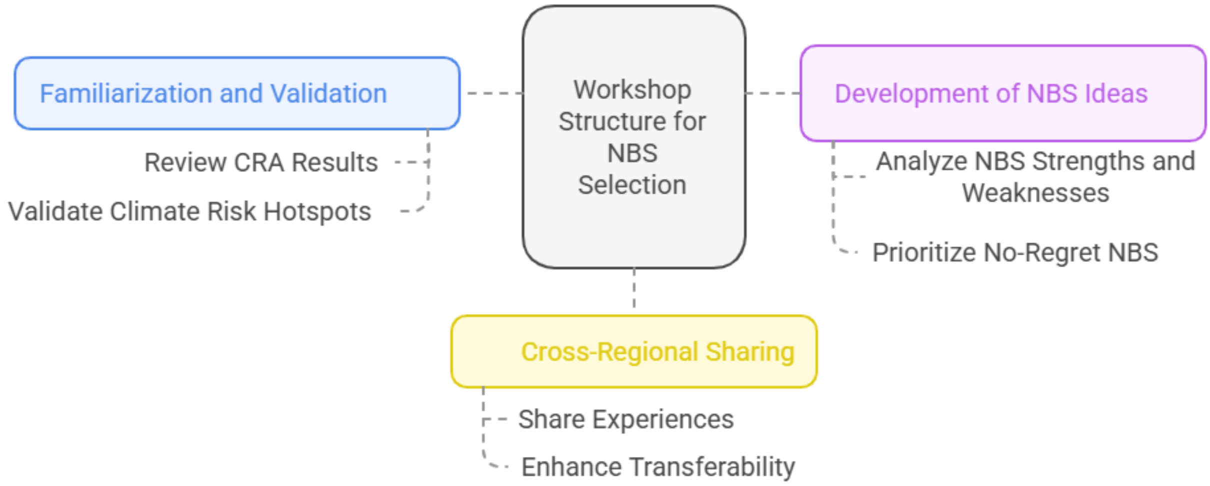


Figure 3 Structure of the 3 workshops organized under LAND4CLIMATE for NBS selection

The workshops developed in each FRR resulted in a comprehensive list of *no-regret NBS* tailored to the specific local climate hazards and risk hotspots. These measures are presented in *Deliverable 1.9 - List of stakeholders preferred no-regret NBS measures – Front-Running Regions* (Freyer, Holtkötter, Klopries, 2024).

CRA succeeded in providing a valuable evidence base for identifying these solutions. However, the local expertise and regional knowledge of participants collected during the workshops enabled a deeper understanding of strengths, weaknesses and implementation barriers for the selected NBS. This emphasizes once more the importance of stakeholder involvement in securing practical and regionally suitable solutions.

The workshop's outcomes also succeeded in providing a replicable framework for identifying no-regret NBS in other regions (replicating regions). For successful upscaling, it is stressed the need to combine the results of CRAs with the outcomes of stakeholder's expertise to deal efficiently with the local socio-environmental dynamics and successfully manage the implementation challenges. Through an effective integration of scientific assessments with stakeholder views, we can ensure that selected NBS are effective, practical, widely accepted, thus paving the way for enhanced climate resilience across regions.

The identified *no-regret* NBS serves as a strong base for subsequent analysis, focused on assessing the effectiveness and efficiency of NBS. In this phase, selected NBS measures are submitted to a modeling evaluation to assess their performance in mitigating climate risks at the identified implementation sites. The results of these evaluations, performed under WP2, are comprehensively presented in *D2.2 – Report on data requirements for biophysical and socio-economic assessment of NBS efficiency, D2.3 – Report on multi-scale numerical simulations of the performance of the NBS and D2.4 – Report on the assessment of potential co-benefits and trade-offs of the implemented NBS measures.*

2.3.3 Stakeholder engagement

The involvement of stakeholders is an essential part of the successful NBS strategy implementation and ensures that it will deliver the expected results. Engaging these stakeholders also helps ensure that the strategy being promoted is more broadly understood, accepted and supported within those specific communities. Effective stakeholder engagement consists of "bringing everyone on board", i.e. identifying all the groups affected by the project, such as government departments, local authorities, individual community members and environmental NGOs.

This NBS strategy part aims to actively involve these stakeholder categories in critical phases like NBS planning and decision-making so that they take responsibility for it themselves, thus fostering a sense of ownership and responsibility. At present, such practices are most used in the community level to fit in with actual conditions on the ground.
Engaging stakeholders should start from the very beginning of an NBS project and must be an ongoing process throughout the project life cycle.

This process starts with an analysis about the type of stakeholder engagement to plan. This can often be done by asking these questions:

- What is your aim/ objective when it comes to stakeholder engagement? What is its purpose in your NBS?
- Who are the main local stakeholders you have identified in your local project area?
- Why should they get involved and why do you want to get them involved?
- How will these stakeholders be engaged? What activities have you planned?
    - How will these local stakeholders stay informed/consulted/involved throughout the duration of the project? *If relevant*, How are you planning to incorporate their input?
- When have you planned these activities for?
- What challenges do you foresee with stakeholder engagement? How could we support you to overcome these hurdles?

This engagement process then involves comprehensive communication strategies which should be designed to give stakeholders some understanding of:

- why the project was set up,
- whatever benefits it hopes to bring them,
- how it will be put into effect.

This phase is often followed by an interactive one, which includes workshops, public consultations and meetings. These activities have the twofold effect of providing a forum for information exchange as well as gathering concerns and proposals from stakeholders which can then be analyzed. If public involvement is widely accepted within society through such inclusive practices, it helps to make the project's goals converge with those of local communities, thereby enhancing their legitimacy and support.

Continuous engagement with stakeholders also encourages local knowledge and expertise to be incorporated into NBS and making policies and actions more effective. Generally, local stakeholders have an updated and much better understanding of the ecology and social systems in their domain, representing an essential condition for planning out sustainable projects that match current conditions.

Involving stakeholders in monitoring and evaluation processes as well, ensures that the NBS project can be progressively refined or modified as the implementation develops and new risks or issues may begin to appear.

Overall, a good stakeholder engagement leads not only to more successful projects but also increases local resilience and a collaborative approach to managing the environment and adapting to climate change.

Developing a comprehensive stakeholder engagement strategy is essential for the success of any project, particularly those involving NBS that rely on community support and active participation. Figure 4 shows the key factors to be considered when developing an effective stakeholder engagement strategy.

Figure 4 Factors involved in the definition of a stakeholder engagement strategy

A short description of each factor involved in the stakeholder engagement strategy is provided as follows:

- Stakeholder identification: all potential stakeholders affected by the project are identified, such as individual community members, local and regional authorities, companies, NGOs and other special interest groups;
- Stakeholder analysis: the interests, potential impacts and attitudes of different groups of stakeholders towards the project are identified through a detailed analysis; based on this analysis, a stakeholder classification is performed based on 3 factors: interest, influence and the level of involvement required.
- Engagement planning: implies creating a plan that clearly defines objectives, tools and engagement activities which must be tailored to various stakeholder groups; the plan must include details concerning the activities to be developed, including e.g. timing, frequency and format (e.g. workshops, meetings, public consultations);

- Communication strategy: based on regular updates, information sharing (using transparent tools) through communication platforms should be aligned with stakeholder preferences.
- Building and maintaining relationships: establishing trust and maintaining relationships throughout the project lifecycle by being responsive to stakeholder problems/concerns, showing flexibility in addressing different issues, consistently delivering commitments, etc.;
- Feedback mechanisms: based on developing and implementing appropriate mechanisms for collecting and responding to feedback;
- Capacity building: providing training and nurturing capacity building based on specific stakeholder needs;
- Periodic evaluation – Regularly evaluating the effectiveness of the engagement strategy and making necessary adjustments is important. This includes monitoring both the engagement processes and outcomes to identify what is working and what is not. This can be done in quite a light touch way, for example, through short feedback questionnaires at the end of an event or after an interaction. Again, these feedback-loop mechanisms help foster a sense of belonging to the project and make stakeholders feel that their views matter, if these are then fed through to delivery or implementation of the NBS.
- Conflict resolution: incorporates efficient measures into the engagement plan to avoid escalating disagreements and prevent jeopardizing the successful implementation of the project.

Communication and dissemination strategy

The communication and dissemination strategy is carefully designed to increase the visibility and impact of NBS across various sectors and regions. The vision is to foster a widespread understanding and appreciation of NBS, promoting its adoption as a mainstream strategy for climate resilience and sustainable development throughout Europe.

NBS are fundamental for climate change adaptation and mitigation and the protection of ecosystems and are a central part of environmental management systems. This vision aims to create a robust knowledge-sharing environment where best practices and successful NBS models are easily accessible, enabling stakeholders at all levels to implement these solutions effectively.

The LAND4CLIMATE communication activities are divided into two levels: the overall project level and the FRRs as best practice demonstration sites. The third aim is to engage local communities and stakeholders, increase awareness of the project and NBS and to promote involvement in the regional initiatives. Site-specific communication needs and socio-cultural contexts of each FRR have led to the development of tailored, iterative communication plans. The plans need to support the design of tailored local communication initiatives as well as the organization of communication systems regarding planned interventions implemented in the FRRs. Accordingly, they serve as a compendium to the national NBS implementation plans.

Figure 5 illustrates the Strategic Goals for NBS dissemination and communication strategy, providing a roadmap for implementing, scaling and enhancing the impact of NBS initiatives. It is organized into six interconnected goals. All these goals and the methods to achieve them are explained in Table 2.

Figure 5 Strategic goals for NBS dissemination and communication strategy.

Table 1 Stakeholder engagement strategy: goals and implementation methods

Strategic goal	Specific goal	Implementation method
Showcasing effectiveness and adaptability	To demonstrate the practical effectiveness and adaptability of NBS in enhancing climate resilience and environmental sustainability. Reaching this goal involves highlighting successful NBS implementation on private lands that present major ecological, social and economic benefits.	Utilize case studies, impact assessment and success stories to illustrate the tangible benefits of NBS across diverse environmental and cultural landscapes.
Enhancing accessibility and transferability	Ensure that the knowledge and insights from various NBS projects are easily accessible and transferable, enabling replication across different European regions.	Comprehensive resource hubs development (e.g. online platforms, digital libraries) that provide tools, guidelines and methodologies for NBS implementation.
Raising awareness and building capacity	To increase awareness and understanding of NBS among stakeholders, including local communities, government entities and industry players,	Conduct workshops, seminars and training sessions tailored to different audiences. Leverage social media, newsletters and other media outlets to

	thereby building capacity for its broader adoption.	disseminate information and engage with a wider audience.
Fostering stakeholder engagement and collaboration	Cultivate active engagement and collaboration among all stakeholders involved in or affected by NBS projects to ensure that these initiatives are inclusive and aligned with local needs.	Implement participatory planning processes that involve stakeholders in decision-making. Set up regular forums and networks that facilitate dialogue and partnership among diverse groups.
Supporting policy integration	Advocate for the integration of NBS into local, regional and national policy frameworks to ensure sustainable and supported implementation.	Prepare policy briefs, conduct advocacy meetings with policymakers and participate in policy forums to highlight the benefits of NBS and the need for supportive legislation and funding.
Monitoring, evaluation and feedback	Continuous monitoring and evaluation of the effectiveness of the communication strategy to adapt and respond to emerging needs and feedback from stakeholders.	Utilize feedback mechanisms such as surveys and feedback forms at events, online analytic tools and engagement metrics to assess the impact of communication efforts and refine strategies accordingly.

More information about the communication and dissemination plans both at the FRR-level and overall project-level can be found in *D6.5 – Demonstration sites communication plans (Dorato, Firus, Giorgi, , 2024) and D6.1 - Communication and Dissemination Strategy – first version (Dorato, et al (2023).*

2.3.4 Prioritization of NBS measures

A very important part of strategic planning is the process of prioritizing NBS measures. The results of this process will provide the necessary framework to ensure that resources are efficiently allocated for addressing the most pressing socio-economic and environmental challenges. An effective prioritization of NBS measures is key for the impact of these initiatives and supports long-term sustainability and resilience goals.

Prioritization is an iterative process that needs to be reviewed regularly, considering that new research emerges, environmental conditions change, and community feedback is considered. This approach makes sure that NBS measures remain relevant and are effective at achieving the defined ecological and social objectives.

To systematically prioritize NBS measures, planners typically use a set of criteria, including the urgency of environmental issues, potential for large-scale impact, community vulnerability and the feasibility of implementation (Figure 6).

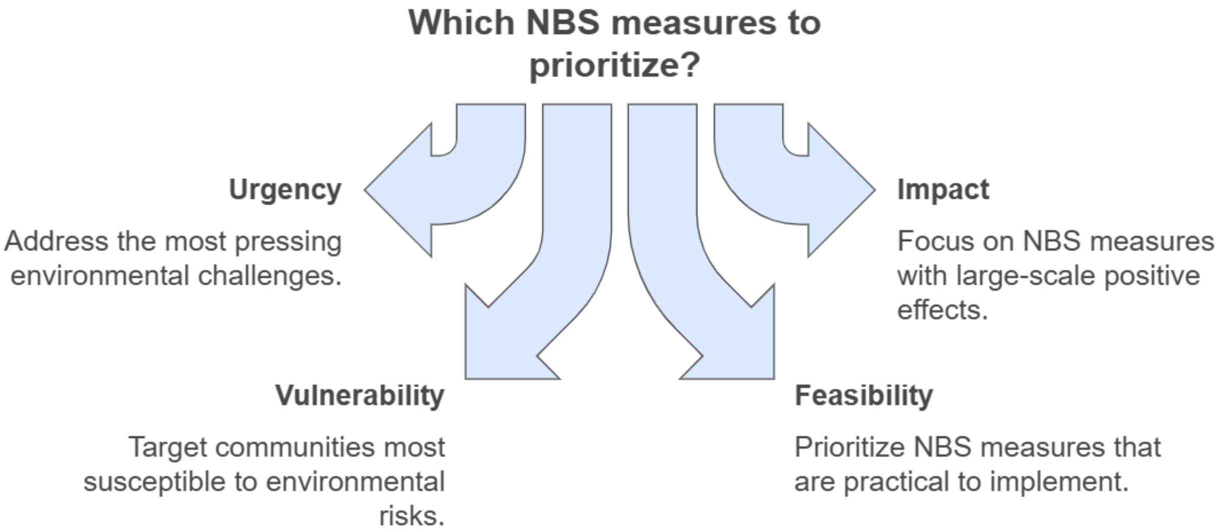


Figure 6 Factors to be considered in the prioritization of NBS measures

In LAND4CLIMATE, the identification of "no-regret" NBS was based on the specific context of each FRR. This prioritization was developed in a participatory and iterative process through workshops, stakeholder interviews, and a rigorous evaluation framework, the involvement of stakeholders being critical for the site-specific tailoring of NBS. Field and/or contextual interviews with local stakeholders revealed different levels of resolution among participants about feasibility, acceptability and barriers to potential solutions. Questions raised were about land use, economics and socio-political barriers. This process allowed for local knowledge and regional nuances to shape the prioritization process.

The evaluation framework of the proposed NBS was based on identified effectiveness, efficiency, legitimacy and justice as key criteria. The measures assessed were evaluated in terms of their effectiveness to reduce climate risks at hotspots, enhance co-benefits, and to achieve a favorable cost-benefit ratio. Finally, this framework ensures that the implementation of selected measures on private lands considers that the rights, concerns and responsibilities of private landowners are respected and fairly addressed.

Using a collaborative approach to prioritize the “no-regret” NBS for each FRR, to address different climate risks for each FRR ensured that the selected NBS not only contribute to climate resilience goals but were also aligned to local socio-economic and environmental contexts. This process, which combines scientifically based analysis with broader stakeholder opinions, serves as a model for other regions and highlights the need for effective and equitable climate adaptation approaches.

More details on how this prioritization process was conducted can be found in *D1.9 - List of stakeholders preferred no-regret NBS measures – Front-Running Regions* (Freyer, Holtkötter, Klopries, 2024)and *D3.1 – Guidance document of good institutional practices, success and limiting factors of NBS implementation (*Hartmann, Slavíková, Raška, 2024).

2.3.5 Monitoring and evaluation of NBS

Two crucial components in this process are monitoring and evaluation (M&E) of NBS aiming to strengthen climate resilience (Figure 7). M&E helps to ensure that investments are carried out in an efficient manner and lead to the expected environmental, social and economic benefits. To address this convergence of factors, we have brought together different professional perspectives within the

NBS community to highlight the impact of maladaptive approaches that can hamper NBS and raise awareness of the inevitable trade-offs and uncertainties inherent to NBS management.

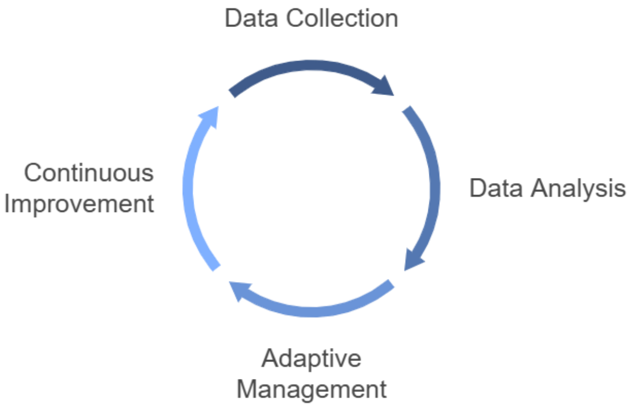


Figure 7 Monitoring and evaluation cycle for NBS.

M&E entails the routine collection of data on certain indicators used to measure the performance and impact of NBS projects. These indicators can involve improvements in water management and water quality, improvements in biodiversity, carbon sequestration rates, or enhancements in community welfare. To enable time-series based comparisons between projects and/or regions, data collection should be systematic and harmonized. Technologies like remote sensing, GIS mapping and community-based reporting can greatly support the effective and accurate collection of this vital information.

Evaluation consists of analyzing the data obtained to understand how the NBS initiatives are performing in relation to their stated goals. This process needs to assess the direct and indirect projects effects, including consequences on short and long-term period. Evaluations should take place at different points in time, during and after implementation. This approach will make it possible to track how change unfolds over time, identify any unintended consequences (or the absence of them) and highlight areas for improvement.

In addition, the lessons learned from M&E activities should provide feedback for the planning and implementation processes, improving the scalability and sustainability of NBS projects. By observing rigor in applying M&E, thus making NBS investments accountable and transparent, stakeholders can contribute to more resilient and sustainable communities. Such evaluations also strengthen the case for increased investments in NBS, by elucidating their value and effectiveness in addressing the impacts of climate change.

The LAND4CLIMATE proposal did not originally include M&E tasks and thus no specific budget has been provided for such activities. Yet, M&E is one of the vital components to be able to determine the effectiveness and impact of project interventions.

2.4 NBS implementation strategy roadmap adapted to private lands

This chapter presents an NBS implementation roadmap organized around several key elements:

- analysis of regional context and climate vulnerabilities
- definition of vision and goals
- identification of priority locations and NBS types
- assessment of efficiency and co-benefits
- integration with land policies

- considerations of legitimacy and justice.

The present roadmap also highlights mechanisms for stakeholder engagement, participatory monitoring and evaluation and eligibility criteria, thus ensuring that interventions are effective, legitimate and sustainable in the long term.

By following this structure, the strategy emphasizes the critical role of private land in scaling up NBS, also offering a practical framework through which landowners become co-implementers and long-term stewards of climate resilience, supported by financial incentives and recognition of the public benefits their land provides.

2.4.1 Regional Context and Climate Challenges

Understanding the regional context is very important when we intend to implement NBS on private land, considering that it is focused on a framework where natural processes intersect with human land uses. Landscape specifics and socio-economic conditions directly impact and shape landowners' willingness and capacity to adopt NBS. Climate vulnerabilities and risk hotspots emphasize where interventions are most urgent. For private lands, this NBS strategy component provides the evidence base to engage landowners by connecting climate risks directly to their lands and livelihoods.

This first section of NBS implementation strategy on private lands has the following components:

- Analysis of regional landscape specifics: Focus on landscapes dominated by private parcels (floodplains, riparian corridors, farmland, pastures). Mapping should integrate parcel-level land tenure data to reveal fragmentation and ownership patterns.
- Analysis of regional socio-economic specifics: Analyze the farm structures and how they depend on their livelihoods. This section should also approach the cultural attitudes on landownership, historical skepticism towards external authority and landowners' economic priorities like productivity, inheritance and income stability.
- Climate vulnerabilities analysis
- Highlight vulnerabilities where private land use intensifies risk
- Identification of climate risk hotspots: Identify private parcels overlapping with risk hotspots (erosion-prone slopes, flood retention zones, sealed rural yards etc.)

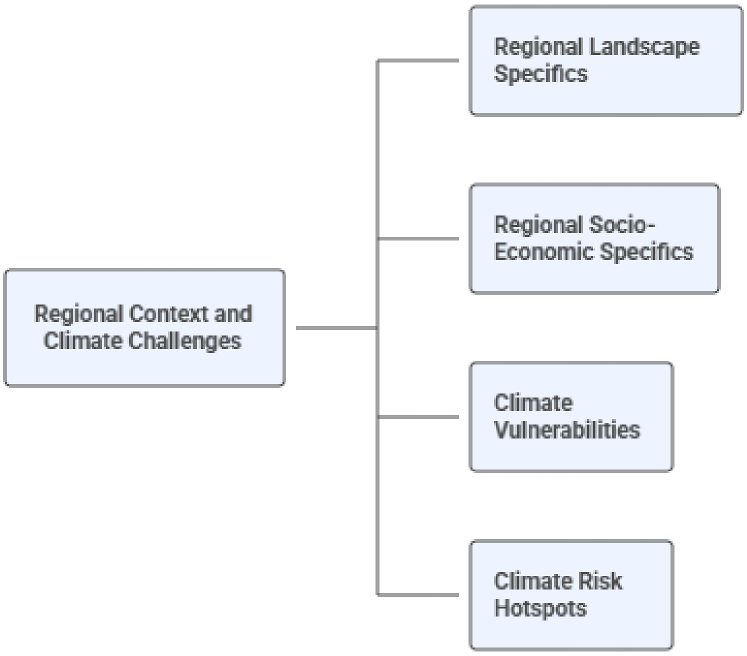


Figure 8 Key dimensions of regional context and climate challenges for NBS implementation on private lands

2.4.2 Vision, goals and operationalization

Ensuring that both public authorities and private landowners are working toward common objectives is based on a shared vision. Defining goals such as resilience, biodiversity restoration and fair compensation helps landowners see themselves as central actors in climate strategies. A clear operationalization of these goals provides practical guidance for how voluntary landowner action, financial incentives and cooperative governance can turn NBS from concepts into reality.

Structure:

- NBS strategy vision
- NBS strategy goals: These goals can support enabling voluntary adoption of NBS on private land, guaranteeing fair compensation and long-term maintenance support as well as establishing governance models where landowners co-decide.
- NBS strategy activities and topics.

This section can have a two-fold approach:

- Farm-compatible measures: buffer strips, hedgerows, agroforestry, small retention ponds etc.
- Landscape-scale measures requiring easements: floodplain reconnection, wetland restoration.

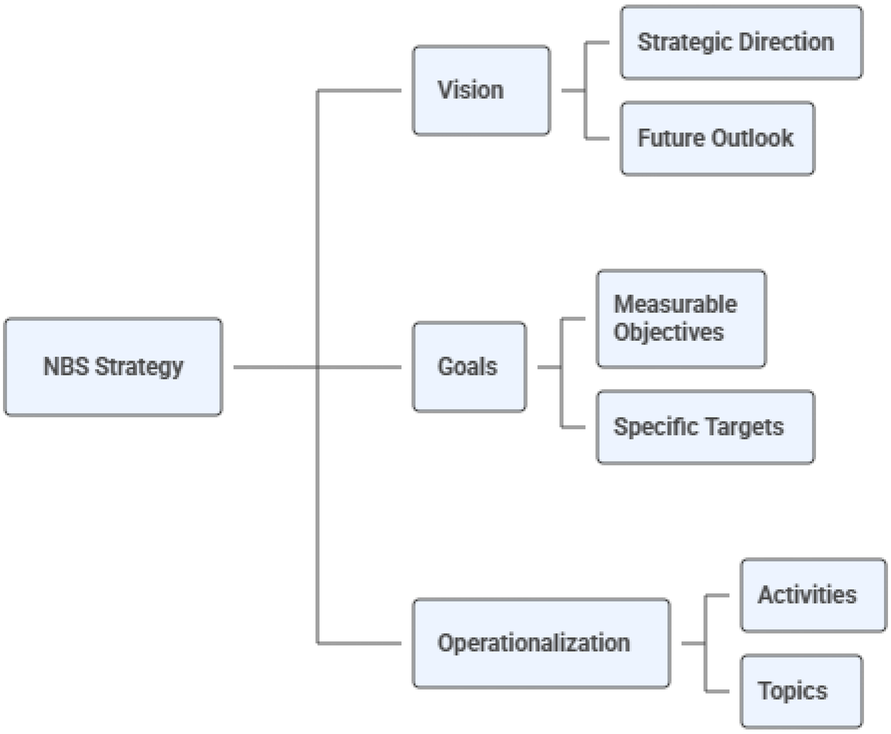


Figure 9 Implementing NBS strategy on private lands: vision, goals and operationalization

2.4.3 NBS location and identification

Identifying and selecting the proper locations are critical aspects, considering that private lands vary in ownership, productivity and risk exposure. Hotspot mapping and co-design with landowners identify where NBS can provide the greatest combined benefits. By justifying why certain sites are prioritized and comparing alternatives, this process builds landowner trust and ensures the legitimacy of interventions on privately owned land.

This section is based on providing answers to the following questions:

- How were the hotspots identified and prioritized?
- What is the justification for NBS location?
- What alternatives were considered for scale/ location?
- Which NBS have been selected?

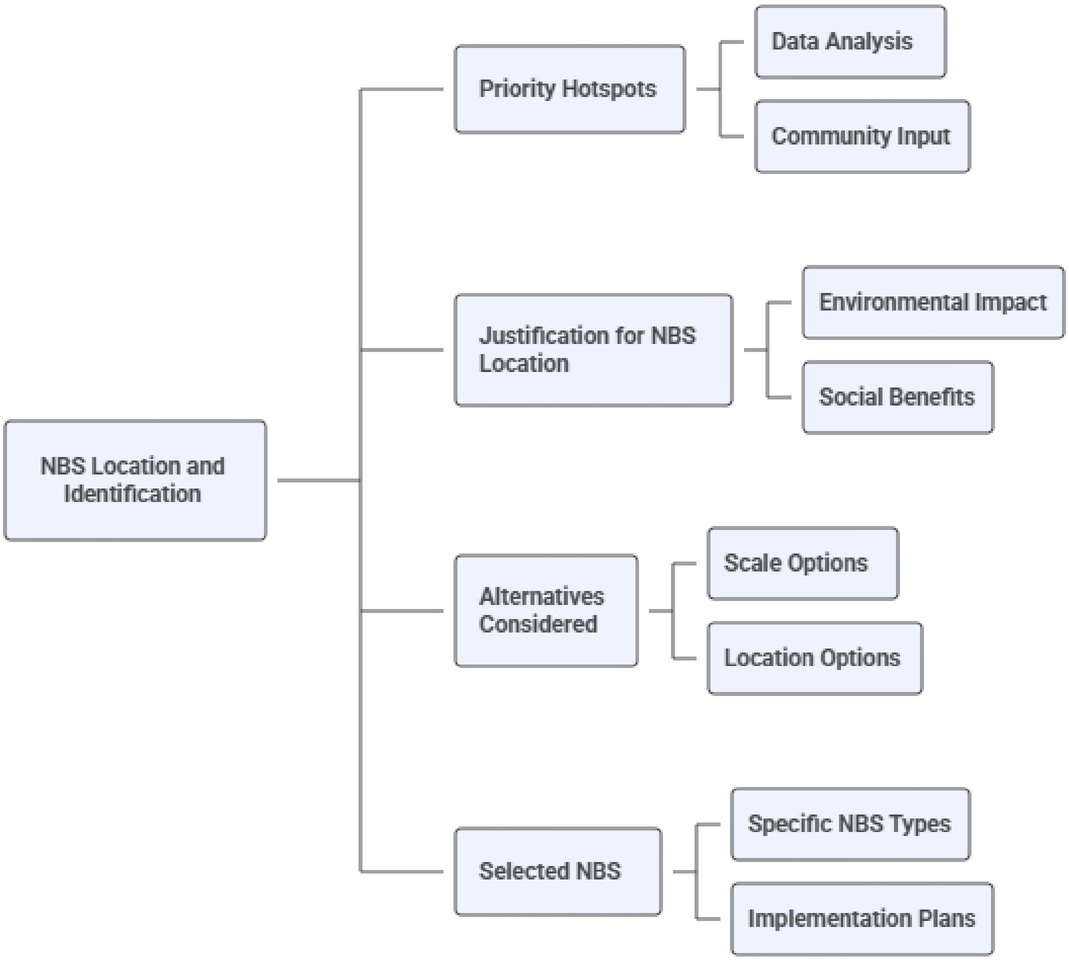


Figure 10 A practical framework for identifying and locating NBS on private lands

2.4.4 NBS efficiency and effectiveness

To convince the private landowners to adopt NBS, they must be confident that measures will work and generate benefits beyond ecological gains. Efficiency and effectiveness assessments show how NBS reduce climate hazards while also improving soil quality, crop yields, or property resilience. The consideration of performance indicators and co-benefits will help shifting the narrative from NBS as environmental obligations to NBS as opportunities that can serve both private and public interests.

In this strategy section, for each NBS type that has been selected in the previous section, several aspects/ questions must be addressed/ answered:

- Climate hazards addressed: e.g., riparian buffers against floods and erosion; ponds for drought mitigation etc.
- Evaluation process: combine hydrological modelling with participatory monitoring
- Performance indicators (e.g. flood peak reduction, soil organic matter, biodiversity scores, farmer satisfaction etc.)
- How does NBS mitigate the identified risks?
- Defining multi-functionality/ co-benefits (e.g. improved yields, diversified farm products, increased property resilience etc.)

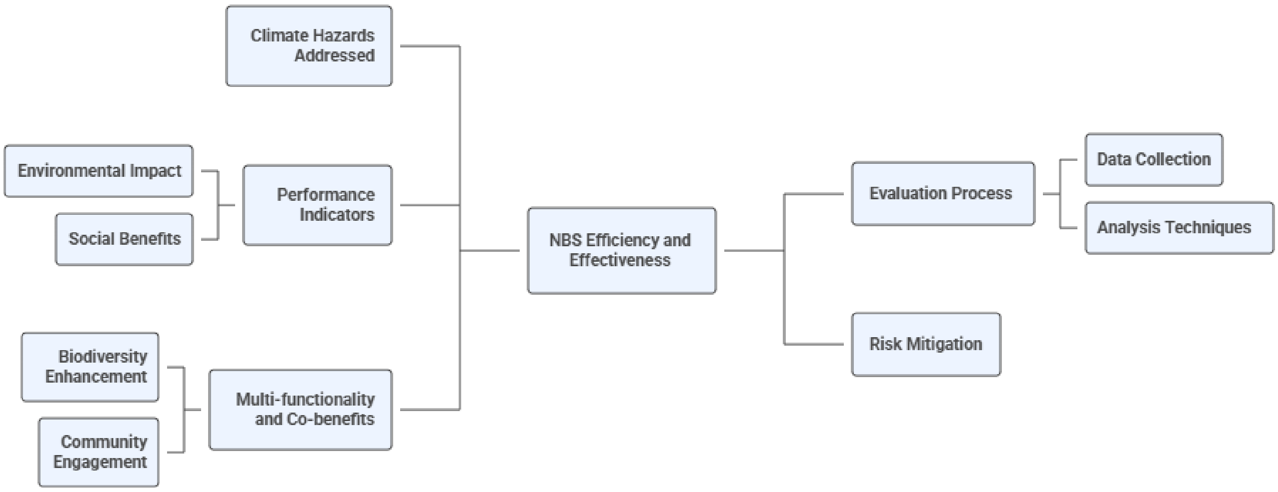


Figure 11 Framework for Evaluating NBS Effectiveness on Private Lands

2.4.5 Land policies and NBS implementation

Policies and planning tools are generally designed considering public land. For private land, instruments like CAP eco-schemes, PES contracts or easements can sustain voluntary adoption. By clarifying intervention types and potential impacts on land values, private landowners can be reassured that NBS will not undermine their property rights but can instead enhance the long-term value of their land and livelihood security.

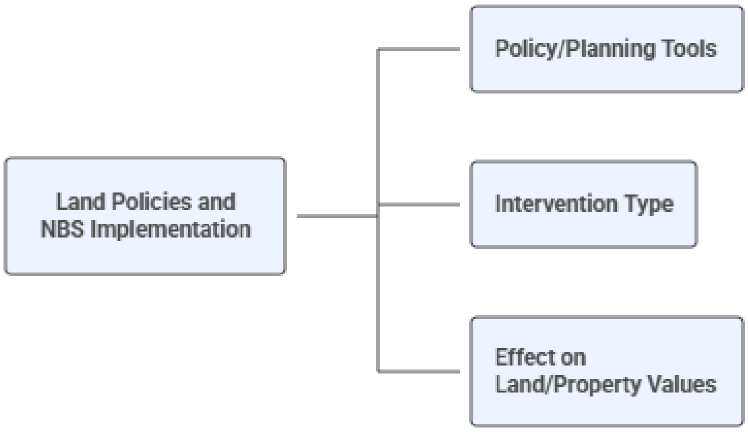


Figure 12 Policy and Planning Framework for NBS on Private Lands

For each NBS considered the following aspects should be considered in defining and implementing the strategy:

- Policy/ planning tools used: CAP eco-schemes, PES schemes, municipal hazard maps.
- Intervention type: voluntary contracts, conservation easements, cooperative agreements.
- Effect on land/ property values: may reduce value for intensive agriculture but increase long-term ecosystem service value, PES revenues and disaster protection.

2.4.6 Legitimacy and justice considerations

Legitimacy is critical and fundamental when we aim to implement NBS on private lands, especially where voluntary participation is non-negotiable. Input, throughput and output legitimacy are some key aspects that ensure landowners' genuine involvement, that decisions are transparent and that outcomes are both effective and fair. By carefully addressing justice dimensions, we can build trust by showing that private landowners will not bear disproportionate costs while others enjoy the benefits.

- Input legitimacy: landowners are involved in co-design workshops, contract drafting and pilot site selection.
- Throughput legitimacy: defining transparent rules for payments, contracts and monitoring results; use of trusted intermediaries (NGOs, farmer associations).
- Output legitimacy: effectiveness is measured not only in ecological terms but also in economic fairness and landowner satisfaction.

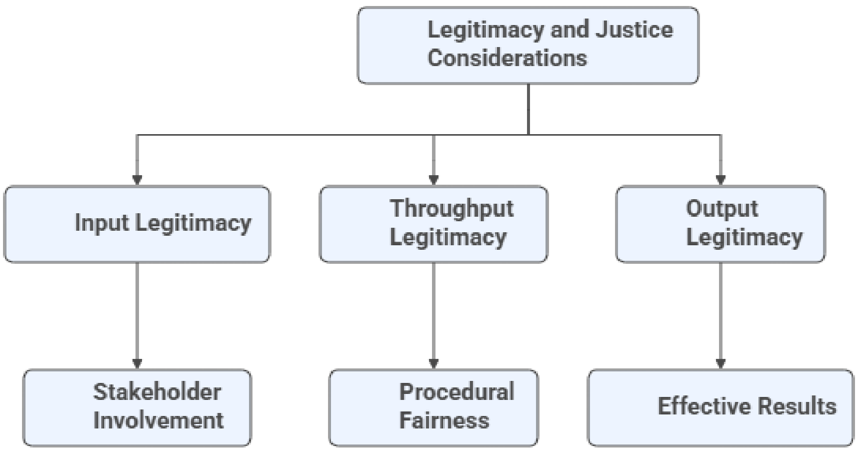


Figure 13 Framework for Assessing NBS Legitimacy on Private Lands

2.4.7 Stakeholder engagement

Engagement is the bridge between strategy and implementation. On private land, engagement goes beyond consultation. It is about forming lasting cooperatives, building trust and empowering landowners as co-decision makers. Using trusted intermediaries and peer-to-peer influence fosters credibility and helps overcome historical distrust of authorities, which is often a barrier to uptake.

The key aspects/ concepts that should be approached here are:

- From Land Stewardship Cooperatives to coordinate multiple smallholders.
- Rely on peer-to-peer influence (early adopters as ambassadors).
- Use farmer associations, church groups and NGOs to overcome distrust in authorities.

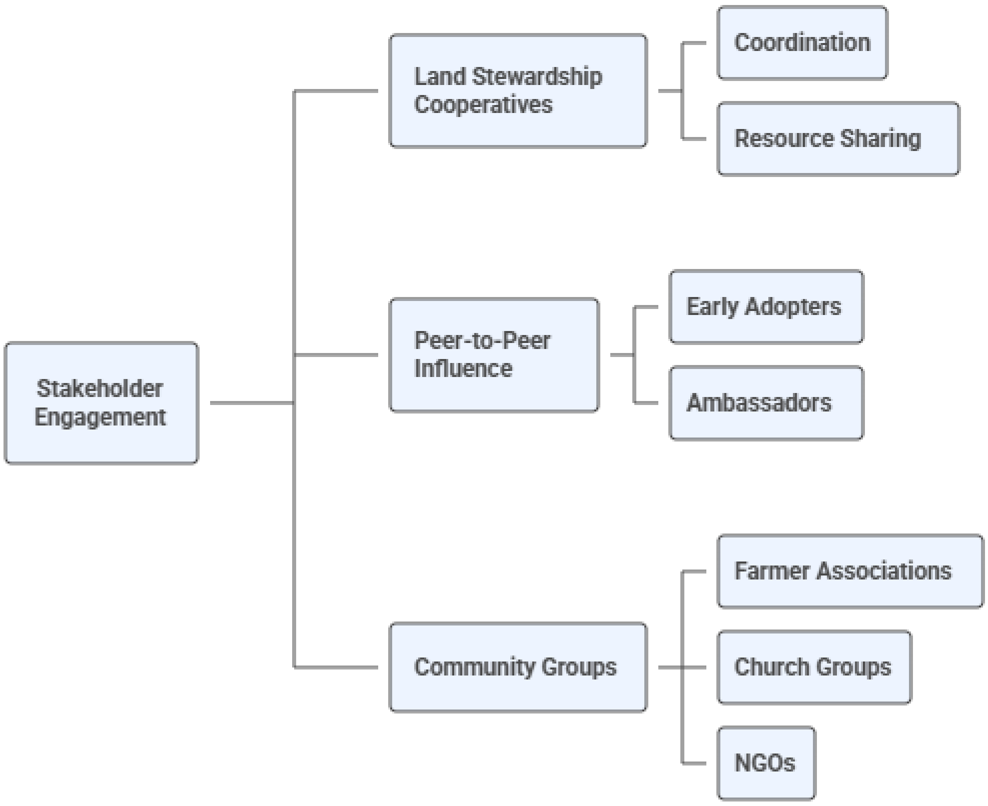


Figure 14 Stakeholder Engagement Framework for NBS on Private Lands

2.4.8 Monitoring, evaluation and learning (MEL)

Monitoring is critical for proving that NBS on private land deliver expected results. MEL framework will ensure accountability, track ecological and socio-economic outcomes and build adaptive feedback loops. For private landowners, transparent monitoring will ensure that agreements are fair and that benefits are tangible. Reflexive learning allows adjustments over time, making NBS strategies flexible and responsive to landowner needs.

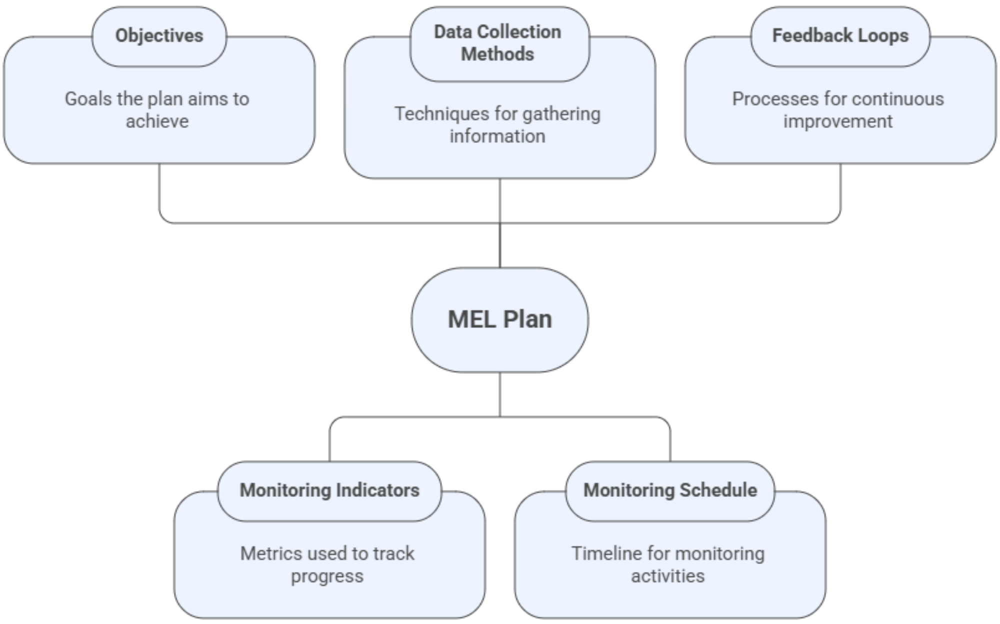


Figure 15 MEL framework for NBS on private lands

This section is based on defining the following:

- MEL objectives - to ensure that NBS deliver resilience benefits while remaining attractive to private landowners.
- Monitoring indicators (e.g. hydrological, ecological, socio-economic, governance etc.)
- Data collection methods - can combine expert assessments with private landowner self-reporting.
- Monitoring schedule/ evaluation
- Feedback loops - the contracts and incentives can be adapted based on monitoring results and landowner feedback.

2.4.9 Eligibility Assessment

In this strategy section, NBS proposals are evaluated against five private-land criteria:

- Location (addresses aspects like land suitability, risk relevance, etc.)
- Effectiveness (focused on proven ecological/ hydrological impact)
- Efficiency (ensures a fair cost-benefit balance for private landowners.)
- Legitimacy (based on voluntary landowner consent).
- Justice (ensures a fair distribution of costs/ benefits across the community).

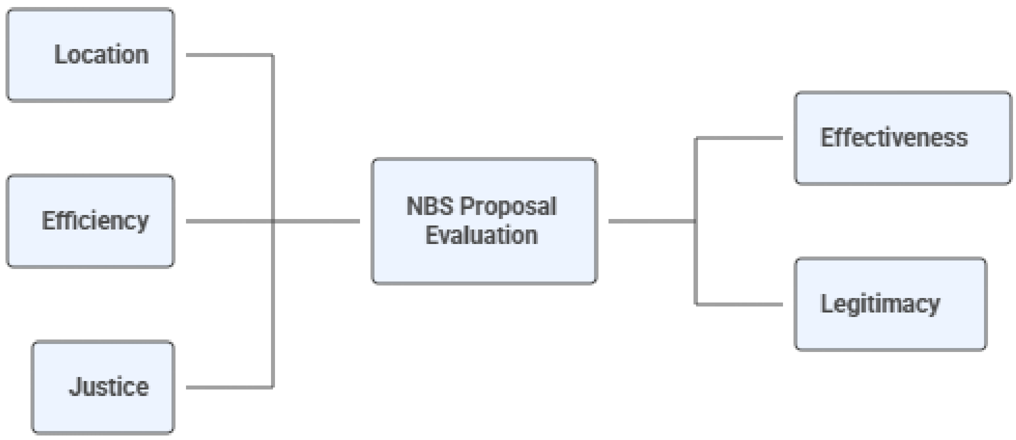


Figure 16 Criteria for evaluating NBS proposals on private lands

Eligibility analysis needs to create transparent rules to decide which NBS projects can and should move forward. On private land, this approach ensures fairness in selecting sites, distributing incentives and managing expectations. Evaluating location, effectiveness, efficiency, legitimacy and justice makes the decision-making process clear to landowners, reducing suspicion and increasing willingness to participate.

2.4.10 Key general messages

- Scaling NBS requires unlocking private land potential.

- Trust, fairness and incentives are as important as technical design.

- Private landowners must be treated as co-implementers and long-term stewards, not passive recipients of regulation.

- Stable financing (CAP, PES, cooperatives) and transparent governance models are essential for success.

NBS implementation on private land shows that scaling these solutions depends on critical factors like trust, fairness and adequate incentives together with a sound technical design. Private landowners must be approached and considered as co-implementers and long-term stewards, supported by transparent governance arrangements and stable financing. Each regional strategy reveals some specific features that should be translated into key messages for potential replicators in similar areas. These include key factors like local traditions, cultural values, levels of education and awareness, distinctive landscape characteristics and the broader political or institutional environment. Together, these context-specific factors model how NBS can be successfully adopted and maintained on private lands. They also offer practical lessons that have the capacity to go beyond technical replication and address the realities of local governance and community life.

3. NBS implementation strategy in FRR

This section is developed based on the analysis of NBS strategies and implementation plans developed in similar projects at European level.

The strategy was also built on the results generated in work packages 1 (WP1) and 2 (WP2). WP1 provided relevant results on local climate change adaptation scenarios, identified climate risks, cause-effect relationships and stakeholders' preferred "no-regret" NBS measures. WP2 provided relevant contributions on an ex-ante evaluation of the efficiency and effectiveness of selected no-regret NBS measures to be applied on private lands in the FRR regions.

These evaluations provided an important framework for understanding the anticipated impact of NBS interventions and contributed to establishing strategic priorities.

The development of this strategy is also based on the results of direct consultations with FRR representatives, who contributed with local expertise, contextual information and specific priorities. These interactions ensured a deeper understanding of the real challenges and opportunities existing at local level.

The strategy was designed in close coordination with the activities carried out within WP3, which developed key, essential documents containing relevant contributions on the institutional framework, barriers and enabling factors in the implementation of NBS, as well as the existing support mechanisms at the regional and national level.

This correlation allowed the integration of the practical and dynamic dimension of the implementation, ensuring coherence and relevance between strategic planning and concrete application.

In the development of the NBS Strategy and Implementation Plans, WP6 – *Communication, dissemination, networking and joint activities* also played an important role, facilitating dialogue between regional authorities, local communities, regional networks, private landowners and the public, and contributing to raising awareness of the value of NBS in promoting climate resilience.

This effort was essential for anchoring the strategy in a framework of shared understanding and social support, thus supporting the acceptance and effective implementation of NBS in practice.

Section 3 proposes an integrated strategy, based on scientific knowledge, applied assessments and dialogue with local actors, to ensure the efficient and transformative implementation of NBS in the pilot regions.

3.1 NBS strategy for Euskirchen County, Germany

3.1.1 Regional context and climate challenges

The district of Euskirchen has set out the goal in its climate adaptation strategy that it will be climate-resilient and well prepared to deal with the increasing climate risks by 2030. In doing so, the strategy is based on a holistic approach that says equal consideration must be given to the interests of environmental protection, nature conservation, the social security of citizens and the functioning of the county as a business location. Furthermore, the strategy demands that climate change adaptation measures should also serve climate protection and must not conflict with it.

In a nutshell the district of Euskirchen and its municipalities intend to pursue the following climate impact adaptation goals by developing and implementing measures:

People

- Raising awareness among politicians, businesses and the general public about climate adaptation issues and how to deal with the challenges
- Protecting the population from heat stress and extreme weather events

Environment

- Preserving agricultural and forestry land, cultural landscapes and natural landscapes
- Increasing the resilience of cultural landscapes and natural landscapes to extreme weather
- and other climate-related influences
- Reducing additional stress factors for ecosystems
- Creating corridors and biotope networks
- Ensuring water availability and preserving and expanding natural retention Infrastructure
- Protecting and securing water resources (groundwater and surface water), including for drinking water supply
- Climate-adapted infrastructure planning, e.g., by ensuring decentralized infiltration
- (sponge city) or adapting materials used in road construction
- Risk prevention and mitigation in infrastructure (energy, transport, wastewater, etc.)
- Reduction of flood risk during heavy rainfall events

Structures

- Strengthening and continuing cross-agency and cross-municipal cooperation on climate adaptation
- Exchange of experience on successfully implemented measures
- Climate adaptation as a cross-cutting issue in district and municipal administrations

Strategies and measures for adapting to climate change should be permanently anchored in the district of Euskirchen. For the long-term success of municipal adaptation to the consequences of climate change, the continuous interaction of various local social power centers is crucial, i.e., non-profit and professional actors and networks that are relevant to the cross-cutting issue of municipal climate change adaptation.

The district of Euskirchen can build on existing and long-established cooperation structures.

- Cooperation with the towns and municipalities belonging to the district is institutionally anchored and bindingly regulated in many areas (e.g., urban land-use planning, administration, etc.). But beyond that, cooperation structures have also been formed that can be used for collaboration in the area of climate change adaptation.

- In the area of climate protection, based on the integrated climate protection concept from 2012, a wide range of cooperation has developed within the administration, but also with associations and other committed citizens.

Moreover, the district of Euskirchen developed an integrated sustainability strategy that combines ecological, social and economic goals as part of the “Global Sustainable Municipality in North Rhine-Westphalia” project carried out from 2019 to 2021 in a broad participatory process. The topics of the sustainable district development are to be understood as a cross-cutting task, which means that there is cooperation with many departments of the district administration. The 2030 Agenda with its 17 Sustainable Development Goals (SDGs) forms the basis for the strategic framework. The SDGs touch on all policy areas, from economic, social, environmental and financial policy to agricultural and consumer policy, as well as areas such as transport, urban development, education and health.

The district of Euskirchen has set out to align district development with the goals of Agenda 2030 and thus develop it sustainably.

LAND4CLIMATE goals to mitigate climate risks through nature-based solutions align with the goals defined in Euskirchen's climate adaption strategy as well with the topic area 3 of its sustainability strategy: Resource conservation & climate change adaptation.

More specifically LAND4CLIMATE aims to create resilient agricultural and urban environments able to endure environmental stressors and future productivity. NBS measures will enhance the capacity to deal with the effects of climate change by adding carbon sequestration through projects like the "Tiny Forests", as well as the planting of carbon-eating crops like miscanthus in agricultural land.

Table 2 German FRR brief description

Location  Figure 17 German FRR location map
Climate Euskirchen County experiences a temperate climate, marked by moderate rainfall and temperature variations, typical of the North Rhine-Westphalia region. The area is subject to the influences of both the Atlantic climate from the west and continental patterns from the east, which can lead to varied weather conditions throughout the year.
Soil The region features two distinct soil types due to its topographical variation. The northeastern part, the Zülpicher Börde, is primarily composed of deep, calcareous loess deposits formed during the last Ice Age, which are highly fertile and well-suited for agriculture. Opposing, the southwestern part, the Eifel, is characterized by an hilly terrain and diverse geology, including

Devonian rocks, red sandstone and volcanic formations. This geological diversity leads to a variety of soil types, such as brown soils, podzols, gleys and pseudogleys, which are generally less fertile than those in the Zülpicher Börde, leading to a landscape dominated by forests and grasslands.
Topography Euskirchen is divided into two main topographical areas: the low mountain range of the Eifel in the southwest and the flat farmland of the Zülpicher Börde in the northeast. This diversity influences local climate conditions and land use patterns.
Land Use The county is predominantly rural with significant agricultural activity, especially in the Zülpicher Börde, which is part of the productive Lower Rhine Bay area. The Eifel area is largely covered by forests and is less densely populated.
Population Euskirchen has a total population of approximately 199,000 inhabitants, with the largest towns being Euskirchen and Mechernich. The population distribution is uneven, with higher concentrations in the urban centers and sparser populations in the Eifel region.

LAND4CLIMATE ecological objectives in Euskirchen also include promoting biodiversity and resource conservation. NBS measures aim to enrich local biodiversity (based on planting dense clusters of native and beneficial species) and creating habitats that support a wide variety of wildlife and facilitate ecological connectivity. Alongside these efforts, strategies for improved soil conservation and water management will also be implemented. This includes using plant species known for their soil-enhancing qualities and integrating innovative rainwater infiltration systems to reduce flooding risks and improve water quality.

In addition, the LAND4CLIMATE project actively promotes community engagement and sustainable development. Through initiatives like this, residents will get involved, take ownership of their local assets and change their own behavior towards sustainability. In parallel to this community involvement, efforts are being made to develop sustainable agricultural practices and urban development strategies that minimize environmental impact while ensuring that it is economically viable. By educating and raising awareness in the community, local people will get involved in protecting the environment to ensure Euskirchen not only reacts to the effects of climate change but thrives because of adaptive management and greater accountability during the life of the project.

Climate vulnerabilities

The County of Euskirchen, located in an area subject to extreme climate change, is increasingly challenged by global warming. Euskirchen’s topography and land use patterns make it particularly vulnerable to various climate hazards, such as severe floods, persistent droughts and rising urban heat. These challenges disrupt natural ecosystems, infrastructure, agricultural practices and urban planning efforts.

Key climate-related hazards and risk assessment

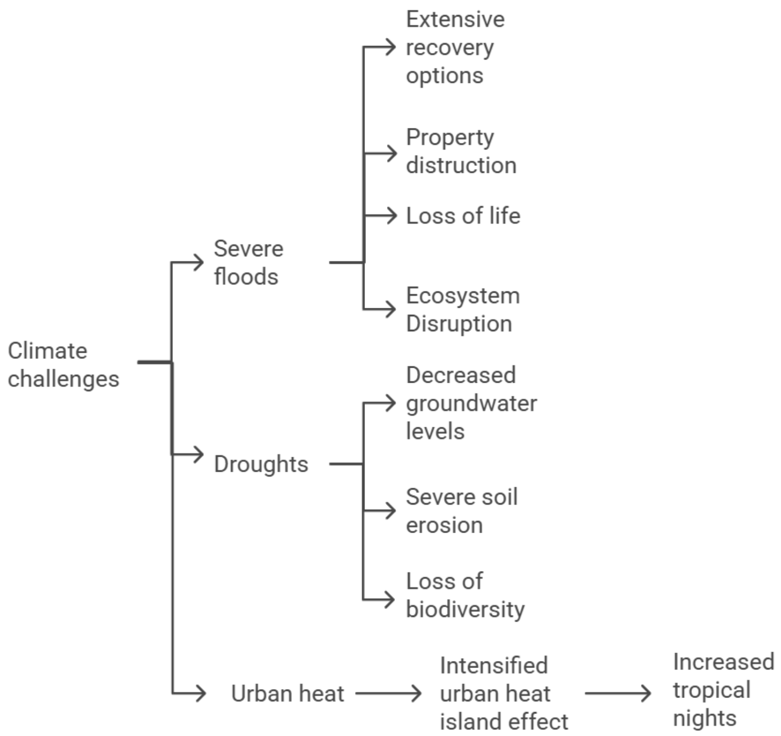


Figure 18 Climate challenges in Euskirchen: the cascading effects of climate challenges

Table 3 Climate risk assessment in Euskirchen.

Hazard	Risk assessment		
	People	Assets	Environment
Flash floods	Very high risk	Very high risk	Very high risk
Drought	Moderate risk	High risk	High risk
Urban heat	High risk	High risk	High risk
Heat waves	High risk	High risk	High risk

(blue)	No risk	(green)	Low risk	(yellow)	Moderate risk	(orange)	High risk	(red)	Very high risk

The Euskirchen case study highlights the severe consequences of flash floods, droughts, urban heat and heatwaves, each posing significant risks to people, assets and the environment (Table 4).

Table 4 Summary of climate and main consequences in Euskirchen

Flash floods	Drought	Urban heat	Heat waves
- 2021 flood caused 27 fatalities; - Major infrastructure, housing and agricultural damage. - Drainage systems failed due to excessive water volume. - Severe environmental impacts: soil erosion,	- Moderate risk to people; worsened by urban heat islands. - High risk to assets and environment: decreased agricultural productivity, soil dehydration. - Infrastructure suffers material degradation, water shortages.	- Driven by urban heat islands and more frequent tropical nights (>20°C). - Elevated health risks for vulnerable populations. - Healthcare system under strain. - Degradation of infrastructures, cooling	- Significant health risks for the elderly, children and individuals with pre-existing conditions. - Rural and urban populations impacted. - Deepens socio-economic gaps. - Amplifies drought and soil degradation;

biodiversity loss, water quality impairments.	- Long-term environmental damage: soil erosion, biodiversity loss, declining groundwater.	costs rise, energy systems stressed. - Biodiversity and soil health decline; requires urban greening and heat-adaptive design.	raises infrastructure costs. - Roads and buildings deteriorate under extreme heat. - Groundwater depletion and biodiversity loss threaten long-term ecology.

The challenges and risks affecting Euskirchen FRR ask for a dynamic and proactive approach to climate adaptation. By understanding these risks and mobilizing effective measures, Euskirchen can become a model for other regions facing similar climatic threats, contributing to broader efforts to combat the adverse effects of climate change.

Identified climate risk hotspots

Based on the exposure to multiple climate-related hazards and specific socio-economic vulnerabilities, the County of Euskirchen has been identified as a significant climate risk hotspot in the LAND 4CLIMATE project. The Climate Risk Analysis (Deliverable 1.3) identifies three major threats for the region: heatwaves, droughts and flood events, all of which are predicted to intensify, both in frequency and severity, as a result of climate change (Deliverable 1.1).

Urban and peri-urban areas (which include a greater proportion of sealed surfaces relative to vegetation) are particularly at risk of experiencing heat stress and pluvial flood risk. The catastrophic flood from 2021 revealed how vulnerable both residential and critical infrastructure are, particularly in low-lying and river-adjacent areas. Farmland on sloped land is prone to soil loss and water shortages during the hot summer months, these risks being enhanced by socio-economic factors.

The identified hotspots were prioritized for the identification and localization of NBS interventions, ensuring that NBS measures provide targeted support to the most urgent spatial and systemic vulnerabilities of the region.

3.1.2 Vision and goals

LAND4CLIMATE initiative in Euskirchen aims for a balanced relation of people and nature and is based on new plans and nature-oriented measures. This ideal doesn't just aim to mitigate the impacts of climate change but also to create a sustainable ecosystem for future generations. The initiative integrates different policies and traditional practices and will define Euskirchen as a best practice for how localized efforts can contribute in the climate resilience efforts.

Community participation in environmental management is at the heart of this vision. The establishment of a platform to engage relevant stakeholders assures that nature-based initiatives take the local conditions into consideration and ensure strong support from the community. This ensures that the proposed solutions are aligned with the specific needs of Euskirchen and there is support for their implementation. All in all, the vision aims to make Euskirchen area a much greener and prosperous area, being a role model in development sustainability and proving that a well-thought-out plan for climate-proofing with a long-term focus will result in great ecological, social and economic values.

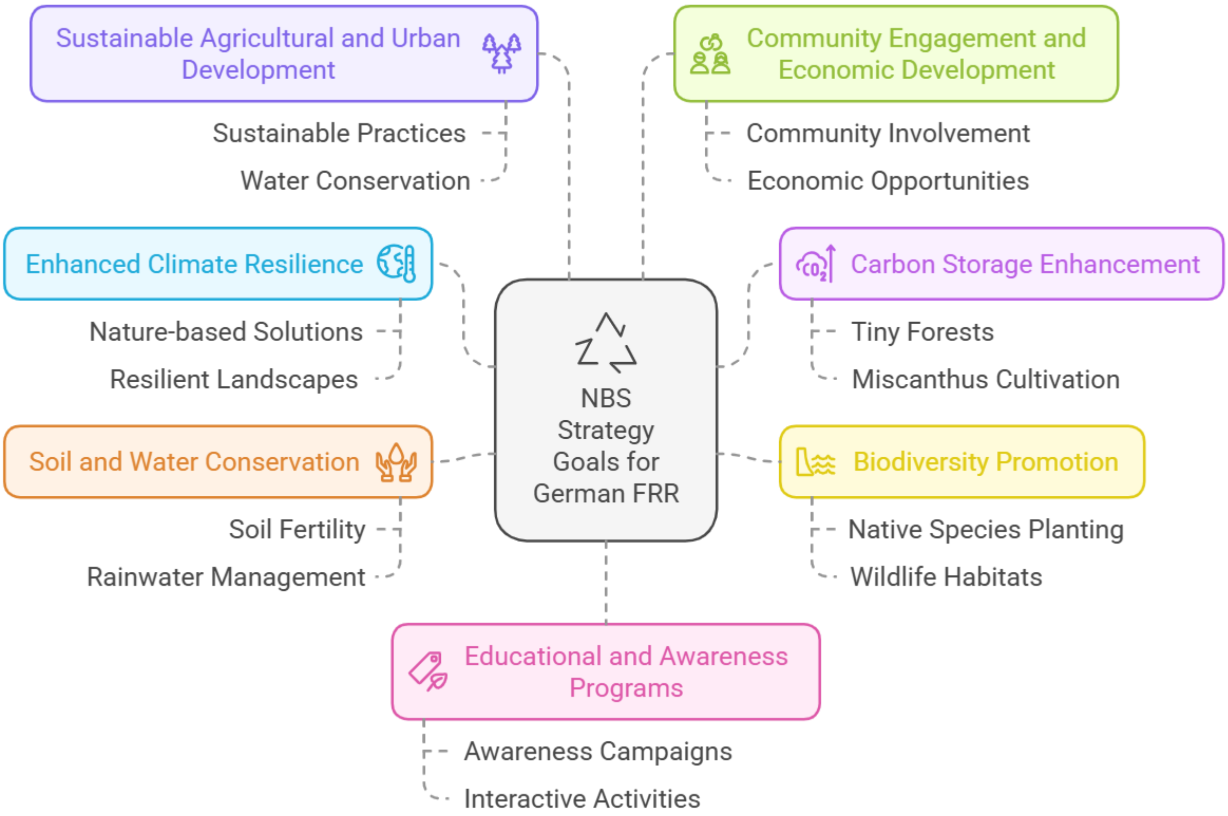


Figure 19 NBS strategy goals for Euskirchen outlining key objectives and action areas to enhance environmental sustainability and resilience.

Table 1 Key aspects of Land4Climate NBS strategy operationalization in Euskirchen

Activities	**Topics**
Implementation plans: adopting plans for NBS.	Community engagement: integrating practices with local community involvement
Workshops: organizing sessions for community input and planning	Local alignment: ensuring actions meet climate resilience goals.
Education campaigns: prioritizing awareness and education on sustainability	Partnerships: developing strong ties with local stakeholders.
	Ownership: fostering community ownership through workshops.
	Sustainable agriculture: implementing eco-friendly farming practices.
	Ecological health: aligning farming with environmental well-being.
	Culture of sustainability: fostering resilience and sustainable practices.

By these efforts, the LAND4CLIMATE project wants to show how local activities can contribute to global climate targets and promote Euskirchen as an example of best practices.

3.1.3 Identification of non-regret NBS measures

The non-regret NBS in Euskirchen County were identified and selected using a participatory and evidence-based workshop that combined climate risk analysis with stakeholder expertise. This workshop was organized during the third consortium meeting of LAND4CLIMATE in Timișoara, Romania and used a methodology that allowed local and regional stakeholders to validate the results of the CRA, to prioritize regional and collaboratively select specific NBS interventions to address specific climate hazards hotspots such as heatwaves, droughts and pluvial flooding.

The selection process involved a workshop organized on several phases. In the first phase, stakeholders worked with spatial data tools and ArcGIS dashboards to locate and confirm climate risk hotspots. This validation step ensured that scientific assessments were based on the real-world experiences of local actors.

The second phase focused on linking those hotspots with targeted NBS options. Drawing from Deliverable 1.5, participants analyzed and evaluated potential NBS measures (climate parks, tiny forests, bioswales, rain gardens) based on aspects like feasibility, multi-functionality, social acceptability etc.

The term "non-regret" was at the core of the selection process, emphasizing NBS that are able to generate net positive outcomes across different future climate scenarios, without imposing negative trade-offs. Stakeholders considered each NBS option against a matrix of ecological benefits, implementation barriers, land ownership dynamics and expected socio-economic co-benefits.

The result was a regionally anchored portfolio of non-regret NBS for the German FRR that aligns with both spatial risk profiles and local preferences. This process reflects the LAND4CLIMATE principle of integrating scientific modelling with participatory governance, ensuring that the selected measures are both technically sound and publicly legitimate. The outcomes of this workshop directly informed the implementation strategy presented in this chapter.

Table 2 Overview of stakeholder-selected no-regret NBS measures for climate risk hotspots in the German FRR

How were priority hotspots identified?	Multi-criteria CRA - Hazard data - Exposure analysis - Vulnerability indicators	The urban zones with high-density housing and limited green space, emerged as climate risk hotspots to heatwaves, heavy rains and floods.
What is the justification for NBS location?	Selected locations were based on: - Overlay of climate risk maps and socio-economic vulnerability - Stakeholder-driven decision-making - Voluntary land access	The justification is both risk-driven and legitimacy-driven, balancing climate needs and stakeholder cooperation.
What alternatives were considered for scale/ location?	- Green roofs - Large-scale green corridors - Other areas	These options were identified and finally rejected by the stakeholders due to: - High costs - Technical complexity - Legal barriers - Low impact in terms of risk and social vulnerability - Reduced feasibility due to fragmented urban ownership patterns - potential conflicts with existing land uses
Which NBS have been selected?	- Climate parks - Tiny forests - Miscanthus - Bioswales	These NBS were selected for their optimal combination of feasibility, impact and social equity.

	- Rain gardens	

3.1.4 NBS effectiveness and efficiency

In LAND4CLIMATE, an integrated assessment methodology has been developed to evaluate the performance of selected NBS in mitigating hydro-meteorological hazards such as heatwaves, droughts, floods and salt-water intrusion. This methodology was originally developed under the OPERANDUM project and has been adapted for LAND4CLIMATE to assess NBS across five components identified in Table 5.

Table 3 Methodologies/ approaches used to assess NBS effectiveness and efficiency in Euskirchen

Methodologies/ approaches	Description
Hazard reduction	Evaluates the direct effect of NBS on specific hazards using actionable and impact indicators.
Co-benefits assessment	Identifies indirect environmental, social and economic benefits.
Risk assessment	Integrates hazard, exposure and vulnerability using normalized indicators to identify climate risk hotspots.
Cost-benefit analysis	Assess the cost-effectiveness of interventions across life cycles, including the use of cost-effectiveness ratios.
Public acceptance evaluation	Focused on understanding stakeholder engagement, legitimacy and the drivers/barriers of NBS perception and mainstreaming.

A well-defined indicator library outlining indicators against broad thematic areas (i.e. hazard reduction, co-benefits, risk components (exposure and vulnerability) and social acceptance) has been developed. These indicators encompass both quantitative (e.g., reduction of air temperature, biodiversity index, coverage of early warning systems) and qualitative (e.g., trust in implementers, perceived legitimacy) measures.

The assessment methodology is based on modeling (e.g. ENVI-met, WRF, HEC-RAS etc.) to predict NBS effects on existing conditions and future climate scenarios through RCP 4.5 and 8.5 (2031-2060). This involves a multi-step workflow that encompasses the selection of the variables, evaluation of the performance indicators, etc., but maintains consistency with the CRA (WP1), allowing for long-term tracking and scalability. This methodology also includes social dimensions of NBS interventions, acknowledging procedural justice, community empowerment and transparency as critical for successful delivery and replicability.

Table 4 Synthesis of integrated assessment methodology and indicators for German FRR

NBS	Climate hazard	Evaluation process	Performance indicators
Tiny forests	Heatwaves	The methodology employed to assess this intervention integrates climate risk data, stakeholder input, environmental modeling (ENVI-met and BIO-met simulation tools to quantify microclimate regulation benefits	Actionable variables: vegetation structure, surface roughness, evapotranspiration rates. Impact variables: reduced ambient temperatures, heat stress and related health burdens.

		(especially temperature reduction) across three time horizons: baseline, mature (5 years) and fully grown (20 years)) and cost-effectiveness analysis.	

More details on the integrated assessment methodology results are provided in *Brogno, L. et al. (2025).* Report on the modelling and monitoring methodology and NBS performance indicators *(LAND4CLIMATE Deliverable 2.1).*

Table 5 Synthesis on NBS effectiveness, multifunctionality and expected co-benefits

NBS	**How does the NBS mitigate the risks?**	**Multi-functionality and expected co-benefits**
Tiny forests	- Mitigate heatwaves - Reduce flooding risk by increasing infiltration in compact urban spaces - Contribute to soil stabilization, especially in disturbed or compacted sites	- Enhance urban biodiversity by creating small ecosystems - Act as living labs and education spaces for schools and the public - Strengthen community stewardship through participatory planting - Visually enhance underutilized land - Improve neighborhood aesthetics and environmental identity

Tiny forests: Co-benefits and trade-off analysis

Tiny forests were assessed as part of the built environment NBS in Germany. The evaluation considered their contribution to climate resilience, particularly in relation to heat mitigation and pluvial flood reduction.

Table 6 Tiny forests: co-benefits and trade-offs

Dimension	Co-benefits	Trade-offs
Environmental	- Enhance biodiversity and microhabitats - Improve air quality - Carbon storage - Soil health and groundwater recharge - Urban cooling and flood mitigation	- Require land space in urban areas, competing with alternative land uses
Social	- Recreation and aesthetic improvement - Education and awareness spaces - Strengthen community well-being	- Possible conflicts with urban planning priorities (e.g., parking, housing)
Economic	- Indirect property value increase	- High initial establishment and maintenance costs

	- Reduce long-term costs (cooling, flood damage)	

For more details on these analyses, please visit *Schindelegger, A., Thaler, T. (2025). Assessment of co-benefits and trade-offs of NBS (LAND4CLIMATE Deliverable 2.4).*

3.1.5 Alignment of NBS implementation with land policy

Table 71 Assessment of Alignment Between Proposed NBS Measures and Existing Land Use and Spatial Planning Instruments in the German FRR

NBS	Policy/ planning tools used	Intervention type	Effect on land/ property values
Tiny forests	- Implemented on an underutilized private land - Voluntary participation - Co-designed with the community - No formal acquisition - Collaboration agreements and participatory planning processes	- performance-based - Encourages co-maintenance	- Improves urban microclimate, biodiversity and aesthetic quality - Can reduce development potential - increase social and environmental value - Can enhance the surrounding property desirability

Table 82 Tiny forests implementation plan

Tiny forests implementation roadmap	
Phase	**Activities**
Feasibility study and site selection	Conduct environmental and topographical assessments to identify areas susceptible to heatwaves, heavy rainfall and soil erosion. Select underutilized or vacant lands within residential zones that can be converted into tiny forests. Collaborate with urban planners to ensure the integration of tiny forests into the existing landscape without disrupting the urban fabric.
Design and planning	Engage environmental scientists and landscape architects to design dense, multi-layered forests that mimic natural ecosystems. Plan for biodiversity by selecting a mix of native tree species that thrive in local conditions. Include pathways and educational signage to enhance the recreational and educational value of the forests.
Community engagement and stakeholder involvement	Conduct community workshops and meetings to gather input, raise awareness and foster a sense of ownership among local residents. Establish partnerships with local schools, environmental NGOs and community groups to support ongoing educational programs and volunteer involvement.
Implementation and planting	Organize community planting days to encourage participation and reduce labor costs. Implement a phased planting strategy, starting with foundational species and gradually adding understory and ground cover layers.

	Ensure proper soil preparation and initial care to facilitate successful forest establishment.

3.1.6 Legitimacy and justice considerations

Implementing NBS on private lands requires a legitimacy and justice analysis to secure long-term success and stakeholder support. Their design and execution require technical feasibility, strong social acceptability and procedural integrity. LAND4CLIMATE followed a participatory and transparent approach to maximize legitimacy from multiple angles.

This subsection evaluates the legitimacy of these interventions through three different dimensions:

- input legitimacy (the extent to which stakeholder involvement is participatory and inclusive)
- throughput legitimacy (about whether decision-making is procedurally fair and transparent)
- output legitimacy (assessing if the interventions are producing, or should produce, effective results)

These points of view together provide a nuanced picture of the extent to which the NBS interventions are just and accepted in the local context of the considered FRR.

Table 93 Overview of legitimacy and justice considerations in the implementation of NBS in the German FRR

Tiny forests			
Dimension	participatory	procedurally fair	effective results
Evaluation	Yes	Yes	Expected
Explanation	Co-designed with local communities Emphasis on civic engagement, education and volunteering	Transparent communication with participants Agreements were clear but non-restrictive Emphasis on community ownership and long-term stewardship	Provides urban cooling, biodiversity and green space Strengthens neighborhood identity and environmental education

3.1.7 Stakeholder engagement

In the NBS co-production, stakeholders' and beneficiaries' involvement is very important to ensure that the strategies and solutions are scientifically solid and culturally appropriate, thus improving their effectiveness and sustainability. This process critically depends on private landowners. First, citizen surveys should be conducted, enabling citizens to present their opinions and wishes concerning local climate adaptation measures. This step generates baseline data and will set the conditions for NBS design and implementation phase. Organized workshops and face-to-face meetings will provide a pertinent platform for community stakeholders to contribute with ideas that may affect the planning process and deployment of NBS once in the local context. These interactive formats enable ownership among participants and ensure that the solutions are very closely adapted to local needs and conditions.

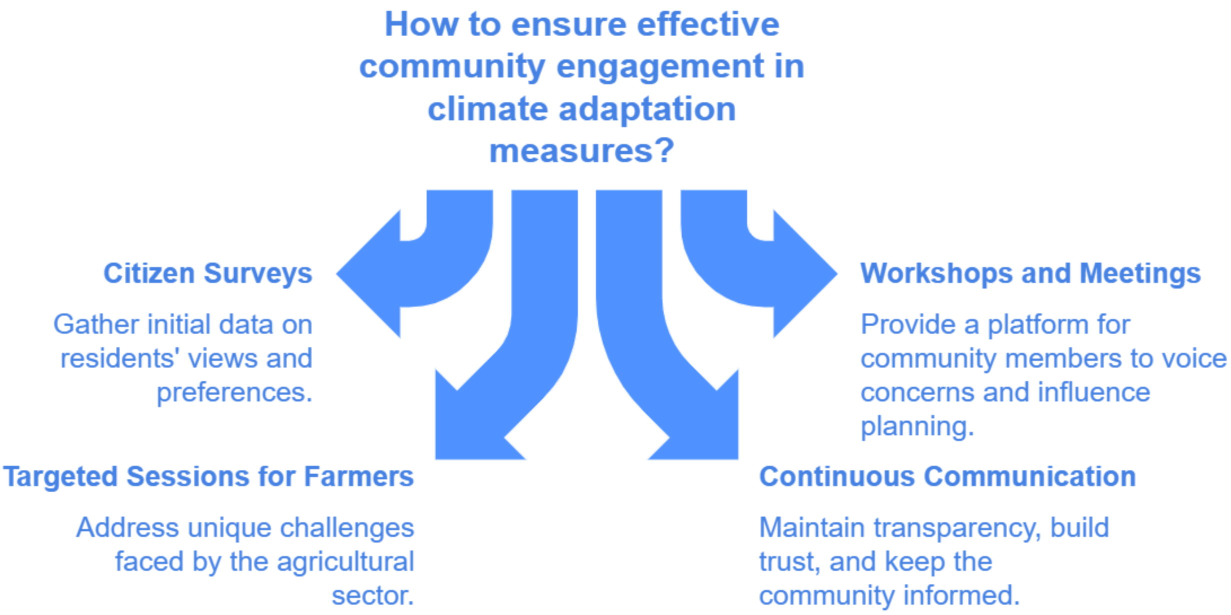


Figure 20 This figure outlines key strategies, including citizen surveys, targeted farmer sessions, workshops and continuous communication, to ensure inclusive and transparent community involvement in climate adaptation measures in Euskirchen county.

Communication is key to keeping everyone involved. The progress and impacts of climate adaptation measures should be shared through social networks and other modes of communication. This ongoing information exchange can increase the transparency, trust and community involvement in NBS activities.
The LAND4CLIMATE initiative in Euskirchen has the ability to set up a model of community-based climate adaptation by empowering stakeholders and beneficiaries. Involving local communities in the creation and development of climate initiatives is crucial to the long-term success of such remediation efforts.

3.1.8 Monitoring and evaluation

Even though the Land4Climate project does not foresee a monitoring and evaluation phase for the implementation of NBS measures, the team that developed this strategy considers that this phase is imperative in the event of identifying future sources of funding.

Therefore, the strategy includes for each NBS measure a brief monitoring, evaluation and learning plan, sufficiently versatile to be adjusted by the FRR in accordance with local needs and availability, at the appropriate time.

1. **<u>Objectives of MEL plan</u>**

- To monitor and evaluate the ecological performance, social acceptance and long-term sustainability of Tiny Forests implemented in the German FRR, using biophysical and socio-economic indicators across the project timeline.
- Evaluate the effectiveness of tiny forests in addressing heatwaves and improving ecosystem health.
- Provide feedback for adaptive management and future replication efforts.
- Generate evidence of "no-regret" benefits and assess sustainability post-project.

2. Monitoring indicators

Table 10 Biophysical indicators

Indicator	Description	Method	Frequency
Vegetation & biodiversity	Species richness, tree survival rate	Field plots, photographic surveys, drone imagery	Bi-annually
Soil health	Soil moisture, pH, organic matter, infiltration rate	Soil sampling, infiltration tests	Annually
Microclimate	Air temperature reduction, humidity, wind buffering	IoT climate sensors, satellite imagery	Quarterly
Carbon sequestration	CO_2 uptake potential, biomass accumulation	Allometric models, drone/LiDAR canopy scans	Annually
Water regulation	Surface runoff reduction, soil water retention	Rainfall-runoff plots, remote sensing	During rain events

Table 11 Socio-economic indicators

Indicator	Description	Method	Frequency
Public perception	Awareness, satisfaction, perceived benefits	Interviews with residents, school surveys	Yearly
Community engagement	Number of participants in planting & care activities	Attendance records, interviews	Each activity
Educational impact	Use in environmental education (schools, NGOs)	Curriculum integration, event tracking	Bi-annually
Maintenance sustainability	Cost, local ownership, community stewardship	Budget review, stakeholder interviews	Annually
Replication potential	Interest from other municipalities, enabling policies	Policy review, qualitative interviews	End-of-project

3. Data collection methods
- Field-based
- Remote sensing
- Socio-economic surveys/ interviews
- Automated sensors
- Participatory monitoring

4. Monitoring schedule and evaluation approach

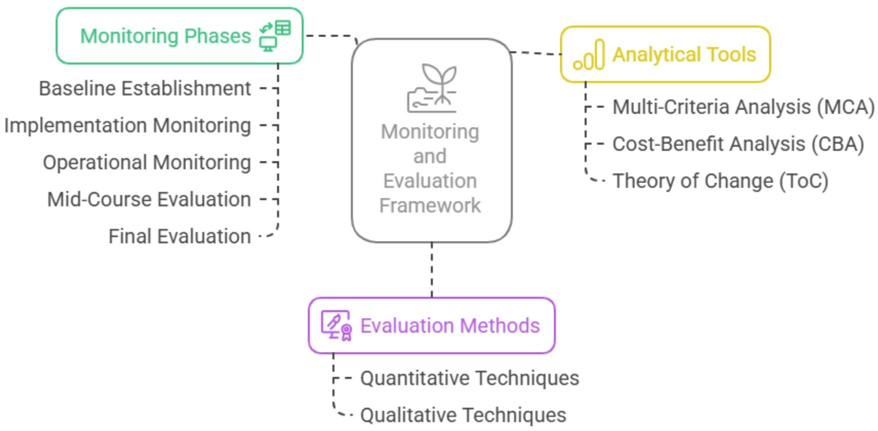


Figure 21 Monitoring and evaluation framework

Land4Climate
A step closer to climate resilience

5. Feedback loops

- Feedback will be fed into policy and planning alignment.
- Lessons will inform communication strategy and replication planning.
- Findings shared with stakeholders via newsletters, workshops and local NBS forums.

3.1.9 Summary of eligibility assessment

The implementation of NBS on private land requires careful assessment of their eligibility in relation to spatial, regulatory and socio-institutional criteria. This summary table synthesizes the outcomes of the multi-criteria eligibility analysis conducted for the German FRR, drawing on insights from stakeholder workshops, spatial planning reviews and the identification of legal, technical and governance-related enablers and barriers.

The table synthesize a view of the non-regret NBS implementing feasibility at the identified hotspots, considering aspects such as land ownership, alignment with land-use plans, stakeholder support and anticipated administrative or financial constraints. This synthesis can serve as a decision-support tool for prioritizing NBS interventions that are desirable from climate adaptation perspective but also realistically implementable within the current territorial framework.

Table 12 Eligibility assessment of tiny forests as NBS in Euskirchen County

Tiny parks	
Criterion	**Key justification**
Location	Planted in small, underutilized urban lots identified as climate risk hotspots (heat, surface runoff). Site selection was guided by local interest, accessibility and willingness to engage.
Effectiveness	Tiny forests mitigate urban heat and improve water infiltration, reducing localized flooding. Their layered structure promotes rapid ecosystem development and microclimate cooling.
Efficiency	Compact and low-cost interventions with high impact per square meter. Utilize small parcels of land not viable for other uses. Community involvement reduces implementation and maintenance costs.
Legitimacy	Co-designed with communities through participatory processes. Transparent communication ensured trust and collaboration.
Justice	Delivers public benefits (cooling, biodiversity, green space) without restricting property use or access. No displacement or exclusion; instead, these forests enhance inclusiveness and local empowerment.

3.2 NBS strategy for Lafnitz, Austria

3.2.1 Regional context and climate challenges

The NBS implementation strategy for the Lafnitz valley is intended to address the effects of land use change and climate change in an integrated manner, considering both environmental and socio-economic aspects of the region.

The main issue addressed in this strategy is soil erosion, which is exacerbated by heavy rainfall and unsustainable agricultural practices. The strategy allows conservative agriculture, which preserves soils against erosion and at the same time increases soil health (e.g. organic matter content and biodiversity). The application of this strategy will generate multiple benefits: enhancing biodiversity by providing habitats for local species; improving the microclimate, as plants and trees along the edges act as natural barriers against wind and water erosion; and reducing pollution.

Table 13 Austrian FRR brief description

Location

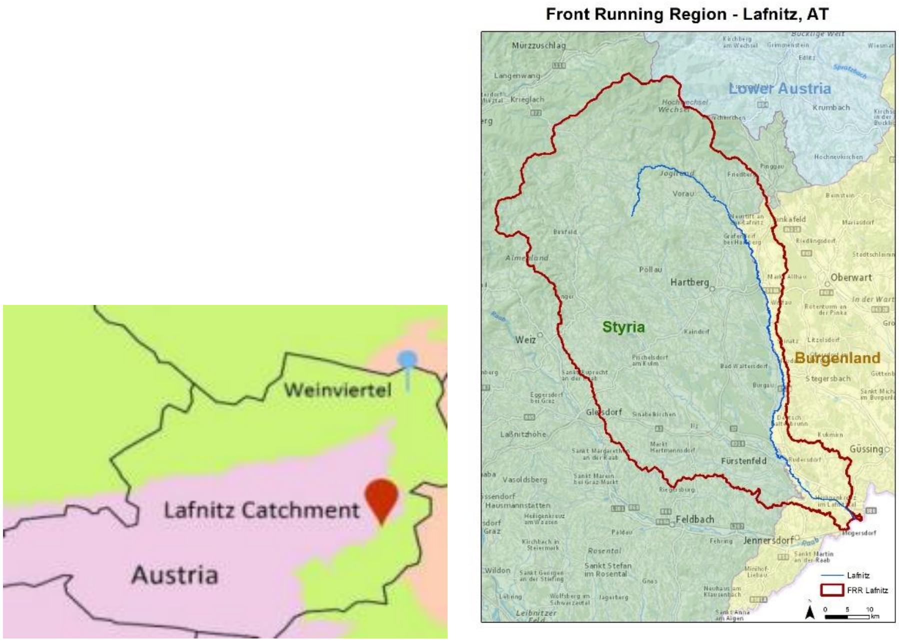


Figure 22 Austrian FRR location map

The FRR Lafnitz comprises the catchment of the lowland river Lafnitz, situated in the Austrian federal states Styria and Burgenland.

Climate

The Lafnitz catchment area can be assigned to two climatic regions, the Pannonian climate and the Illyrian climate. Burgenland is characterized by hot, dry summers, cold winters and low rainfall throughout the year. Styria is located in the Illyrian zone with equally hot summers and cold winters, but with high humidity and large amounts of rain in late summer and autumn.

Soil

Depending on the topographical characteristics, two areas can be distinguished. The southern part is characterized by soils suitable for croplands that are used intensively for agriculture.
The hilly northern part is characterized by forests and meadows.

Topography

The Lafnitz catchment area stretches from the mountainous Wechsel region in the north to the flat and undulating Raab Valley in the south and encompasses both Styria and Burgenland, as Lafnitz extends for long stretches as a border watercourse between the two federal states. It covers a region of about 2.000 km². The River Lafnitz has a total length of 114 km. In the upper reaches the bed gradient is about 15 ‰, and in the lower reaches about 1,2 ‰.
A characteristic feature of the Lafnitz Valley is the development of broad valley floors with extensive drag slopes (especially on the eastern side of the valley).

Land Use

The Lafnitz catchment is predominantly rural with significant agricultural activity, especially in the wide Lafnitz valley. The mountainous northern part is characterized by forests and

meadows, although in recent years there has been an increase in arable farming, even on slopes. The settlement areas are predominantly village structures.
Population The Lafnitz region has a population of approximately 150,000 inhabitants in an area extending over 1900 km². The population distribution is uneven, with higher concentrations in the urban centers and sparser populations in the mountain region.

A crucial component of this strategy is education and engagement at the community level. The progress of climate adaptation measures shall consistently be communicated to all stakeholders via multiple communication channels to facilitate their involvement and participation in protecting and enhancing their environment.

While immediate challenges are targeted, the FRR Lafnitz strategy also lays the groundwork for a future in which humans and nature exist in a constantly evolving, mutualistic and symbiotic equilibrium.

Climate vulnerabilities

The Lafnitz Valley is currently affected by climate change as well as by evolving land use patterns. These alterations disrupt the ecological equilibrium and increase the population vulnerability as well as valley economic utility. Thus, integrated solutions and collaborative efforts are required.

In the Lafnitz Valley, the dual threats of prolonged droughts and intense heatwaves, occurring with increasing frequency due to climate change, are creating major problems by severely limiting water availability (a critical resource for local agriculture) and exacerbating water scarcity (with effects in jeopardizing crop yields and natural ecosystems health).

Adding to this challenge are short, intense rainfall events that lead to significant soil erosion. This kind of rainfall episode (characterized by rapidity and severity) will favor only partial water absorption by the soil. The topsoil will inevitably be washed away, decreasing soil fertility and agricultural productivity and contributing to increased Lafnitz River sedimentation. This sedimentation exacerbates flooding risks and negatively affects the gravel banks (crucial habitats for aquatic life).

Moreover, the sediment deposits resulting from these intense rainfall events will lead to narrowing the river’s cross-section. This narrowing can potentially trigger more severe flooding of the surrounding areas, posing a direct threat to the local communities, agriculture and the overall landscape integrity of the valley.

Urban areas from Lafnitz Valley are susceptible as well to the climate change challenges. Rising temperatures, exacerbated by increased surface sealing (resulting from urban expansion), contribute to the urban heat island effect, making these areas uncomfortably hotter and disrupting local climates.

Key climate-related hazards and the risk assessment

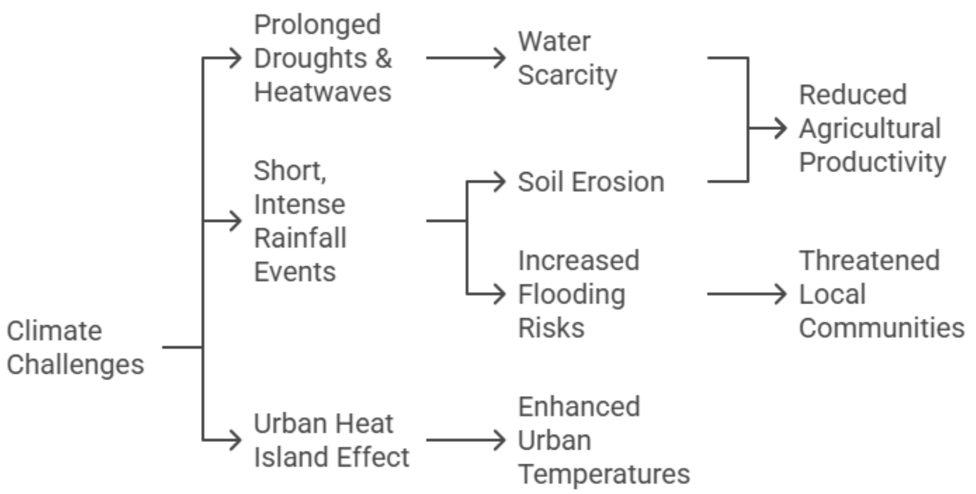


Figure 23 Climate change challenges and responses

This figure illustrates the impacts of climate challenges such as prolonged droughts, intense rainfall and urban heat, along with actionable measures including sustainable land management, tree planting and collaborative approaches to mitigate risks and promote resilience.

Table 14 Climate risk assessment in Lafnitz

Hazard	Consequences		
	People	Assets	Environment
Flash floods			
Drought			
Urban heat			
Heat waves			

	No risk		Low risk		Moderate risk		High risk		Very high risk

The Lafnitz region case study highlights the consequences of flash floods, droughts, urban heat and heatwaves, each posing moderate to significant risks to people, assets and the environment.

Table 15 Summary of climate and main consequences in Lafnitz

Climate risks analysis and interpretation			
Flash floods	**Drought**	**Urban heat**	**Heat waves**
- Triggered by frequent torrential rains and rapid runoff - Severe threats to people, infrastructure and agriculture. - Economic disruptions from flood damage and erosion. - Environmental damage includes soil	- Primarily affects agriculture, critical to local livelihoods. - Leads to socio-economic stress for farmers and communities. - Causes ecosystem disruption, biodiversity loss and degradation of	- Affects vulnerable populations (elderly, chronically ill) with heat-related health risks. - Urban infrastructure experiences stress but benefits from vegetation and water-based NBS. - Biodiversity and water resources are	- Pose health risks to vulnerable groups and stress infrastructure. - Environmental effects include intensified drought, heat stress, biodiversity decline and soil degradation.

erosion, biodiversity loss and destruction of wetlands/ ecological corridors	wetlands/ riparian zones.	impacted by increased heatwave frequency.	

A joint effort involving all categories of stakeholders is crucial to approach these challenges both efficiently and effectively. The creation of climate action plans, investment in green infrastructure and promotion of sustainable agricultural practices are just some potential examples. In addition, the education and community initiatives will help build awareness and understanding for these kinds of initiatives.

Identified climate risk hotspots

The Lafnitz catchment was identified as a key climate risk hotspot within the project Land4Climate because of high ecological vulnerability, hydro-climatic sensitivity and socio-economic exposure. The area is affected by extreme weather hazards exacerbated by climate change (increased number of drought events, increased temperatures, fluctuations in precipitation regime), all jeopardizing existing land uses and natural ecosystems.

The Lafnitz River corridor was historically altered for drainage and agricultural purposes and is still at risk of flooding, particularly in areas with little natural water retention capacity. Better ecological conditions as a result of restoration efforts are observed, yet hydrological extremes, both pluvial flooding and prolonged dry periods, raise significant concerns. Wetlands and floodplains are essential to water regulation and are one of the first ecosystems to feel the effects of prolonged drought or shifted seasonal flows.

Agricultural zones, especially those relying on rainfed systems, are also exposed to rising water stress, the CRA underlines. At the same time, riparian habitats and gentler climates and biomes are being degraded by changing climate regimes. These factors, along with the region's socio-economic dependence on agriculture, forestry and tourism, position the Lafnitz catchment as a priority area for nature-based adaptation. This region illustrates the interconnectedness of climate risk, land use pressure and ecosystem vulnerability, making a case for targeted and cross-border resilience strategies.

3.2.2 Vision, goals and operationalization

The Lafnitz region aims to become a model of climate resilience and ecological sustainability by integrating human development with nature conservation. By innovative land and water management strategies having NBS as the core measures, the region will maintain and enhance the ecological characteristics of the Lafnitz River, thus protecting and supporting biodiversity as well as local communities for future generations.

The Lafnitz FRR vision aims to improve the river's natural beauty and rich biodiversity by transforming these natural valuable resources into assets that will bring benefits and co-benefits for both local communities and ecosystems. Through a holistic and integrative approach, the Lafnitz region will establish a standard for ecological innovation and adaptation, having the capacity to inspire other regions that have the same aims in combating climate change and promoting sustainable development. This vision is focused on demonstrating how local communities can coexist with nature by applying sustainable agricultural practices (promoting soil health and biodiversity). Moreover, using technological innovations and ecological engineering methods, the strategy will address specific climate challenges. Having the same importance is the development of a qualitative ecological education program which will follow increasing community awareness and developing new capacities for sustainable management of natural resources.

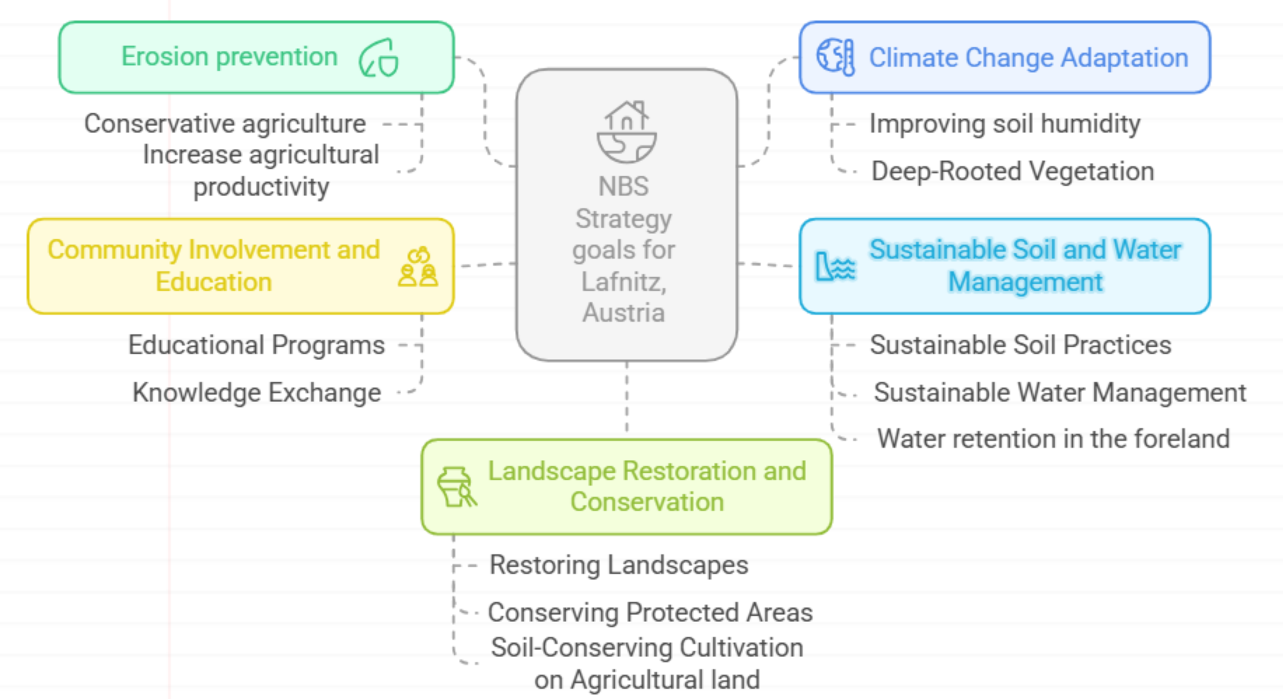


Figure 24 Specific goals of NBS strategy for Lafnitz, Austria

This figure highlights key focus areas, including biodiversity conservation, climate change adaptation, sustainable soil and water management, landscape restoration and community involvement and education, aimed at fostering environmental sustainability and resilience.

Operationalizing the Land4Climate Strategy in Lafnitz

Table 16 Key aspects of Land4Climate NBS strategy operationalization in Lafnitz FRR

Activities	Topics
Collaboration: collaborating with stakeholders for habitat restoration	Ecological corridors: creating corridors for significant ecological impact
Community engagement: involving locals in discussions about NBS benefits	Sustainable practices: implementing eco-friendly water and soil management.
Awareness raising: encouraging participation in NBS initiatives	Conservation agriculture: promoting practices to improve soil health
Continuous monitoring: ensuring long-term efficacy through ongoing adjustments.	

The operationalization of the NBS strategy for the Lafnitz area within the Land4Climate project involves a series of concrete steps and integrated measures designed to address the region's specific ecological, climatic and socio-economic issues.

Through these efforts, the Lafnitz area can become a model for efficient and sustainable natural resource management, showcasing how collaboration among the public sector, private sector and local communities can foster climate resilience and create a healthy environment for all inhabitants.

3.2.3 Location and NBS identification

Table 17 Overview of stakeholder-selected no-regret NBS measures for climate risk hotspots in the Lafnitz FRR

How were priority hot-spots identified?	multi-criteria CRA - Hazard data - Flood risk maps - Exposure analysis - Vulnerability indicators	Priority hotspots were identified through an integrated CRA combining hazard data, exposure mapping and vulnerability indicators, providing a robust evidence base for spatially targeted NBS planning
What is the justification for NBS location?	- Overlap of risk hotspots with available or accessible private lands. - Stakeholder preferences gathered during local co-design workshops (D1.9), ensuring alignment with community needs and landowner interests. - High ecological potential of the identified areas - Suitability of sites for implementing “no-regret” NBS that offer tangible local benefits regardless of future climate scenarios	NBS locations were selected based on risk severity, ecological suitability and stakeholder input, ensuring both strategic relevance and local legitimacy
What alternatives were considered for scale/ location?	- De-sealing, - green drainage paths - overall management adjustment	Alternative scales and sites were considered, but finally rejected, considering the following constraints: - very expensive - time-intensive - Multiple landowners are necessary - The willingness of the landowner to implement is unclear
Which NBS have been selected?	- Diversity and greening o catch crops, mixed crops and undersown crops o greening areas at risk of erosion - Soil-conserving tillage - Framing direction & field division o Mulch sowing & strip-till o Direct seeding o Aerial drone - Agroforestry and water management o Agroforestry o Infiltration trenches (with agroforestry strips) o Collection basin and swales o Bottom stabilization of a natural ditch	These NBS were selected for their optimal combination of feasibility and impact.

3.2.4 Effectiveness and efficiency

Table 18 Synthesis of integrated assessment methodology and indicators for Lafnitz FRR

NBS	Addressed hazard	Evaluation process	Performance indicators
Agroforestry measures	Soil erosion and sediment runoff, flooding and pluvial waterlogging, drought and reduced water availability, heat	Numerical modelling, field monitoring, socio-economic surveys, MCDA	Reduction in soil erosion rate, increase in infiltration capacity/ groundwater recharge, runoff retention volume, implementation and maintenance costs,

	stress and microclimate regulation		stakeholder acceptance and satisfaction

Table 19 Synthesis on NBS effectiveness, multifunctionality and expected co-benefits

NBS	How does the NBS mitigate the risks?	multi-functionality and expected co-benefits
Agroforestry measures	- Tree rows, hedges and buffer strips reduce surface runoff velocity, trap sediments and stabilize soils - Enhanced infiltration and water storage in root zones delay runoff and attenuate flood peaks. - Improved soil moisture retention and shading reduce evapotranspiration and increase water availability for crops - Tree canopies create microclimatic regulation, lowering local air and soil temperature	- Combines erosion control, water regulation and carbon sequestration in one system - Enhances crop yield stability, diversifies production and improves soil fertility. - Provides local cooling effects, supports carbon storage and improves resilience to extreme events. - Improved biodiversity, enhanced soil health and organic matter content, better water quality through nutrient and sediment retention

Agroforestry measures: Co-benefits and trade-off analysis

In the Austrian FRR, agroforestry measures were assessed as potential NBS for the built environment. The evaluation focused on its capacity to mitigate erosion, pluvial flood risks and heat stress while also addressing long-term water retention.

Table 20 Agroforestry measures: co-benefits and trade-offs

Dimension	Co-benefits	Trade-offs
Environmental	- Enhance biodiversity and microhabitats - Improves soil health and reduces erosion - Contributes to carbon storage - Increases water retention and drought resilience - Strengthens landscape aesthetics	- Reduction of productive crop-land area - Possible decline in short-term agricultural yields
Social	- Provides multifunctional landscapes - Supports cultural identity and local heritage - Creates opportunities for education and awareness	- May conflict with farmers' short-term land use priorities and preferences
Economic	- Diversifies farm income - Strengthens long-term resilience of agriculture against climate stress	- High initial establishment and ongoing maintenance costs - Long payback period

For more details on this analysis, please visit *Schindelegger, A., Thaler, T. (2025). Assessment of co-benefits and trade-offs of NBS (LAND4CLIMATE Deliverable 2.4).*

3.2.5 Land policy and implementation

Table 21 Assessment of alignment between proposed NBS and existing land use and spatial planning instruments in the Lafnitz FRR

NBS	Policy/ planning tools used	Intervention type	Effect on land/ property values
Agroforestry measures	- Voluntary participation of farmers, supported by local governments in Styria and Burgenland. - Alignment with Austrian agri-environmental subsidy schemes (e.g. ÖPUL), which already incentivize buffer strips and hedgerows. - Information events, mailing lists and direct negotiation with landowners used as informal planning instruments (no coercive tools). - Expert consultation and catalogue of measures developed with contractors ensured technical fit with local conditions	- Planting tree rows, hedgerows and buffer strips on private farmland. - Non-structural and structural green measures integrated into existing agricultural landscapes. - Implemented through voluntary agreements rather than statutory land-use plans.	- Positive long-term impacts like improved soil quality, reduced erosion and higher resilience - Increases land productivity and attractiveness. - Property values likely increase due to ecosystem services and eligibility for subsidies. - No restrictions on land use; - Interventions are reversible and maintain agricultural potential. - Short-term trade-offs: minor reduction of productive land at field edges, but compensated by soil fertility and reduced damage costs.

Implementation plans

Table 22 Implementation plan

Agroforestry measures	
Phase	**Activities**
Feasibility and site selection	- Identify erosion-prone slopes, flood-prone fields and drought-sensitive agricultural plots in the Lafnitz catchment - Use GIS, soil maps and hydrological risk data - Consult local farmers and cooperatives to determine willingness and land availability. - Prioritize sites with high erosion risk and potential for ecological corridors.
Design and co-creation	- Organize participatory workshops with farmers, municipalities and local NGOs to co-design agroforestry layouts (hedgerows, buffer strips, tree rows). - Select suitable native tree/ shrub species for multifunctionality (soil stabilization, biodiversity, shade, carbon uptake). - Define planting density, spacing and management options adapted to local farming practices.

	- Develop a "catalogue of options" balancing ecological effectiveness with farm operations.
Permitting and funding	- Clarify legal requirements under Austrian agricultural and environmental law (minimal permitting as measures are voluntary and reversible) - Align interventions with ÖPUL agri-environmental schemes and CAP subsidies. - Explore potential co-financing sources - Negotiate compensation models for farmers (e.g., reduced opportunity cost, long-term contracts).
Implementation	- Prepare sites: mark strips, prepare soil where needed, ensure access - Plant hedgerows, tree rows and buffer strips during suitable seasons (spring/autumn). - Combine planting with soil protection measures (mulching, fencing against browsing). - Involve local contractors and farmers' cooperatives in planting and initial maintenance. - Promote visibility through local press and demonstration fields.
Monitoring and adaptive management	- Establish baseline indicators (soil erosion rates, infiltration, biodiversity counts, farmer satisfaction surveys). - Annual monitoring of vegetation growth, erosion control and water retention. - Adjust management: pruning, replanting, weed control, adaptive species selection. - Evaluate economic effects (yield stability, subsidy uptake) and social acceptance. - Share lessons learned and integrate results into replication toolboxes.

3.2.6 Legitimacy and justice considerations

Implementing NBS on private lands requires legitimacy and justice analysis to secure long-term success and stakeholder support. Their design and execution required technical feasibility, strong social acceptability and procedural integrity. LAND4CLIMATE followed a participatory and transparent approach to maximize legitimacy from multiple angles.

This subsection evaluates the legitimacy of these interventions through three different dimensions:

- input legitimacy (how participatory and inclusive the stakeholders' involvement is)
- throughput legitimacy (about whether decision-making is procedurally fair and transparent)
- output legitimacy (assessing if the interventions are producing, or should produce, effective results)

These points of view together provide a nuanced picture of the extent to which the NBS interventions are just and accepted in the local context of the considered FRR.

Table 23 Overview of legitimacy and justice considerations in the implementation of NBS in Lafnitz FRR

Agroforestry measures			
Dimension	**Participatory**	**Procedurally fair**	**Effective results**
Evaluation	**Yes**	**Yes**	**Yes**
Explanation	Participation relied on voluntary involvement of farmers (through public information events in Styria and email outreach in Burgenland). Stakeholders could select preferred measures from a catalogue.	Site selection was transparent and pragmatic, based on farmer willingness ("first	The agroforestry measures are expected to reduce erosion and runoff on

		come, first served") and municipal readiness. Expert teams provided continuous guidance. Trade-offs were openly discussed with stakeholders.	farmland, restore wetlands for water retention and biodiversity and decrease pluvial flooding and heat stress. Benefits are shared.

3.2.7 Stakeholder engagement

Stakeholder engagement in the LAND4CLIMATE project is fundamental to the overall approach of the project, relevant to the Lafnitz Valley challenge. The project acknowledges that active collaboration and participation of local stakeholders, particularly private landowners who are critical to the adaptation measures, is an important way in which meaningful progress on climate change adaptation can be achieved.

Private landowners have the best understanding of the land and are directly impacted, positively and negatively, by climate change challenges and the solutions proposed to address them. Their participation guarantees that Land4Climate measures are practical and sustainable and take into account the special features of the Lafnitz Valley.

Figure 25 The roles of stakeholder engagement, community involvement and climate adaptation in fostering sustainable and practical measures (NSB) to enhance local resilience to climate change.

Planning and implementing NBS it's a collaborative, iterative process that already includes landowner input, suggestions and feedback. As such, this participatory process not only helps the articulation of project actions to the specificities of the valley but also nurtures the link between the project team and local citizenry, contributing to a shared sense of ownership towards common goals around improving climate change resilience in the valley.

More importantly, the project allows greater participation from the community. Because climate change concerns every single local of Lafnitz Valley, this process encourages all locals to contribute and take part in measures like these through LAND4CLIMATE. Because they are well aware that a healthy, sustainable space for living and economic development cannot be created individually, the project partners are eager to promote strong ties within the community. By engaging local communities, the project aims to harness local knowledge and resources, increasing the effectiveness and sustainability of adaptation strategies.

3.2.8 Monitoring, evaluation and learning

Although the LAND4CLIMATE proposal does not formally allocate resources for monitoring and evaluation, the Austrian strategy recognizes that systematic assessment of agroforestry measures is essential to demonstrate effectiveness, improve adaptive management and enable replication.

Therefore, the strategy includes for each NBS measure a brief monitoring, evaluation and learning plan, sufficiently versatile to be adjusted by the FRR in accordance with local needs and availability, at the appropriate time.

1. Objectives of the MEL plan

- Monitor hydrological and ecological improvements (soil infiltration, groundwater recharge, biodiversity).
- Evaluate hazard reduction (erosion, drought stress, pluvial floods, heat stress).
- Capture co-benefits and trade-offs (ecosystem services, land-use restrictions).
- Assess legitimacy and justice dimensions (distribution of costs/benefits, inclusiveness of processes).
- Generate transferable knowledge for EU-wide NBS upscaling.

2. Monitoring indicators

Table 24 Biophysical indicators

Indicator	Description	Method	Frequency
Soil erosion reduction	Sediment yield, topsoil loss	Field erosion plots, remote sensing	Annually, after heavy rains
Infiltration and soil moisture	Water retention capacity, soil water balance	Soil moisture probes, infiltration tests	Quarterly
Groundwater recharge	Changes in groundwater levels	Piezometers, hydrological modeling	Twice per year
Flood peak attenuation	Reduction in downstream discharge	Hydrological modelling, river gauges	Event-based
Microclimate regulation	Temperature and humidity changes	Climate sensors, ENVI-met	Continuous
biodiversity	Species richness	Field surveys	Annually

Table 25 Socio-economic indicators

Indicator	Description	Method	Frequency
Agricultural productivity	Crop yield stability, soil fertility	Farm surveys, yield monitoring	Annually
Damage cost reduction	Avoided flood/ erosion damage	Insurance data, cost–benefit analysis	After major events

Maintenance costs	Cost borne by farmers/ municipality	Budget review, stakeholder interviews	Annually
Carbon sequestration	Biomass accumulation in agroforestry/ wetlands	Remote sensing	Every 2-3 years
Public perception	Acceptance, trust, satisfaction	Citizen surveys, interviews	Twice per year
Stakeholders involvement	Participation in workshops/ maintenance	Attendance records	Each activity
Procedural fairness	Inclusiveness of selection and co-design	Interviews	Annually
Equity of benefits	Who benefits/ loses from interventions	Target groups, surveys	Twice per year

3. Data collection methods

- Field-based
- Remote sensing
- Socio-economic surveys/ interviews
- Automated sensors
- Participatory monitoring

4. Monitoring schedule and evaluation approach

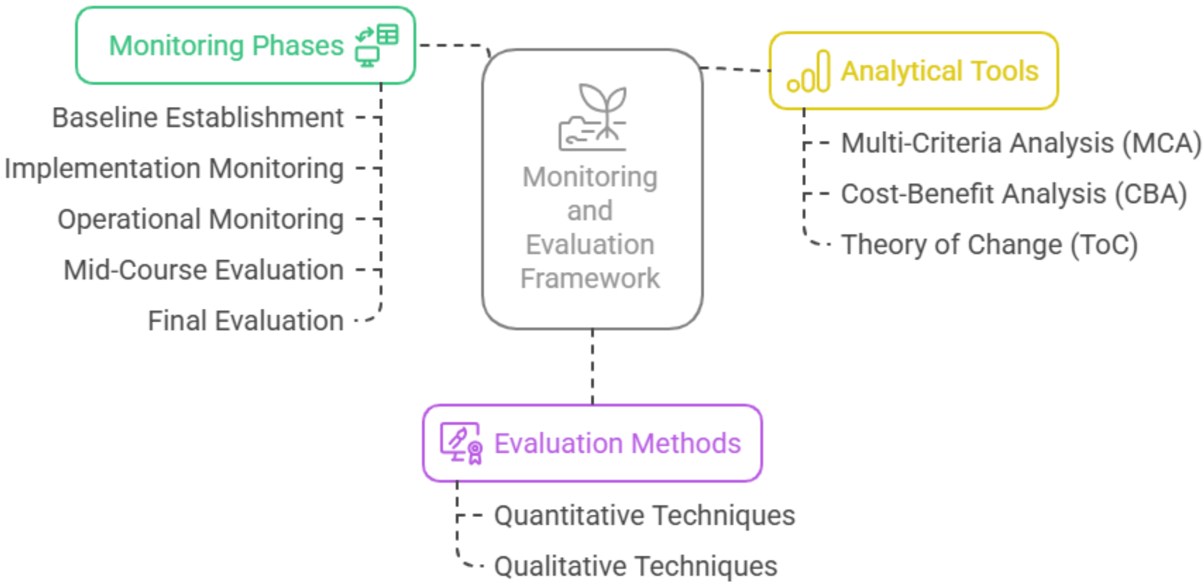


Figure 26 Monitoring and evaluation framework

5. Feedback loops

- Findings integrated into annual adaptive management workshops.

- Results communicated via regional platforms, stakeholder meetings and EU climate adaptation networks.

- Lessons used to refine funding applications, land-use plans and replication strategies.

3.2.9 Summary of eligibility assessment

Table 26 Eligibility assessment of agroforestry measures as NBS in Lafnitz area

Agroforestry measures	
Criterion	**Key justification**
Location	Agroforestry is suited for erosion-prone slopes and agricultural land in the Lafnitz catchment, identified as hotspots by previous GEM project analyses and stakeholder consultations. The interview guideline confirms farmers' willingness to participate and the focus on erosion and drought risks
Effectiveness	Proven to reduce erosion, improve infiltration and stabilize soils, while also moderating microclimates and enhancing biodiversity. Numerical modelling results (e.g., SWAT+, ENVI-met) show positive impacts on runoff reduction and microclimate regulation
Efficiency	The measures build on existing agricultural practices minimizing implementation costs. Funding is available via CAP eco-schemes, ÖPUL and EU adaptation funds. Co-benefits (improved soil fertility, biodiversity, reduced flood damages) increase the overall cost–benefit ratio, making the agroforestry measures economically efficient.
Legitimacy	The process is based on voluntary participation of farmers and municipal stakeholders, supported by expert assessments and public information sessions. Sites were chosen transparently ("first come, first served") and interventions co-designed with landowners ensuring procedural fairness and local ownership.
Justice	Farmers benefit directly from healthier soils and improved yields; broader society gains from better water quality, flood mitigation and biodiversity. No landowners are forced into participation; instead, voluntary agreements ensure fairness. Trade-offs (small reduction in productive area) are compensated by ecological and financial benefits, consistent with the "no-regret" framing.

3.3 NBS strategy for Upper Timis River FRR, Romania

3.3.1 Regional context and climate challenges

The NBS strategy for Upper Timiş River catchment is part of the Land4Climate project and aims to make the region climate-resilient, offering a demonstration of how NBS could be implemented in other catchments. Essential to this vision, is the restoration of abandoned gravel pits by transforming these barren, derelict lands into prosperous biotopes that support biodiversity and create recreational spaces for the community. To remedy this, the region must convert these basins to wetlands (or community green spaces) that transform potential liabilities to valuable, healthy public assets that serve ecological and social purposes.

The strategy also emphasizes the role of the Upper Timiş River catchment in showcasing to Europe how local actions can contribute to the wider goals for sustainability and climate resilience. It includes preserving and improving the natural landscape and promoting a cohesive approach to managing land and water that could be a model for other areas facing similar environmental issues. The NBS uptake increases the resilience of the Upper Timiş River catchment against climate change and it represents a continental-level action towards the restoration of the ecosystem functions, the biodiversity enhancement and the sustainable development.

Similar to the Upper Timiş River catchment, advanced water resource management is also a priority in the strategy. Through advanced hydrological strategies, the region will optimally manage excess water during flood periods and water scarcity during droughts. Water retention channels and ponds/wetland restoration will create natural water flow and storage balancing which is a sustainable response to hydrological balance for the region.

Restoring ecosystems and promoting biodiversity is another key aspect of the strategy. Within the Upper Timiş River catchment area the effort will concentrate on the rehabilitation of degraded habitats and the expansion of natural territories, including areas along river banks and wetlands. Projects that widen the river and plant certain types of vegetations to allow for diverse, healthy and resilient ecological networks to thrive will go a long way to support the native species.

Notably, sediment and nutrient management is high on the agenda due to the need to enhance water quality to avoid further degradation of the riverbed and aquatic habitats. The second objective of these data would be to create strategies to use along silting rivers, to help decrease sediment loads and nutrient runoff.

Table 27 Romanian FRR brief description

Location

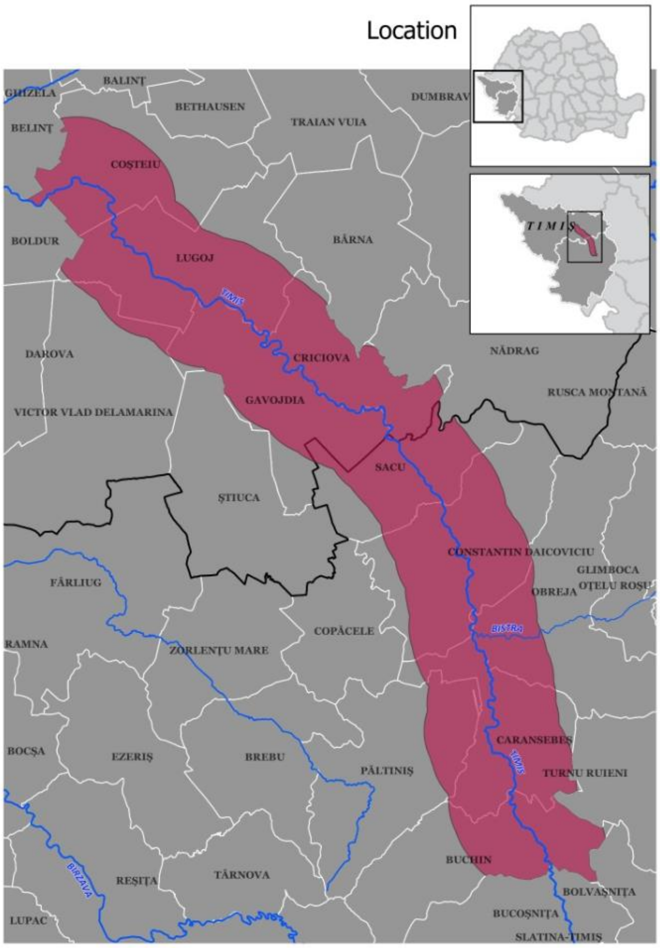


Figure 27 Romanian FRR location map

Climate Upper Timiș river has a temperate continental climate with some Atlantic and Mediterranean influences from the west and south, with hot summers and mild winters.
Soil

In most parts of the floodplain of Timiș river there are alluvial soils. At the edges of the FRR the soil type varies from argilluvisols (clay soils) to cambisoils (in the east and south)and on smaller areas hydromorphic soils and mollisoils.
Topography The most part of the FRR is overlapping the Lugoj Plain. Smaller areas are part of the Lugoj Hills and the Caransebeș Depression in the east, the Buziaș Hills and Semenic Mountains in the south.
Land Use The FRR is mostly rural, the largest areas are arable lands, forests and pastures. Arable lands are located in the floodplain and forests on the hills. There are 2 towns, Lugoj in the north and Caransebeș in the south, where most of the land has an industrial and commercial use.
Population Upper Timiș river has a total population of approximately 78.000 inhabitants. The distribution of the population varies, with concentrations in the 2 towns and villages and large areas with low density. Lugoj is the largest town, with almost half of the total population.

By understanding that engaging the community in the strategy's success is important, residents will also be encouraged to learn and engage in better practices that enhance their environment. It will include workshops, training sessions and other materials to create awareness and facilitate communities to adopt sustainable practices.

Broadly, strengthening climate resilience is a primary goal, entailing both structural and natural adjustments to buffer the region against climatic extremes. This includes strengthening flood defenses, increasing drought resistance through the rise of groundwater and combating the urban heat island effect with green spaces.

Through these actions, the Upper Timiş River catchment aims to serve as a model for efficient natural resource management in western part of Romania. It promotes adaptability and resilience in the face of climate change, demonstrating the region's commitment to sustainable and environmentally respectful development.

Climate vulnerabilities

The Upper Timiş River catchment, an essential ecological and hydrological area, faces a variety of pressing challenges that undermine regional stability and environmental integrity. Addressing these challenges is crucial for ensuring the sustainable management of natural resources and the safety of the communities within the region. The primary issues currently impacting the catchment include flood-related threats, hydrological drought, the degradation caused by non-functional gravel pits and riverbed erosion.

This figure outlines key issues such as flooding, hydrological drought, non-functional gravel pits and riverbed erosion, along with their impacts and the corresponding need for strategic flood management, rehabilitation, erosion control and immediate attention to ensure sustainable hydrology and ecosystem stability.

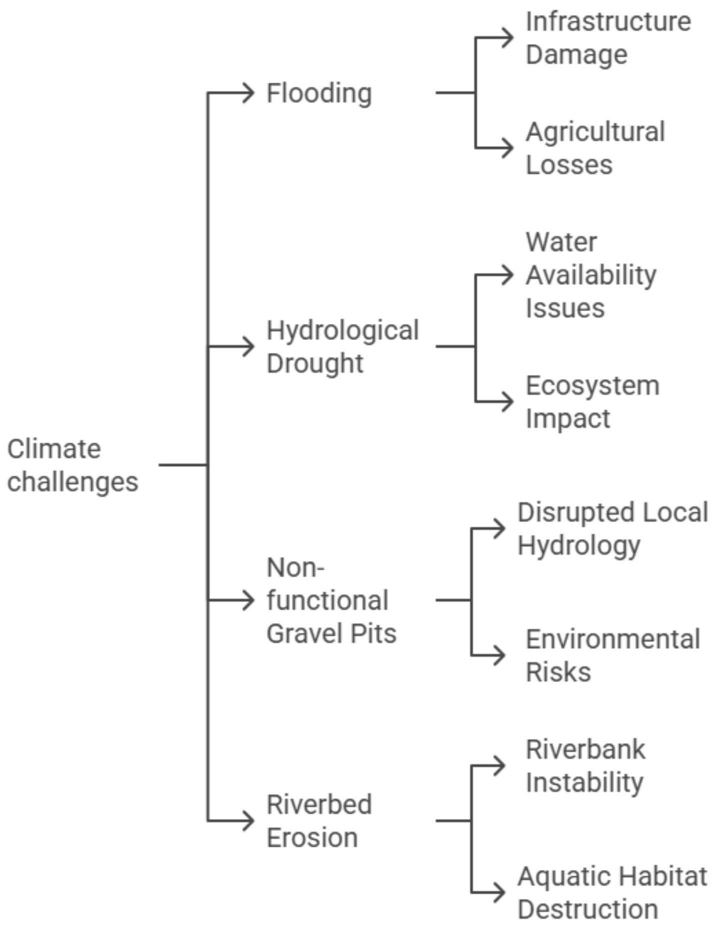


Figure 28 Challenges and risks in the Upper Timiș River Catchment

Table 28 Climate change risk assessment in Upper Timis River region

Hazard	Consequences		
	People	Assets	Environment
Flash floods			
Drought			
Urban heat			
Heat waves			

	No risk		Low risk		Moderate risk		High risk		Very high risk

Upper Timis River Catchment case study highlights the moderate to severe consequences of flash floods, droughts, urban heat and heatwaves, each posing significant risks to people, assets and the environment.

Table 29 Summary of climate and main consequences in Upper Timis River region

Climate risks analysis and interpretation			
Flash floods	**Drought**	**Urban heat**	**Heat waves**
- Frequent and intense floods threaten both rural and urban areas.	- Reduces water availability for agriculture, drinking and sanitation.	- Affects vulnerable groups (elderly, children, people with health issues) through urban	- Health risks to vulnerable populations; mitigated through

- Severe impacts on human safety, infrastructure, agriculture and food security. - Major damage to roads, buildings, utilities; high risk of injury, displacement and death. - Environmental consequences: soil erosion, habitat loss, water contamination.	- Moderate risk to people (especially rural, agriculture-dependent communities). - High risk to assets and environment: decreased crop productivity, soil degradation and biodiversity loss.	heat islands and tropical nights. - Damages infrastructure (e.g., material stress) and worsens environmental degradation (e.g., soil dehydration).	preparedness and public education. - Increases energy demand and infrastructure wear; agricultural losses due to heat stress.

In addition, this area is scarred by many abandoned gravel exploitation pits. The pits created after gravel extraction often remain uncared for, leading to non-esthetic sights and providing a breeding ground for certain fauna and flora. Rehabilitation and repurposing of these sites is important in maintaining ecological functions and enhancing the aesthetic and recreational status of the region.

Riverbank erosion is still an issue to be worried about. This natural degradation threatens the structural integrity of riverside banks, resulting in loss of area, increased sediment enter the water network and destroying habitats for aquatic and riparian species. Implementing appropriate erosion control methods will protect the riverbed from washout and sustain the articulation of diverse groups of aquatic organisms sustained by this river system.

For an efficient answer to all these issues, a multi-faceted strategy (involving engineering measures, educational initiatives and responsible resource governance) is needed. Achieving this will entail a collaborative effort among stakeholders across all sectors, for developing and implementing solutions that are environmentally sound, economically feasible and socially responsible. If these challenges are successfully met, the Upper Timiş River catchment will grow to adopt an integrative perspective on the usage of land and water resources, thereby improving the resilience and sustainability of this landscape for generations to come.

Identified climate risk hotspots

The Timiș River basin, part of Timiș County, Romania, is defined by complex hydrologic dynamics and is becoming increasingly susceptible to climate-related risks. Historical trends and climate projections are analyzed to highlight the area as an important climate risk hotspot in the region.

The key risks identified include extreme precipitation events, soil erosion and water shortage and droughts in the summer period in both ecosystems and agricultural activities. Increasing temperatures and changing precipitation regimes lead to reduced water availability during the dry season.

Socioeconomic exposure is extensive, since many rural communities and agricultural regions rely on the river system for irrigation, drinking water and livelihoods. Existing vulnerabilities in infrastructure - from insufficient flood protection systems to aging water management infrastructure - compound climate risks.

Due to this exposure and the high level of ecological and socioeconomic sensitivity, the Upper Timiș River basin is a climate risk area (with Lugoj, Caransebes and Daicoviciu localities identified as hotspots), especially when considering the spatial dependence of the indicators taken into account.

This calls for targeted adaptation measures, including better land and water management, early warning systems and climate-resilient infrastructure planning.

3.3.2 Vision, goals and operationalization

Building on the premises defined by the Land4Climate project, the vision for the Upper Timiş River Catchment intends to transform this region into a climate resilience model for western Romania through an innovative implementation of NBS. At the core of this vision is the abandoned gravel pits. Transforming these pits into wetlands or community green spaces can increase the region's ecological functionality and aesthetic appeal. Potential liabilities can thus be transformed into assets for both ecological and social functioning.

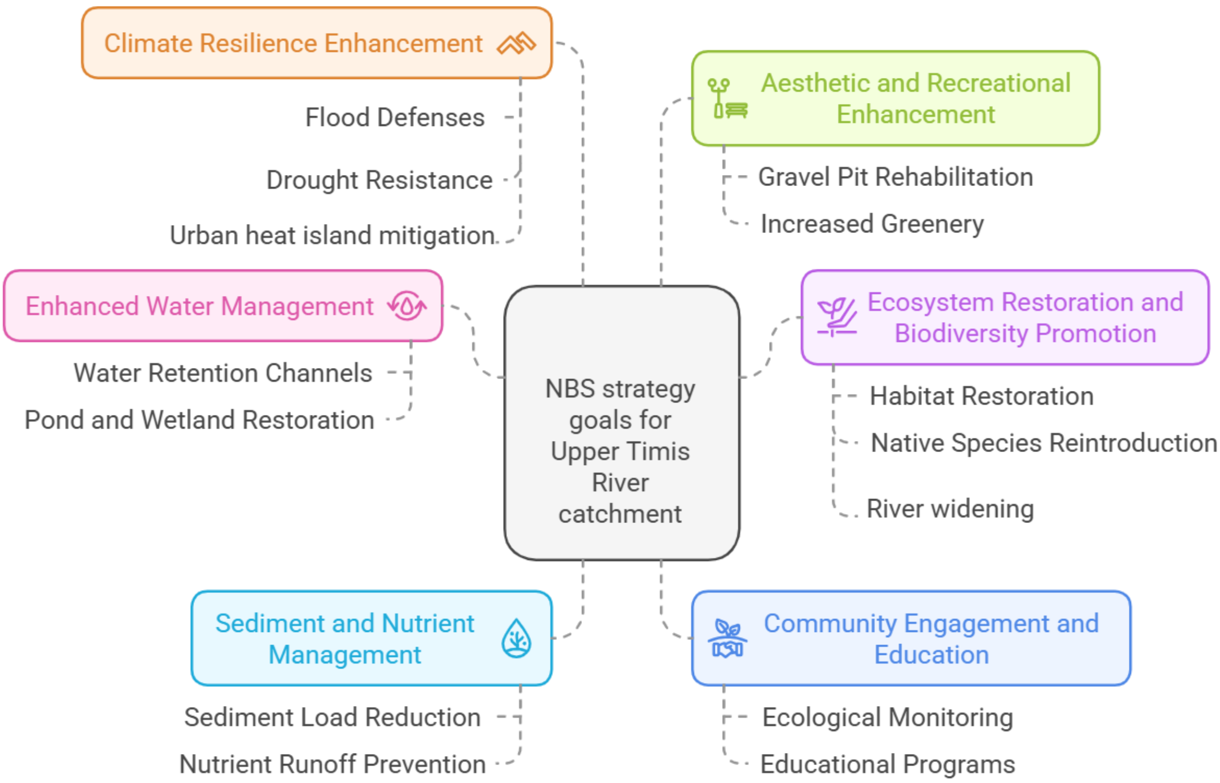


Figure 29 Specific goals of NBS strategy for Upper Timiș River Catchment

The vision identifies the Upper Timiş River Catchment as a proper area for showcasing how local initiatives can centralize within higher sustainability ideals associated with European-wide climate change resilience. This means not only defending and augmenting this natural environment, but also implementing a holistic land-and-water management methodology that can serve as a model for other parts of the world experiencing comparable environmental struggles. By applying strategic NBS within the Upper Timiş River Catchment, thus creating synergetic ecosystems, is protecting its own future while mitigating the effects of climate change, supporting biodiversity and sustainable development on the mainland.

This figure outlines strategies including community engagement, ecosystem restoration, enhanced water management, sediment and nutrient management, aesthetic and recreational enhancements and climate resilience to promote sustainable development and environmental restoration.

Table 30 Key aspects of Land4Climate NBS strategy operationalization in Upper Timis River Region

Activities	Topics
Water channels: construction of channels to manage water flow effectively	Ponds and wetlands: restoration of ponds and wetlands to enhance biodiversity
Riverbank enhancement: improving riverbanks to prevent erosion and boost biodiversity	
Water area connection: connecting water areas to improve resource management	
Forestation: planting and restoring trees to enhance climate resilience and biodiversity	

Table 31 Overview of stakeholder-selected no-regret NBS measures in climate risk hotspots in the Romanian FRR

How were priority hotspots identified?	multi-criteria CRA - Hazard data - Flood risk maps - Exposure analysis - Vulnerability indicators	Priority hotspots were identified through an integrated CRA combining hazard data, exposure mapping and vulnerability indicators, providing a robust evidence base for spatially targeted NBS planning
What is the justification for NBS location?	- Overlap of risk hotspots with available or accessible private lands. - Stakeholder preferences gathered during local co-design workshops (D1.9), ensuring alignment with community needs and landowner interests. - High ecological potential of the identified areas - Suitability of sites for implementing “no-regret” NBS that offer tangible local benefits regardless of future climate scenarios	NBS locations were selected based on risk severity, ecological suitability and stakeholder input, ensuring both strategic relevance and local legitimacy
What alternatives were considered for scale/ location?	Caransebeș was acknowledged as a hotspot but deprioritized because its main hazards originate upstream (outside project scope), making local NBS interventions less effective compared to Lugoj or C-tin Daicoviciu.	Given limited budget and strong reliance on private landowner cooperation, the project prioritized places where land availability and stakeholder engagement could lead to faster and more visible implementation.
Which NBS have been selected?	- Reforestation - Riparian buffer zones - Retention ponds - Reconnection of floodplains - Creation of retention areas	These NBS were selected for their optimal combination of feasibility and impact.

While reforestation has been selected as an example NBS to be implemented on private lands in the Romanian FRR within Deliverable 4.1, this does not imply that it is the most important or the most relevant option for Romania's specific conditions. Reforestation was chosen primarily for illustrative purposes, as this NBS type has been most extensively analyzed across the

LAND4CLIMATE consortium, thus providing the most consistent data and information for comparative assessment.

3.3.4 Effectiveness and efficiency

Table 32 Synthesis of integrated assessment methodology and indicators for Romanian FRR

NBS	Addressed hazard	Evaluation process	Performance indicators
reforestation	Heat Floods Heavy rain	Simulation of runoff storage.	Decrease in inundation depth. Flood frequency reduction. Water retention capacity.

Table 33 Synthesis on NBS effectiveness, multifunctionality and expected co-benefits

NBS	how does the NBS mitigate the risks?	multi-functionality and expected co-benefits
reforestation	- Reduce runoff - Reduce erosion - Mitigate heat	- Carbon sequestration - Cooling effects - Improved soil quality - Habitat creation

<u>Reforestation: Co-benefits and trade-off analysis</u>

In the Romanian FRR, tree planting in the built environment was assessed as a key NBS to mitigate climate risks such as heat stress, drought and pluvial flooding.

Table 34 Reforestation: co-benefits and trade-offs

Dimension	Co-benefits	Trade-offs
Environmental	- Improves biodiversity and ecological connectivity - Enhances soil health and reduces erosion - Contributes to carbon storage and groundwater recharge - Supports drought prevention and fluvial flood mitigation	- Loss of productive agricultural land when forested - Risk of crop yield reduction during flood events - Potential contamination issues in floodplains
Social	- Provides recreational opportunities and landscape aesthetics - Enhances local well-being and cultural ecosystem services	- May limit land use flexibility for local communities - Possible conflicts with short-term land use priorities
Economic	- Long-term resilience of landscapes (reduced flood damages, improved water retention) - Potential job opportunities in maintenance and forestry-related activities	- High establishment costs (planting, maintenance) - Long payback period for benefits

For more details, please visit *Schindelegger, A., Thaler, T. (2025). Assessment of co-benefits and trade-offs of NBS (LAND4CLIMATE Deliverable 2.4).*

3.3.5 Land policy and implementation

Table 35 Assessment of alignment between proposed NBS measures and existing land use and spatial planning instruments in the Romanian FRR

NBS	Policy/ planning tools used	Intervention type	Effect on land/ property values
reforestation	- Voluntary participation mechanisms; - afforestation strategies under national climate adaptation plans	Ecological land conversion	- Increase via improved microclimate, carbon sequestration and aesthetics; - potential reduction in short-term agricultural output or land use flexibility

Implementation plans

Table 36 Implementation plan

Reforestation implementation roadmap	
Phase	**Activities**
Site assessment and planning	- Identify erosion-prone and degraded slopes based on CRA risks mapping. - Verify land ownership and obtain voluntary participation agreements. - Classify soil types and determine native species suitability.
Technical design	- Define reforestation layout (species mix, planting density, contour alignment). - Develop a soil preparation and water retention strategy. - Align the intervention with national afforestation and climate adaptation policies.
Stakeholder engagement	- Conduct awareness meetings with landowners and local communities. - Sign agreements on maintenance and access. - Disseminate educational materials on long-term benefits (carbon, microclimate, biodiversity).
Site preparation	- Remove invasive species (if present). - Prepare planting beds and soil amendments. - Implement initial erosion control measures (e.g., mulch, terracing).
Tree planting and installation	- Select and plant native tree and shrub species in designed patterns. - Install protective fencing if needed (e.g., grazing areas).
Maintenance and monitoring	- Regular weeding, watering (if necessary) and pest control. - Replace failed seedlings. - Implement co-monitoring with local stakeholders to ensure performance.
Evaluation and adaptation	- Assess effectiveness via indicators (e.g., runoff reduction, canopy growth, soil moisture, biodiversity presence). - Document lessons learned and refine design for replication.

3.3.6 Legitimacy and justice considerations

Implementing NBS on private lands requires a legitimacy and justice analysis to secure long-term success and stakeholder support. Their design and execution required technical feasibility, strong social acceptability and procedural integrity. LAND4CLIMATE followed a participatory and transparent approach to maximize legitimacy from multiple angles.

This subsection evaluates the legitimacy of these interventions through three different dimensions:

- input legitimacy (how participatory and inclusive the stakeholders' involvement is)
- throughput legitimacy (about whether decision-making is procedurally fair and transparent)
- output legitimacy (assessing if the interventions are producing, or should produce, effective results)

These points of view together provide a nuanced picture of the extent to which the NBS interventions are just and accepted in the local context of the considered FRR.

Table 37 Overview of legitimacy and justice considerations in the implementation of NBS in the Romanian FRR

Reforestation			
Dimension	**participatory**	**procedurally fair**	**effective results**
Evaluation	**Yes**	**Yes**	**Expected**
Explanation	- Early stakeholder engagement, especially landowners - Focused on highlighting ecological, social and economic benefits - Participation is voluntary and depends on perceived value - Broader community involvement still limited	- Transparent selection and participation process - Aligned with national legal frameworks - Landowners engaged via information campaigns and calls for interest - Ensures procedural fairness and clarity	- Aims to reduce flood and drought risks - Supports biodiversity and carbon sequestration - Improves soil stability and water retention - Includes 3 years of maintenance support by BWBA

3.3.7 Stakeholder engagement

In the Upper Timiș River catchment, the involvement of local stakeholders and beneficiaries in the LAND4CLIMATE project is pivotal to the success of implementing NBS. This collaborative effort hinges on the active participation of both locals and private landowners, ensuring that the environmental initiatives resonate with the community's needs and leverage local insights for more effective outcomes.

NBS awareness meetings are organized by project partners to ease the stakeholder engagement process. These meetings represent a critical platform for raising awareness in the community on the benefits of NBS and the specific environmental challenges of the Upper Timiș River catchment. Through the participation in these meetings, locals learn more about how NBS can improve ecological resilience and stability, flood risk reduction calls, hydrological droughts and erosion issues seen in the region.

In addition, these events aim to empower community members to participate in the ecological restoration of their area. Therefore, engaging community members in these hands-on activities helps solidify their connection to the land/the project, which improves the sustainability of the work.

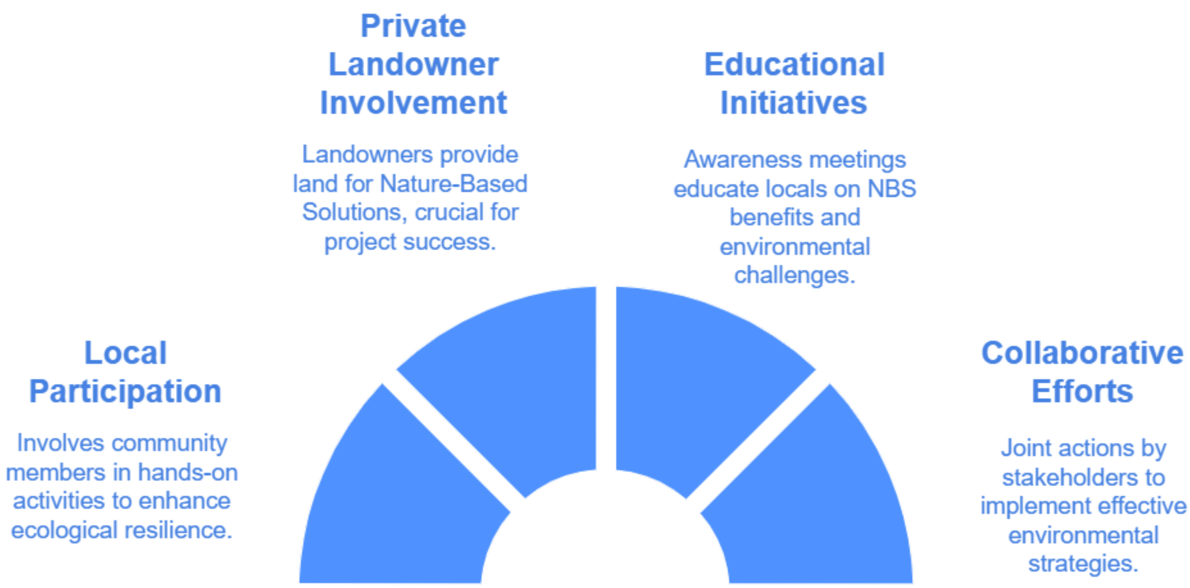


Figure 30 The importance of private landowner involvement, educational initiatives, local participation and collaborative efforts to effectively implement ecological resilience and environmental strategies.

LAND4CLIMATE project depends largely on the involvement of the private landowners of the Upper Timiș River catchment. All of these factors is instrumental to expanding the project`s scope and effectiveness, of which their readiness to allow land use for NBS implementation. Private landowners also directly help with biodiversity, water retention and soil stability in the region through letting their lands be used in ecological initiatives including creating wetlands, restoring indigenous timberlands, or developing buffer zones.

Together with these joint engagements and community participations both inhabitants and private land users help determine the course of the LAND4CLIMATE initiative in the Upper Timiș River basin. This ensures that the implementation of NBS is not only practical, but is also informed by local values and needs, which contributes to more sustainable and resilient environmental solutions.

3.3.8 Monitoring, evaluation and learning (MEL)

Even though the Land4Climate project does not foresee a monitoring and evaluation phase for the implementation of NBS measures, the team that developed this strategy considers that this phase is imperative in the event of identifying future sources of funding.

Therefore, the strategy includes for each NBS measure a brief monitoring, evaluation and learning plan, sufficiently versatile to be adjusted by the FRR in accordance with local needs and availability, at the appropriate time.

1. Objectives of MEL plan

- Monitor biophysical and socio-economic impacts of reforestation activities.
- Evaluate the effectiveness of reforestation in reducing flood/drought risks and improving ecosystem health.
- Provide feedback for adaptive management and future replication efforts.
- Generate evidence of "no-regret" benefits and assess sustainability post-project.

2. Monitoring indicators

Table 38 Biophysical indicators

Indicator	Description	Method	Frequency
Infiltration rate	Soil water absorption capacity	Field infiltration tests	Annual
Canopy cover growth	Increase in forest density	Remote sensing (NDVI), drone surveys	Seasonal
Surface runoff volume	Reduced flow from rainfall events	Hydrological modeling, in-situ sensors	Post-rainfall events
Soil erosion rate	Sediment load and stability	Silt traps, erosion pins	Semi-annually
Soil moisture and organic content	Resilience to drought	Soil sampling	Quarterly
Biodiversity	Ecosystem recovery	Camera traps, flora/ fauna counts	Bi-annually
Carbon sequestration potential	Climate mitigation contribution	Estimations via allometric equations	Annually

Table 39 Socio-economic indicators

Indicator	Description	Method	Frequency
Landowner participation	Number of involved private actors	Project records	Continuous
Perceived benefits	Stakeholder satisfaction and NBS valuation	Structured interviews, Likert-scale surveys	Annually
Knowledge and capacity gains	Stakeholder awareness and adoption	Pre-/ post-training questionnaires	Each training
Maintenance engagement	Local involvement in stewardship	Interviews, signed agreements	Ongoing

3. Data collection methods

- Field-based
- Remote sensing
- Socio-economic surveys/ interviews
- Automated sensors
- Participatory monitoring

4. Monitoring schedule and evaluation approach

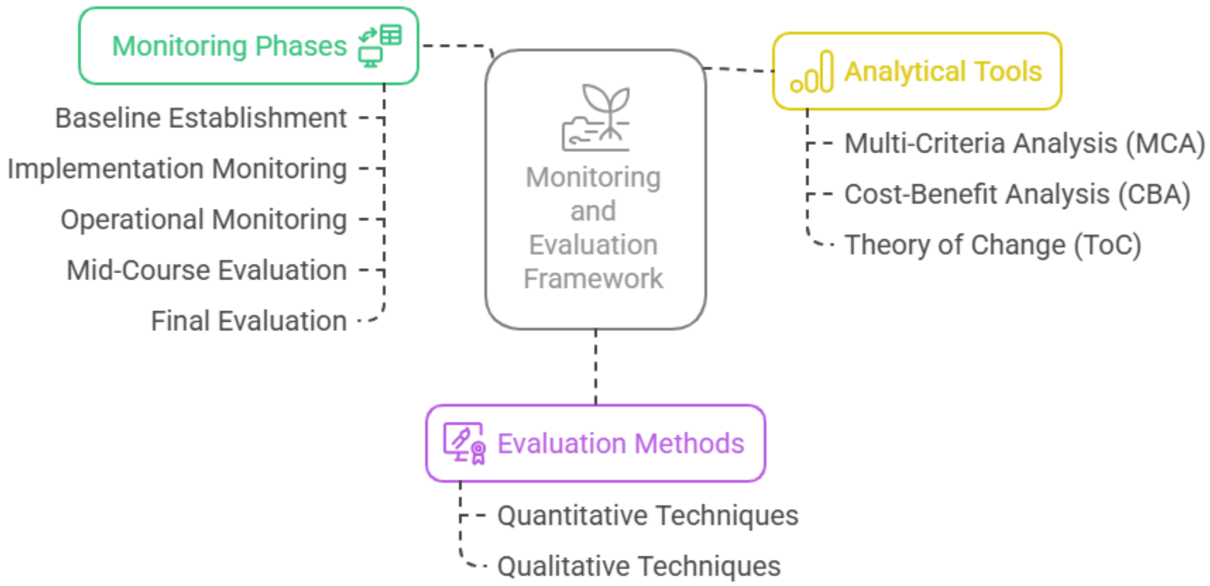


Figure 31 Monitoring and evaluation framework

5. Feedback loops
- Feedback will be fed into policy and planning alignment.
- Lessons will inform communication strategy and replication planning.
- Findings shared with stakeholders via newsletters, workshops and local NBS forums.

3.3.9 Summary of eligibility assessment

Table 40 Eligibility assessment of reforestation as an NBS in Upper Timis River Region, Romania

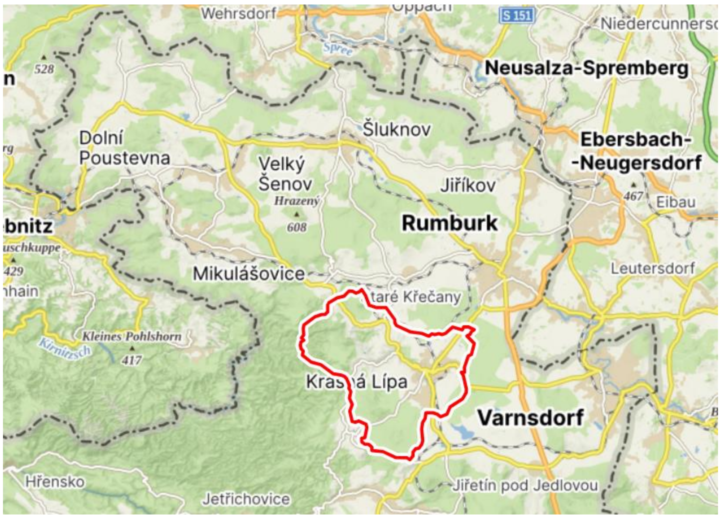
Reforestation	
Criterion	**Key justification**
Location	Sloped and degraded lands within the catchment identified as erosion hotspots and microclimate stress zones. Site selection based on accessibility and ecological potential.
Effectiveness	Enhances infiltration, reduces surface runoff and erosion, increases evapotranspiration and carbon sequestration.
Efficiency	Delivers long-term benefits for low initial investment. Implemented through voluntary participation and existing afforestation programs.
Legitimacy	Informed by national afforestation strategies. Stakeholders invited via open calls; 3-year support package from BWBA enhances trust.
Justice	Improves ecosystem services and public goods (air, water, soil). Maintains landowner autonomy. Access to benefits is equitable across affected communities.

3.4 NBS strategy for Czech Front Running Region

3.4.1 Regional context and climate challenges

NBS strategy in Krásná Lípa, Bohemian-Saxony Switzerland National Park, is focusing on interconnectivity between ecological sustainability and community resilience. Influenced by the typical geographical and environmental conditions of the region, the strategy will make Krásná Lípa a frontier of sustainable ecological management and innovative water retention in Europe.

Table 41 Czech FRR brief description

Location  Figure 32 Czech FRR location map
Climate Krásná Lípa has a mild continental climate with cold winters and warm summers, high humidity and changeable weather.
Soil The Křinice River contributes to a humid environment and the presence of soils with a higher organic matter content, especially around watercourses. The area is dominated by soils typical of mountain and foothill areas, such as medium-fertile soils and less fertile soils, which are common in the forested areas of the Lusatian Mountains. The location on the border of protected areas (Bohemian Switzerland National Park and the Lusatian Mountains Protected Landscape Area) limits intensive agricultural activity, which contributes to the preservation of the natural quality of the soil, which is less affected by industrial pollution due to its natural character.
Topography The town of Krásná Lípa, Děčín district, lies in the valley of the Křinice river. Its altitude is approximately 426 meters above sea level. The town is located on the border of the Bohemian Switzerland and Lusatian Mountains Protected Area and is part of the Krásnolipská uplands, which is partially included in the Elbe Sandstone Protected Area, the Lusatian Mountains Protected Area and the Czech Switzerland National Park. Cadastral area: 3141 ha, consisting of the parts of Krásná Lípa, Krásná Buk, Kamenná Horka, Dlouhý Důl, Hely, Kyjov, Sněžná, Vlčí Hora and Zahrady
Land Use Agricultural production: There is a mowed meadow in the city and its surroundings, which is actively used for agricultural production.

Recreation areas: A recreation area with cottages, farm buildings and infrastructure such as roads, parking lots, sidewalks and public green spaces. Forest lands: Forests surround the city, both commercial and protected forests. Permanent grassland: There is permanent grassland in the affected area, which is the main soil unit.
Population Krásná Lípa is a town with approximately 3,400 inhabitants in the Děčín district in the Ústí Region in the Czech Republic.

Central to this strategy is the rehabilitation of private and public lands to increase their ability to hold water and manage floodplains more effectively. Considering that the town has relatively weak permeable sand swales and the landscape was previously modified, the approach focuses on the restoration and construction of small gutters, ponds and cascades. These activities help to ensure that groundwater is replenished, surface water runoff is slowed down and soil erosion is reduced, thereby in turn reducing the chances of floods that have conventionally ravaged the region.

Additionally, the strategy offers a nature-based restoration of watercourses in Krásná Lípa. With the widening and restructuring of these water bodies, the project not only seeks to decrease the speed at which water flows during heavy rains but also to improve the quality of the ecosystems in these aquatic environments. Through this method, Land4Climate aims to boost biodiversity and stabilize local ecosystems, leading to improved ecological connectivity across the region.

The other main facet of the NBS strategy is the establishment of strategic tree plantings and the restoration of native ecosystems (using native vegetation) of natural hydrological regimes. Not only will these actions strengthen the flood resistance capacity of the town, but also enhance the local microclimatic conditions, acting to cool down the tie zone naturally and increase the atmospheric humidity, which in turn has a positive impact on air quality and urban comfort.

Community engagement and education are the two key pillars behind this broad strategy. It also ensures that the results produced are relevant through the active involvement of local residents, businesses and policymakers in the planning and implementation phases.

Educational programs and workshops will empower community members with the knowledge and skills necessary to practice climate-resilient resilient sustainable practices.

The strategy will serve as a model for local responses to climate challenges, striving to foster a resilient, flourishing, ecologically sound community while providing a scalable framework for sustainable city design and governance.

Climate vulnerabilities

Different environmental and hydrological issues have occurred in the Czech FRR, posing risks to its ecosystem and the community's well-being. Tackling these challenges requires a multi-layered strategy to a nexus of climatic extremes, ecological decline and infrastructure deficits.

Water retention is one of the main problems in Krásná Lípa. The region does not receive precipitation from any incoming watercourses, while its permeable sandy subsoil further aggravates the situation, causing the water to be filtered through too quickly, thereby diminishing the stored surface water. This trait of the soil, together with the extensive drainage of the landscape through industrial agriculture and forestry, makes water retention very difficult in the region. Consequently, since 2015 Krásná Lípa has been experiencing periodic droughts, resulting in severe water shortages with a critical impact on both residential and ecological well-being. Here, this often leads to a situation where the municipality must hand out water through cisterns, while enforcing strict water use limitations.

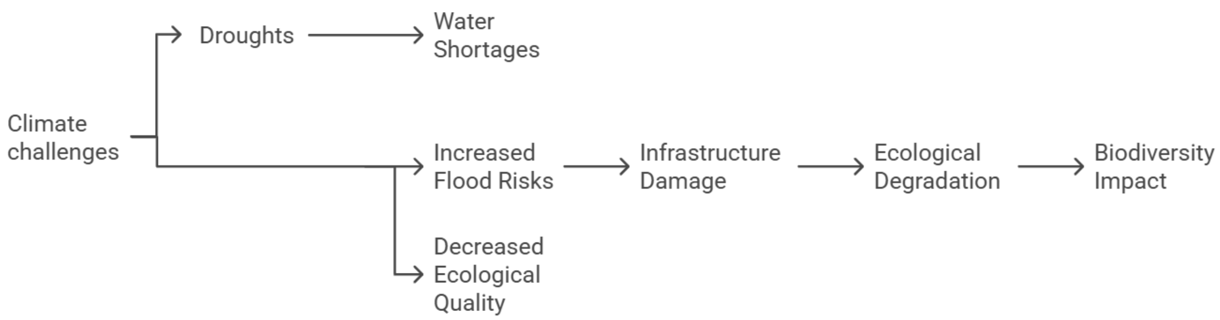


Figure 33 Climate challenges in Krásná Lípa

This figure outlines key challenges such as droughts, water shortages, inadequate infrastructure and increased flood risks, leading to infrastructure damage, ecological degradation and biodiversity impacts.

Table 42 Climate change risk assessment in Krasna Lipa FRR

Hazard	Consequences		
	People	Assets	Environment
Flash floods			
Drought			
Urban heat			
Heat waves			

	No risk		Low risk		Moderate risk		High risk		Very high risk

Table 43 Summary of climate risks and main consequences in Krasna Lipa FRR

Climate risks analysis and interpretation			
Flash floods	**Drought**	**Urban heat**	**Heat waves**
- Region vulnerable to flooding from local rivers and ponds. - Poor condition of town reservoirs increases flood risk when full. - High threat to people (especially elderly and children), infrastructure, homes and agriculture. - Major economic damages in areas lacking robust flood infrastructure. - Environmental harm includes soil erosion,	- Impacts livelihoods and health, especially in agriculture-dependent communities. - Crop failures and financial stress on farmers due to water scarcity. - Strains water infrastructure and degrades soil, threatening biodiversity and ecosystems.	- Health risk for vulnerable groups due to rising temperatures and more tropical nights. - Infrastructure suffers from material degradation and increased energy demands. - Green spaces lose effectiveness; - urban biodiversity is threatened. - Exacerbates the urban heat island effect.	- Increased health risks, hospitalizations and mortality among urban populations. - Infrastructure degradation - Intensifies drought, - reduces water supply, - damages agriculture and harms sensitive habitats like wetlands.

pollution and biodiversity loss affecting areas like Bohemian Switzerland National Park			

Ecosystem degradation as a result of biophysical factors such as drought, flash floods and historical land management practices has substantially affected the area. The degradation will have a direct impact of the flora and fauna of the locality, it also reduces the aesthetics and the functional value of the ecology in the region, which is crucial for the eco-tourism and leisure activities that sustains the area (community).

The infrastructure in Krásná Lípa, more specifically the water management systems, is not able to address these environmental challenges. The bottom line is that watercourses poorly managed or simply outdated can lead to excessive flood risks while also degrading ecological quality, a multi-faceted argument for holistic revitalization and modernization of watercourses protective of both community and ecological safety.

These challenges will need to be addressed through a multifaceted approach that integrates strong water management practices, ecological restoration and community engagement to increase the resilience and sustainability of Krásná Lípa and to ensure its future as a viable environmental and economic entity.

Identified climate risk hotspots

Bohemian Switzerland National Park, surrounding Krásná Lípa Municipality, based on the analysis performed under WP1, has been classified as a climate risk hotspot in the Czech Republic. This region is subject to climate-induced hazards (like forest fires) considering the rising temperatures, prolonged droughts, shifts in rain patterns, etc.

In 2022, a massive wildfire severely affected the park and nearby communities. This event demonstrated the region's susceptibility to increasing fire hazards enhanced by monoculture forests (largely spruce, susceptible to both drought and bark beetle infestations).

Climate modelling, introduced in Del.1.3, indicates a growing trend of high average temperatures and heat wave occurrences in this region. These conditions are increasing the risk of wildfires, threatening biodiversity and the delivery of several ecosystem services. These risks are further enhanced by socioeconomic vulnerabilities. Both Krásná Lípa and the administrative infrastructure of the park do not possess the necessary tools and adaptive capacity needed to counter increasing climate stressors.

Thus, the Bohemian Switzerland National Park region, a climate risk hotspot, combining high exposure to extreme events (particularly wildfires), ecological vulnerability and economic sensitivity, requires targeted adaptation and resilience-building efforts.

3.4.2 Vision, goals and operationalization

The aim of the Czech FFR, especially in Bohemian Switzerland and the town of Krásná Lípa is to become a role model for sustainable ecological management of the landscape and water management in Europe. The objective of the region is to demonstrate that NBS can effectively address climate-related challenges, improve biodiversity and strengthen community resilience to natural disasters such as floods and droughts.

The Bohemian Switzerland and Krásná Lípa strategy includes the stimulation of private areas for water retention and to flood the flood plains to manage the negative impact of climatic extremes. A network of small water bodies, ponds and wetlands at strategic locations will help not only in enhancing groundwater recharge but also in reducing surface runoff velocity, thus helping the region.

Figure 34 NBS strategy vision for Krásná Lípa

These measures will create a stable aquatic habitat for biodiversity whilst preventing soil erosion and reducing flood risk. This approach encourages the use of indigenous species as well as natural hydrological systems that are focused on ecology and water sustainability. In addition, these programs are framed within wider climate resilience objectives that can create a benchmark for successful local adaptations to climate stressors.

Within the framework of the LAND4CLIMATE project, the region has made efforts to develop a replicable experience that takes advantage of the link between ecological restoration and community development. In part, this model is grounded in the initiative to enhance flood protection by increasing the application of nature-based revitalization treatments and planting in urban environments. This demonstrates a proactive urban planning approach that prioritizes ecological and water management while enhancing the aesthetic and recreational value of the landscape, ultimately fostering a healthier, more resilient and economically vibrant community.

This figure showcases key focus areas including community engagement, ecological preservation, flood protection, climate resilience, water management and biodiversity restoration to enhance environmental sustainability and quality of life.

Land4Climate
A step closer to climate resilience

Table 44 Key aspects of Land4Climate NBS strategy operationalization in Krasna Lipa

Activities	Topics
Implementation plans: adopting plans for NBS	Community engagement: integrating practices with local community involvement.
Environmental assessments: mapping critical areas	Local alignment: ensuring actions meet climate resilience goals
Ownership: community engagement and monitoring	Partnerships: developing strong ties with local stakeholders
Education campaigns: prioritizing awareness and education on sustainability	Sustainable water management: constructing water basins, revitalizing small ponds, cascades and water courses
	Vegetation management: planting native vegetation, ecological corridors restoration
	Culture of sustainability: fostering resilience and sustainable practices

3.4.3 Location and NBS identification

Table 45 Overview of stakeholder-selected no-regret NBS measures for climate risk hotspots in the Krasna Lipa FRR

How were priority hotspots identified?	- Field observation during the 2010 flash flood - Hydrological bottleneck mapping - Participatory insights - Hydrological modelling	Priority hotspots were identified through a combination of empirical data and community experience, ensuring a locally grounded identification of risk zones
What is the justification for NBS location?	- Direct evidence of previous flood damage - Proximity to the problematic stream regulation infrastructure - Technical feasibility within budget and time constraints of the project - Local stakeholder support	Although upstream areas were initially prioritized, lack of landowner consent led to selecting a more feasible downstream site within municipal ownership
What alternatives were considered for scale/ location?	- Upstream expansion near Cimrák pond, requiring land readjustment over a larger territory. - Other private parcels along the stream were considered for extension of NBS	The initial sites were rejected due to: - failure to obtain 80% landowner consent (required by Czech law). - unwillingness of owners to negotiate or respond. Final site selection was therefore a compromise between: - Risk-based evidence, - Ownership and legal feasibility, - Available time and funding.
Which NBS have been selected?	- Small infiltration ponds - Closing drainage ditches	

	- Removing drainage systems - Bioswales - Unsealing of surfaces	

3.4.4 Effectiveness and efficiency

Table 46 Synthesis of integrated assessment methodology and indicators for Czech FRR

NBS	Addressed hazard	Evaluation process	Performance indicators
Small infiltration ponds	Flash floods droughts	Hydrological modelling	Reduction in runoff peak flow Groundwater recharge rates

Table 47 Synthesis on NBS effectiveness, multifunctionality and expected co-benefits

NBS	how does the NBS mitigate the risks?	multi-functionality and expected co-benefits
Small infiltration ponds	- capture and store stormwater during heavy rainfall events - reduce peak flows - mitigate flood risks - mitigate drought impacts by storing water	- enhance local biodiversity - improve microclimate conditions - contribute to air quality improvements

<u>Small infiltration ponds: Co-benefits and trade-off analysis</u>

In the Czech FRR, small infiltration ponds were assessed as a key NBS to tackle heat stress, fluvial flooding and pluvial flooding.

Table 48 Small infiltration ponds: co-benefits and trade-offs

Dimension	Co-benefits	Trade-offs
Environmental	- Improve groundwater recharge and soil health - Enhance biodiversity and habitat quality - Support drought prevention and pluvial flood mitigation	- Require land area within the built environment or natural stream corridors - Possible reduction of land available for other uses
Social	- Contribute to landscape aesthetics and quality - Provide recreational and educational value - Improve local microclimate	- Limited accessibility in dense urban settings - May conflict with alternative development needs
Economic	- Reduce long-term costs of flood damages and heat stress - Potential to increase property attractiveness in revitalized areas	- Relatively high construction and maintenance costs - Compensation costs possible if land-use conflicts arise

For more details, please visit *Schindelegger, A., Thaler, T. (2025). Assessment of co-benefits and trade-offs of NBS (LAND4CLIMATE Deliverable 2.4).*

3.4.5 Land policy and implementation

Table 49 Assessment of alignment between proposed NBS measures and existing land use and spatial planning instruments in the Czech FRR

NBS	Policy/ planning tools used	Intervention type	Effect on land/ property values
Small infiltration ponds	- Access secured through a voluntary agreement with the landowner (no coercive tools applied). - Alignment with the forthcoming designation of the site as a natural protection area and proximity to Bohemian Switzerland National Park (compliance with nature protection planning). - Informed by earlier hydrological restoration projects (though previously not implemented due to political changes). - Supported by municipal and regional water management objectives (in line with Water Framework Directive requirements).	- Performance-based: restoration of more natural water dynamics by removing old drainage, constructing ponds, installing small barriers and closing ditches. - Intervention focuses on water retention, groundwater level increase, soil moisture restoration and biodiversity support. - Designed as multifunctional (hydrological regulation, pasture support, biodiversity corridors).	- Expected neutral to positive effect. - Improves soil quality, grazing productivity, biodiversity and microclimate. - Increases the ecological and recreational value of the land, particularly as it borders a protected area. - Property value likely to rise due to improved grazing conditions and landscape attractiveness. - Some limitations may occur for alternative future land uses, but these are balanced by ecological and agricultural gains.

Implementation plans

Table 50 Implementation plans

Small infiltration ponds implementation roadmap	
Phase	**Activities**
Site Selection and Feasibility Analysis	- Identify priority locations based on hydrological bottlenecks - Use CRA (climate risk analysis) and local topographic models to confirm runoff pathways. - Confirm land ownership and accessibility. - Conduct soil permeability and groundwater recharge potential tests. - Evaluate existing regulation structures and natural streamflow features.
Stakeholder Engagement	- Organize workshops with local advisory board and residents to explain the function and benefits of infiltration ponds. - negotiate access agreements if non-municipal land is involved. - Coordinate with local and regional environmental agencies for legal compliance. - Initiate the formal environmental and construction permitting process.

Technical design	- Co-develop pond layout and design with hydrologists and municipal engineers. - Plan vegetation for pond edges (biodiversity and stabilization). - Design inlets/outlets and sediment traps to reduce maintenance needs.
Construction and Implementation	- Mobilize construction teams and logistics. - Carry out excavation, shaping and lining (if needed). - Install inlet and overflow structures. - Plant vegetation and complete erosion control measures. - Monitor construction impact on surrounding areas (e.g., turbidity, habitat disruption).
Monitoring and maintenance	- Establish baseline water retention and biodiversity conditions. - Install simple monitoring tools (e.g., water level markers). - Define a maintenance plan: - Train municipal staff or local volunteers for upkeep.

3.4.6 Legitimacy and justice considerations

Implementing NBS on private lands requires a legitimacy and justice analysis to secure long-term success and stakeholder support. Their design and execution required technical feasibility, strong social acceptability and procedural integrity. LAND4CLIMATE followed a participatory and transparent approach to maximize legitimacy from multiple angles.

This subsection evaluates the legitimacy of these interventions through three different dimensions:

- input legitimacy (how participatory and inclusive the stakeholders' involvement is)
- throughput legitimacy (about whether decision-making is procedurally fair and transparent)
- output legitimacy (assessing if the interventions are producing, or should produce, effective results)

These points of view together provide a nuanced picture of the extent to which the NBS interventions are just and accepted in the local context of the considered FRR.

Table 51 Overview of legitimacy and justice considerations in the implementation of NBS in the Czech FRR

Small infiltration ponds			
Dimension	**participatory**	**procedurally fair**	**effective results**
Evaluation	**Yes**	**Yes**	**Yes**
Explanation	The location and intervention were based on lessons from the 2010 flash floods Participatory approach (the process integrated both expert judgement and community input)	The process respected legal planning norms and followed transparent steps. No coercive instruments were used	Retention ponds have shown effectiveness in reducing erosion, holding stormwater and enhancing biodiversity.

3.4.7 Stakeholder engagement

The co-development of NBS in Krásná Lípa is a collaborative process, which is primarily also about the integration of different stakeholders and beneficiaries already at the stage of planning and implementation of sustainable development initiatives. Not only does this model increase the effectiveness of environmental projects, but it also ties them to the community and builds in elements that address the desires of the community.

Local residents are the most important stakeholders in the NBS strategy, with many opportunities for their involvement. This hands-on involvement allows them to be a part in the process of ecologically rehabilitating their environment. This can be anything from planting native trees and vegetation and land reclamation through to maintenance and monitoring of newly created or restored natural habitats. These levels of engagement not only benefit the projects physically but also reinforce the community's relationship with their natural habitat, prompting feelings of ownership and activism for the environment.

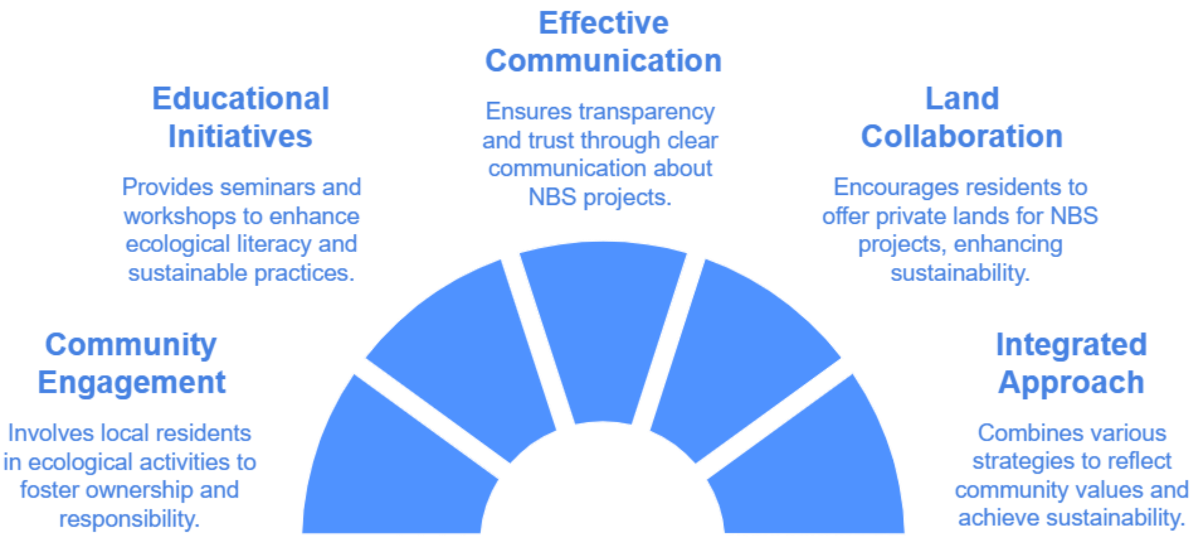


Figure 35 The importance of educational initiatives, effective communication, community engagement, land collaboration, for an effective implementation of ecological sustainability and community participation

The strategy also includes a wide-ranging educational aspect, in which local partners (e.g. education, environmental NGOs) conduct seminars, excursions, workshops on NBS. These events provide opportunities for community members to educate themselves on sustainable practices and learn about the particular environmental threats and mitigation strategies that are expressed in their area. These educational initiatives enhance residents' ecological literacy, enabling them to better engage with NBS projects and make more informed decisions.

Communication is fundamental to the success of these initiatives. Whether dealing with pre-existing initiatives or new ones, enhanced communication ensures transparency, develops trust and facilitates community participation by showcasing the tangible benefits and co-benefits of the NBS efforts (like more biodiversity, better water quality, more places to discover and enjoy nature).

The residents can also get involved by providing their private lands for NBS projects with the municipality or investors. The knowledge, skills and community relationships fostered in this process will allow the facilitation of particular projects, for instance, the creation of micro-wetlands, the restoration of natural floodplains and the establishment of community gardens, all of which contribute to the bigger picture of environmental sustainability and community resilience.

By collaboratively engaging all the relevant stakeholders and beneficiaries, this approach to NBS involvement not only increases the practical outcome of the NBS projects but also guarantees that the NBS projects resonate with the needs and interests of every community involved. The network facilitates a culture of knowledge exchange, capacity development and joint effort for sustainable regional development. This unified approach allows Krásná Lípa to become a pioneer in community-led ecological restoration and resilience, offering a blueprint for other regions around the Europe.

3.4.8 Monitoring, evaluation and learning

Even though the Land4Climate project does not foresee a monitoring and evaluation phase for the implementation of NBS measures, the team that developed this strategy considers that this phase is imperative in the event of identifying future sources of funding.

Therefore, the strategy includes for each NBS measure a brief monitoring, evaluation and learning plan, sufficiently versatile to be adjusted by the FRR in accordance with local needs and availability, at the appropriate time.

1. Objectives of MEL plan

- Assess the hydrological, ecological and socio-environmental impacts of small infiltration ponds implemented in the Czech FRR.
- Track performance related to water retention, biodiversity enhancement and climate resilience.
- Evaluate stakeholder engagement and perceived benefits to ensure the long-term legitimacy and replicability of this NBS.
- Provide evidence and feedback into institutional adaptation and replication strategy.

2. Monitoring indicators

Table 52 Biophysical indicators

Indicator	Description	Method	Frequency
Surface runoff reduction	Decreased flash flood peaks downstream	Inflow/ outflow sensors, post-rain data	After heavy rain events
Infiltration capacity	Effectiveness of water percolation into soil	Infiltration rings, soil moisture sensors	Monthly
Groundwater level	Recharge effect on aquifers	Piezometer readings, local well monitoring	Monthly
Pond water levels	Volume dynamics after precipitation	Staff gauges, remote loggers	Monthly
Biodiversity improvements	Species presence (amphibians, insects, aquatic plants)	Transect surveys, water sampling	Seasonally
Sediment accumulation	Deposition affecting pond volume	Bathymetric surveys, sediment traps	Annually

Table 53 Socio-economic indicators

Indicator	Description	Method	Frequency
Landowner involvement	Degree of cooperation and satisfaction	Interviews, co-monitoring records	Mid-term & final
Public perception and value	Awareness of ecological and flood protection functions	Surveys, workshops, focus groups	Annually
Educational use	Visits from schools and use in public outreach	Event logs, visitor books	Quaterly

Replication potential	Interest in expanding ponds in nearby areas	Municipal reports, local discussions	End of the project

3. Data collection methods
    - Field sensors
    - Remote sensing
    - Biodiversity assessment
    - Stakeholder engagement
    - Socio-economic surveys/ interviews
    - hydrological monitoring
4. Monitoring schedule and evaluation approach

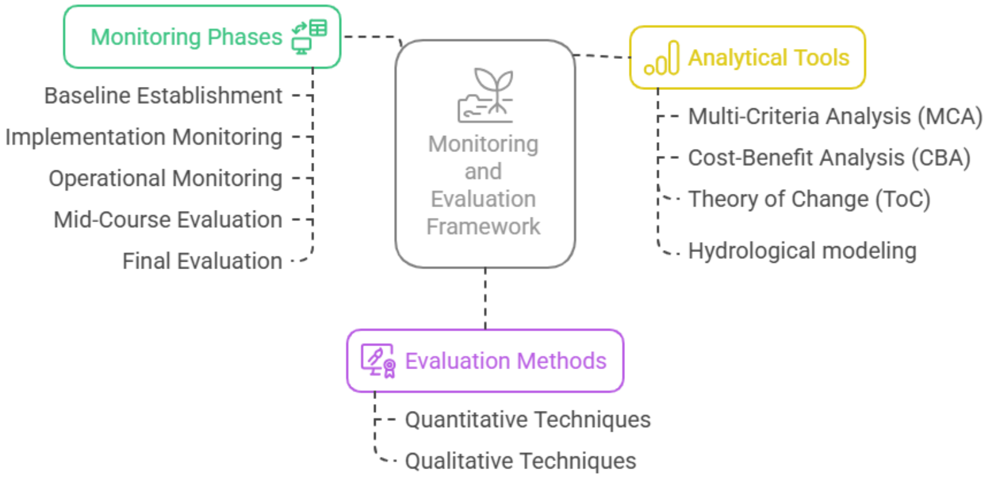


Figure 36 Monitoring and evaluation framework

5. Feedback loops
    - Monitoring results will support adaptive implementation, inform on institutional learning and support scaling strategy.
    - Socio-economic insights from interviews and focus groups will be integrated into the WP6 communication package to foster uptake by other Czech municipalities.
    - Findings will also contribute to the EU-wide dialogue on rural NBS deployment and water retention in mountainous or protected zones.

3.4.9 Summary of eligibility assessment

Table 54 Eligibility assessment of small retention ponds as an NBS in Krasna Lipa FRR

Small retention ponds	
Criterion	**Key justification**
Location	The intervention is located in a municipally owned green area identified as a flood risk hotspot during the 2010 flash flood. The site was chosen due to its downstream position, past damage evidence and feasibility within time and financial constraints. Upstream alternatives were not viable due to landowner resistance and legal limitations.

Effectiveness	Hydrological modeling confirmed that the proposed NBS would slow runoff and mitigate flood risk for 100-year events. The measure also improves groundwater infiltration and reduces downstream flood hazards.
Efficiency	The NBS reuses existing land and infrastructure, avoiding major new construction. Implementation costs are moderate and multiple co-benefits (e.g., microclimate improvement, urban aesthetics) enhance the cost-benefit ratio. Municipal ownership ensured procedural and financial efficiency.
Legitimacy	The project was co-developed through a participatory process involving an advisory board with local experts and citizens. The decision was made transparently by the municipality, incorporating expert and stakeholder input.
Justice	The approach respected property rights, used voluntary acquisition or swaps and avoided expropriation. Equal conditions were offered to all landowners. The intervention delivers public benefits (flood safety, green space, aesthetic improvement) without displacement or exclusion.

3.5 NBS strategy for Ronava River Catchment FRR, Slovakia

3.5.1 Regional context and climate challenges

In the framework of these dedicated goal-oriented strategies for NBS application in the Roňava River Catchment region, a focused approach in re-introducing NBS, necessitated for counteracting the negative impact of prior unsustainable water management strategies and enhancing ecological functionality, is addressed in this strategy. From this strategy comes the emphasis on re-creating natural processes that help mitigate flood risk, drought and sustainable agricultural practices.

In the first phase of the strategy, a careful diagnosis of the catchment area is to be conducted to identify the greatest vulnerabilities and opportunities for action. These details will direct the strategic distributions of NBS to their maximum effectiveness of water storage and flood mitigation.

After talking through the assessment, the strategy focuses on strong community and stakeholder engagement. It is by getting local landowners, farmers, urban planners and governments into the NBS planning and implementation phase that these solutions are ecological while also corresponding with challenging points: local environmental degradation and local economic activities. Platforms such as workshops and community forums will be used as tools for exchanging information and ideas, in collaboration with communities to develop ways forward. The choice of NBS will depend on the specific needs assessed during the assessment phase. Part of it may be diverse solutions that address these issues, such as restored wetlands to absorb floodwaters, more wetlands, afforestation and reforestation to increase groundwater recharge and reduce runoff, sustainable farming, contour plowing and cover cropping, to reduce soil erosion and more green infrastructure in cities to manage stormwater.

NBS implementation measures will be key to checking what can actually work. Successful NBS measures will subsequently be replicated and incorporated into an overarching catchment management plan, contributing to the integration of NBS in regional planning and land-use policies.

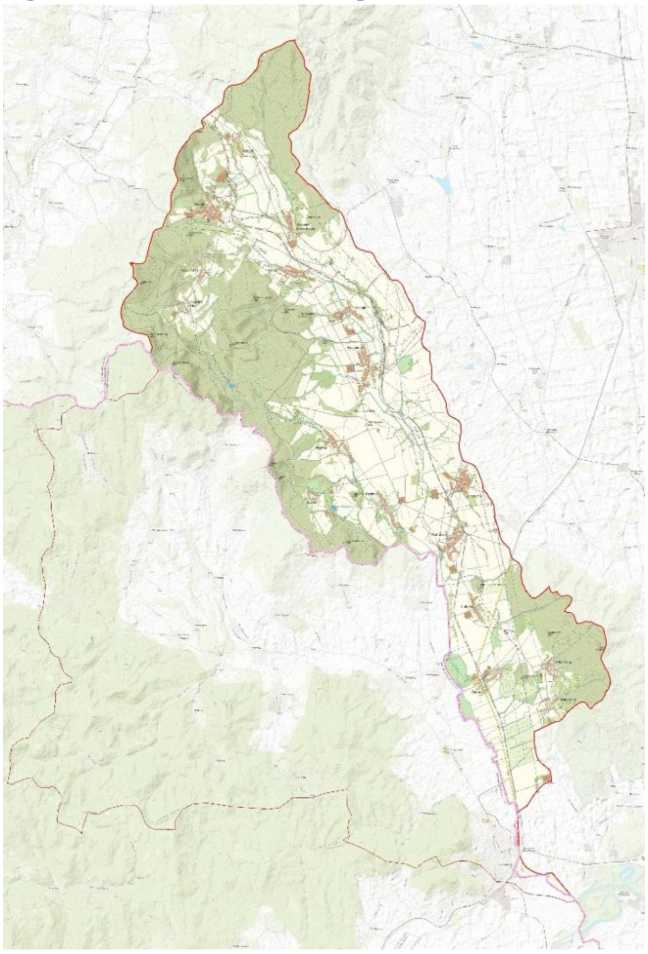
In conclusion, the strategy also involves a framework for continual monitoring and adaptation of the NBS, to ensure their effectiveness under changing climatic conditions. This program of adaptive management enables the catchment to respond adaptively to both expected and unexpected environmental stressors.

The end result will be the Roňava River Catchment moving towards a sustainable future, improved ecological health, reduced susceptibility to climatic extremes and a resilient hydrological system. This orientation can not only contribute to solving currently presented environmental problems, but also to establishing a demonstration of sustainable water and land management that may be replicated worldwide where similar conduct would be required.

Table 55 Slovak FRR brief description

Location

Figure 37 Slovak FRR location maps



The Roňava River basin is situated in the south-eastern part of Slovakia, specifically within the Trebišov district. The river originates in the Slanské vrchy mountains, on the southwestern slope of the Bogota massif, at an altitude of approximately 465 meters. It flows through several

municipalities, including Slančík, Slanské Nové Mesto, Slivník, Kuzmice, Kazimír, Michaľany, Luhyňa, Čerhov and Slovenské Nové Mesto, before joining the Bodrog River
Climate The region experiences a temperate climate with four distinct seasons. Summers are generally warm, with average temperatures ranging from 20°C to 25°C, while winters are cold, with temperatures often dropping below freezing. The area receives moderate precipitation, averaging around 600-700 mm annually. The climate is influenced by both continental and oceanic air masses, leading to variability in weather patterns.
Soil The soils in the Roňava basin are predominantly alluvial, formed from river deposits. These soils are rich in organic matter and nutrients, making them highly suitable for agriculture. The presence of loamy and clayey textures helps retain moisture, which is beneficial for crop growth. However, the soils are also prone to erosion, especially during heavy rainfall events.
Topography The topography of the Roňava basin is characterized by flat to gently rolling terrain, typical of lowland regions. The elevation ranges from about 100 meters in the lowland areas to approximately 465 meters in the mountainous regions where the river originates. The landscape includes floodplains, which are crucial for managing floodwaters and minor elevation changes that influence the flow and distribution of water. The river valley is deeply cut into the bedrock and its alluvial floodplain is relatively narrow (e.g. at Kuzmice 300 m, at Michaľany 600 m). During periods of intense rainfall and rapid snowmelt, particularly in the northern part of the catchment area, large amounts of water flowing over the surface reaches the narrow floodplain, causing flooding.
Land Use Land use in the Roňava basin is primarily agricultural, with large areas dedicated to the cultivation of crops such as wheat, barley, corn and sunflowers. There are also patches of forested land, which provide important ecological functions, including habitat for wildlife and regulation of the water cycle. Urbanized areas are relatively small, consisting of towns and villages that support local industries and services.
Population The population in the Roňava basin is concentrated in small villages. The region is predominantly rural, with a strong focus on agriculture and related industries. The local communities are engaged in farming, livestock rearing and small-scale manufacturing. The population density is relatively low compared to urban areas, contributing to a close-knit community structure.

Climate vulnerabilities

Practices from the past for land and water management that boost agricultural productivity have led to serious environmental challenges in the Roňava River Catchment. Though made to permit intensive agriculture, these practices have caused many unintended and harmful environmental impacts. It is essential for the region to shift gears and adjust its management practices to adapt to these problems and avoid further climate impacts in the future.

These changes to engineer water diversion have drastically increased the vulnerability to floods. Flash floods, defined as rapid onset events, can be extremely challenging to predict, especially in periods of excessive hazard activity (specifically storm) within the Roňava River Catchment. As a whole, the catchment's ability to slow and buffer stormwater flow is diminished and this intensification poses risks to life, property and even the ecosystems they support. The floods often affect the local communities, destroy crops and result in production and economic losses.

Accelerated runoff and increased flood risk are already challenges, which will be exacerbated by climate change impacts -- temperatures are expected to rise at an increasing rate as we move to the end of the century. Sightings of more frequent and more severe weather events, including storms and heavy rainfall, underline the need for a robust adaptation strategy. The region should adopt efficient strategies that alleviate the present risks while improving catchment resilience to endure future climatic changes.

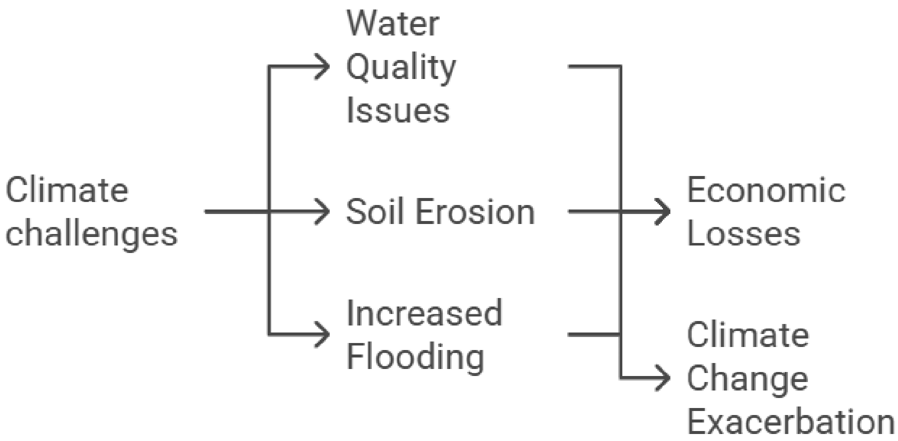


Figure 38 Climate challenges in Ronava Region

This figure outlines key challenges such as droughts, water shortages, inadequate infrastructure and increased flood risks, leading to infrastructure damage, ecological degradation and biodiversity impacts.

Table 56 Climate risk assessment in Ronava Region

Hazard	Consequences		
	People	Assets	Environment
Flash floods			
Drought			
Urban heat			
Heat waves			

	No risk		Low risk		Moderate risk		High risk		Very high risk

Table 57 Summary of climate risks and main consequences in Ronava Region

Climate risks analysis and interpretation			
Flash floods	**Drought**	**Urban heat**	**Heat waves**
- Caused by altered landscapes reducing natural water retention. - High threat to human safety in rural areas with poor flood defenses.	- Threatens water availability for drinking, sanitation and agriculture. - Farmers face reduced yields and economic stress.	- Affects vulnerable populations through intensified heat stress. - Infrastructure damage (roads, buildings) and increased	- Health risks include more heat-related illnesses and hospitalizations. - Increased energy use for cooling, higher

- Infrastructure (roads, bridges) and agriculture face serious damage. - Environmental impacts include soil erosion, biodiversity loss and water contamination through sedimentation.	- Environmental effects: groundwater depletion, soil degradation, habitat and biodiversity loss—especially in wetlands and river systems.	energy demand for cooling. - Environmental degradation includes vegetation stress, soil drying and reduced urban greenery.	business costs, infrastructure strain. - Environmental stress: lower water availability, worsening soil and biodiversity conditions, weakened ecosystems.

To address these issues, there is a vital need to develop measures targeting the protection of slow runoff. These solutions consist of restoring natural wetlands, reforestation and incorporating sustainable agricultural practices that enhance soil structure, improve water infiltration and capture water. These NBS are essential for reestablishing the ecological balance and connectivity of the catchment. They offer a dual effort that both helps the landscape hold, store and cycle more water while also showing great restoration of biodiversity and carbon sequestration.

Different measures are already at work in the Roňava River Catchment addressing the aftermath of historical practices and the current of ameliorated conditioned climate, building resilience and restoring ecologies. This involves a holistic approach to environmental management, incorporating both technological innovations and traditional knowledge. Community engagement and collaborative relationships across stakeholders are essential to the successful adoption of these adaptations, too.

The Roňava River Catchment is confronting complex challenges that need holistic and integrated solutions. Focusing on flood and runoff prevention, in conjunction with climate adaptation strategies, is a key ingredient to ensure the region secures a sustainable and resilient future.

<u>Identified climate risk hotspots</u>

The Rónava River Basin of southern Slovakia has been identified as a climate risk hotspot according to the concept of climate risk as a combination of the exposure and vulnerability to several climate-related hazards, socio-economic pressures and land use changes. This region is mainly an agricultural one, with increasing areas of monocultures and intensive management of the land, thus being more susceptible to climate impacts.

Important climate risks in the Rónava River Basin include:

- more frequent and severe droughts, especially during the growing season.
- heatwaves, which are likely to become more frequent and severe, are also an important climate risk.
- pluvial flooding and flash floods (mostly in upstream areas) of those areas from short length of time, intense rain events that can overwhelm the landscape.
- decreasing water availability during summer months.

The basin's susceptibility is compounded by the absence of strong water retention infrastructure (particularly in upstream sub-catchments), continuous degradation of the land (as a result of unsustainable agricultural practices leading to low assimilation of water in the soil), hindering the adaptive capacity of biodiversity and decreasing climate extremes resilience of landscapes.

This complex interplay, compounded by the uncertainties of climate change, justifiably categorizes the Rónava River Basin as a regional climate risk hotspot, demanding immediate action through adaptive land and water management, ecosystem restoration and sustainable agro-practices.

3.5.2 Vision, goals and operationalization

This vision promotes the embedding of NBS to create a hydrological and ecological resilience system to both floods and droughts. It aims to promote a harmonious relationship between human agricultural practice and the environmental process within the river catchment to promote long-term future ecological health and sustainability. The approach that drives this vision is to improve collaboration and adaptive management of water resources at the catchment scale, with a focus on achievement of multi-objective outcomes, which means working together in action to build resilience to the extremes of climate and hydrology that will cause environmental, economic and social pain if they are not managed well.

The approach to rolling out NBS with Ronava Rver catchment as the main focus is systematically tied to the larger cause of rejuvenating Roňava River Catchment into a watershed of resilience and ecological health. This strategy involves the integration of NBS with community-driven approaches and aims at establishing a sustainable balance between human activities and natural dynamics in the catchment. The adoption of NBS will improve the immediate environmental conditions while also ensuring the long-term sustainability and health of the ecology of the area, making the catchment a relevant best practice for innovative water management and ecological design. The overarching principle of landscape management, targeting collective goals, lays a system of collaboration that allows for overcoming social barriers towards cooperation and provides the solution to tackle climate change and manage the water shortage properly in the 21st-century landscape.

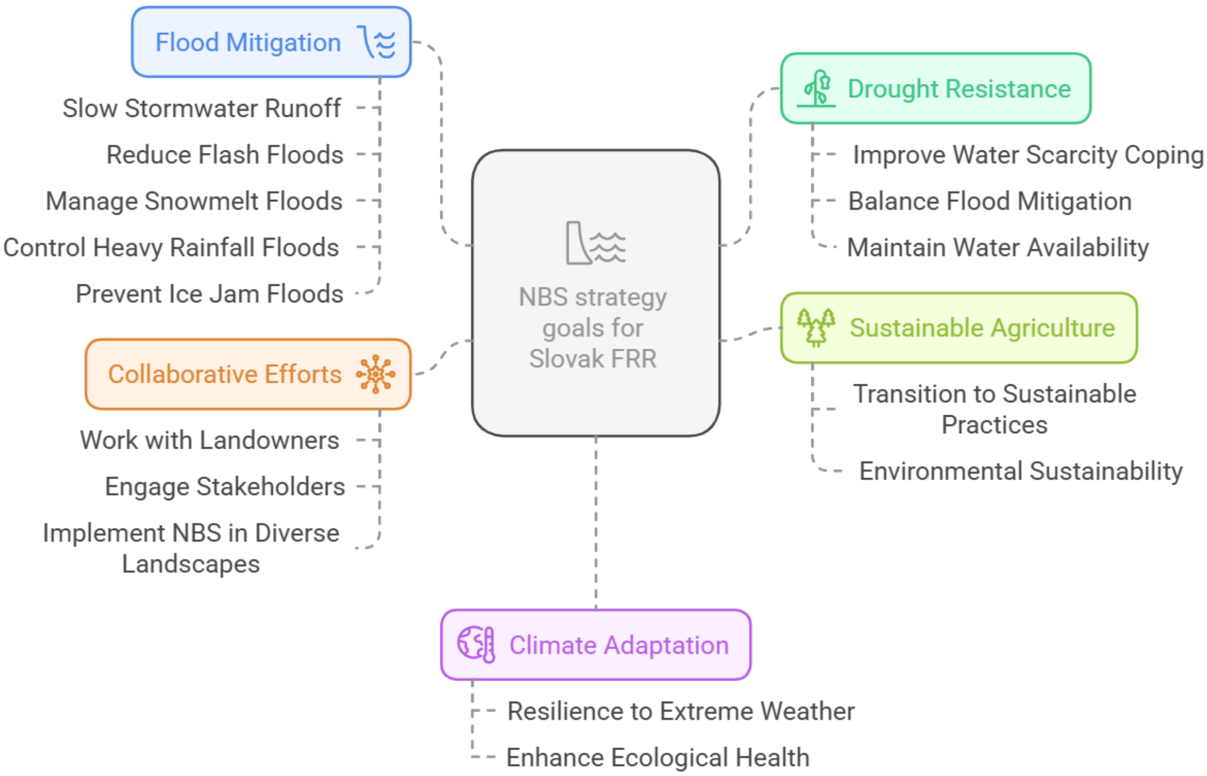


Figure 39 NBS goals for environmental resilience in Ronava River catchment

This figure highlights strategies such as flood mitigation, drought resistance, sustainable agriculture, collaborative efforts and climate adaptation to enhance ecological health and sustainability.

Operationalization of Roňava River Catchment strategy

Table 58 Key aspects of Land4Climate NBS strategy operationalization in Ronava

Activities	Topics
Mapping phase: a detailed mapping of hydrological features.	Community engagement: integrating practices with local community involvement.
Environmental assessments: mapping critical areas	Local alignment: ensuring actions meet climate resilience goals
Stakeholder engagement: collaborating with local communities and partners.	Reforestation: enhancing biodiversity and soil stability
Education campaigns: prioritizing awareness and education on sustainability	Multifunctional landscape: balancing ecology with agricultural productivity
	Wetland restoration: improving flood management and water quality
	Sustainable agriculture: techniques to reduce erosion and retain water.

3.5.3 Location and NBS identification

Table 59 Overview of stakeholder-selected no-regret NBS measures for climate risk hotspots in the Slovak FRR

How were priority hotspots identified?	multi-criteria CRA - Hazard data - Flood risk maps - Exposure analysis - Vulnerability indicators	Priority hotspots were identified through an integrated CRA combining hazard data, exposure mapping and vulnerability indicators, providing a robust evidence base for spatially targeted NBS planning
What is the justification for NBS location?	- The selected locations are justified by a combination of climate risk analysis, expert evaluation and stakeholder engagement	- Flood-prone hotspot - Geological and hydrological conditions - CRA and Climadam project data - Soil degradation and drought - multicriteria analysis
What alternatives were considered for scale/ location?	- Several alternatives were considered during the site selection	- One site was excluded due to lack of cooperation. - The remaining 7 were prioritized based on a structured set of technical, geographic and social criteria. - The final sites emerged from voluntary owner engagement and expert-grounded feasibility screening
Which NBS have been selected?	- Water retention ponds - Check dams - Surface drains - Contour trenches - Wetlands - River meandering	

3.5.4 Effectiveness and efficiency

Table 60 Synthesis of integrated assessment methodology and indicators for Slovakia FRR

NBS	Addressed hazard	Evaluation process	Performance indicators
Water retention ponds	Flash floods droughts	- Flow path analysis - drainage basin delineation - Geospatial analysis with QGIS and GRASS GIS tools - Sites were evaluated topographically to determine suitability for retaining water	- Surface runoff volume collected per catchment - Catchment size - Qualitative assessment of mitigation potential

Table 61 Synthesis on NBS effectiveness, multifunctionality and expected co-benefits

NBS	how does the NBS mitigate the risks?	multi-functionality and expected co-benefits
Water retention ponds	- Slows surface runoff, reducing flood peak intensity. - Increases water infiltration into the soil and groundwater. - Stores water for periods of drought, reducing water scarcity and ecological stress	- Hydrological regulation (flood and drought mitigation). - Improved soil moisture and groundwater recharge. - Ecological restoration by supporting local biodiversity and vegetation. - Potential agricultural productivity improvement and water quality benefits from reduced pollutant runoff

Water retention ponds: Co-benefits and trade-offs

In the Slovakian FRR (Ronava River catchment), retention ponds were assessed as a key NBS, particularly in agricultural areas prone to heavy rain and drought.

Table 62 Water retention ponds: co-benefits and trade-offs

Dimension	Co-benefits	Trade-offs
Environmental	- Enhance biodiversity and ecological connectivity - Improve soil health and groundwater recharge - Contribute to carbon storage - Support drought and pluvial flood mitigation	- Require large land areas and buffers - Reduction of agricultural productive land
Social	- Improve landscape aesthetics - Provide potential for recreation and education - Strengthen local resilience and cultural value of landscape	- Possible land-use conflicts with farming communities - May reduce land-use flexibility
Economic	- Reduce long-term costs of flood damages and drought impacts - Contribute to agricultural resilience (erosion reduction, water availability)	- High construction and maintenance costs - Compensation costs to landowners - Long payback time

For more details please visit *Schindelegger, A., Thaler, T. (2025). Assessment of co-benefits and trade-offs of NBS (LAND4CLIMATE Deliverable 2.4).*

3.5.5 Land policy and implementation

Table 63 Assessment of alignment between proposed NBS measures and existing land use and spatial policy instruments in the Slovak FRR

NBS	Policy/ planning tools used	Intervention type	Effect on land/ property Values
Water retention ponds	- Direct negotiations, motivation and persuasion were used to secure landowner support. - Landowners were approached via personal contacts and an open call; 8 responded, 7 were selected. - No coercive tools (e.g. expropriation, zoning changes) were used or planned. - Written agreements were signed	The interventions are performance-based, tailored to the type of land and specific water/ erosion issues.	- No reduction in property rights or land value is expected. - Ownership remains unchanged. - Some disruption during construction may appear. - positive effects on long-term are expected. - Over time, land value may increase due to enhanced productivity and ecosystem quality

Implementation plans

Table 64 Implementation plan

Water retention ponds implementation roadmap	
Phase	**Activities**
Preparatory phase	– Identify priority locations using climate risk maps, land ownership status and stakeholder interest. – Conduct topographic and hydrological assessments using GIS tools to confirm technical feasibility. – Perform site visits and consultations with landowners. – Sign cooperation agreements with landowners (non-coercive, voluntary basis).
Design and planning	– Develop detailed NBS design for each site with input from hydrologists, ecologists and engineers. – Tailor pond dimensions and infiltration systems to land characteristics and runoff data. – Prepare construction-ready documents, including permit applications if required. – Include measures for biodiversity (e.g., marginal vegetation, wetland buffers).
Stakeholder engagement	– Organize workshops and bilateral meetings with landowners to review designs and clarify roles. – Train landowners in NBS functionality and post-implementation maintenance. – Ensure transparent communication of project goals, co-benefits and timelines.
Implementation	– human and technical resources mobilization – pond development according to design, adjusting to field conditions as needed – Construct associated features: inlets/outlets, spillways, sediment traps. – Monitor implementation progress and ensure ecological safeguards (erosion control, minimal disturbance)

Post-construction and maintenance planning	– Inspect construction quality and verify retention and infiltration performance. – Transfer post-construction monitoring responsibilities to trained landowners. – Formalize long-term maintenance agreements (e.g., 5–10 years).
Monitoring and adaptive management	– Establish monitoring protocol for water levels, vegetation and erosion. – Collect data (e.g., runoff volume captured, infiltration rate, biodiversity indicators). – organizing periodical meetings with landowners to refine maintenance practices and improve designs for future NBS replication

3.5.6 Legitimacy and justice considerations

Implementing NBS on private lands requires a legitimacy and justice analysis to secure long-term success and stakeholder support. Their design and execution required technical feasibility, strong social acceptability and procedural integrity. LAND4CLIMATE followed a participatory and transparent approach to maximize legitimacy from multiple angles.

This subsection evaluates the legitimacy of these interventions through three different dimensions:

- input legitimacy (how participatory and inclusive the stakeholders' involvement is)
- throughput legitimacy (about whether decision-making is procedurally fair and transparent)
- output legitimacy (assessing if the interventions are producing, or should produce, effective results)

These points of view together provide a nuanced picture of the extent to which the NBS interventions are just and accepted in the local context of the considered FRR.

Table 65 Overview of legitimacy and justice considerations in the implementation of NBS in the Slovak FRR

Water retention ponds			
Dimension	**participatory**	**procedurally fair**	**effective results**
Evaluation	**Yes**	**Yes**	**Yes**
Explanation	The NBS site selection was based on an open call and direct outreach, where landowners were invited to express interest	A structured and transparent multi-criteria analysis was used to prioritize sites, applying predefined factors.	The interventions are tailored to local conditions and designed by experts with prior experience in similar contexts

3.5.7 Stakeholder engagement

The co-production process of NBS of the Roňava River Catchment within the LAND4CLIMATE initiative strongly depends on active local stakeholders' and beneficiaries' involvement and cooperation. These initiatives and their activities are programmatic and relative to the specific ecosystem upon which they're placed. Their genesis and evolution are also contextualized and sensitive to the inputs of the people living in these environments.

At the heart of the engagement strategy is the participation of private landholders. Acknowledging their critical power over land use and management, the project partners have hosted targeted workshops to engage this grouping. These workshops provide the opportunity for exchange, explaining to landowners the goals of the project and what specific roles they can play. Topics include the potential benefits of implementing NBS, any technical support available and the wider environmental, social and economic benefits of being part of the project.

Figure 40 Key Pillars of Effective NBS in Ronava River catchment

This figure emphasizes local stakeholder collaboration, continuous engagement, private landowner involvement and empowerment through education as essential components for the successful implementation of NBS strategies.

Through educational sessions, the landowners will receive practical scientific knowledge needed to work on the NBS. They are invited to reflect on how they can manage their land in a way that meets both their personal goals and contributes to larger environmental goals. These decisions can be made in accordance with the tenets of sustainable land management and conservation due to this enabling.

In addition, by engaging local stakeholders in the co-production of NBS, solutions can be effective whilst considering the baseline conditions and challenges of the Roňava River Catchment. Accordingly, this localized focus improves the effectiveness of NBS, as it ensures solutions are designed based on the realities of the site and the support of beneficiaries or those who will be affected by the strategies is harnessed.

Ongoing communication with stakeholders during implementation and monitoring is key. By engaging in this iterative conversation, feedback from all relevant stakeholders is incorporated into project management strategies, enabling adaptive management approaches that are capable of addressing new challenges and seizing new opportunities. In addition to its environmental goals, the project also seeks to serve as a pilot for a community-based model of sustainable management of new areas that can potentially be extended to the rest of the region. This participative approach is making sure NBS deliver benefits from enhanced biodiversity and better water management, to greater ecological resilience and monetary gains, benefits that are sustained in the long term for all generations to come.

3.5.8 Monitoring, evaluation and learning

Even though the Land4Climate project does not foresee a monitoring and evaluation phase for the implementation of NBS measures, the team that developed this strategy considers that this phase is imperative in the event of identifying future sources of funding.

Therefore, the strategy includes for each NBS measure a brief monitoring, evaluation and learning plan, sufficiently versatile to be adjusted by the FRR in accordance with local needs and availability, at the appropriate time.

1. Objectives of MEL plan

- Evaluate the performance of water retention ponds in reducing flood risk, increasing water availability during dry periods and enhancing local biodiversity.
- Assess the cost-efficiency and social acceptance of the intervention as a “no-regret” NBS.
- Provide continuous feedback into governance and institutional learning and scalability and replication strategies.

2. Monitoring indicators

Table 66 Biophysical indicators

Indicator	Description	Method	Frequency
Retention capacity	Volume stored during heavy rainfall	Water level sensors, manual gauging	Post-storm & monthly
Infiltration rate	Water percolation into subsoil	Infiltration tests, soil moisture sensors	Seasonal
Peak flow reduction	Dampening of flood peaks downstream	Flow meters at inlet/outlet	Event based
Biodiversity increase	Amphibians, aquatic insects and vegetation presence	Transects, species inventories, camera traps	Seasonal
Water quality	Impact on local surface water (e.g., sediment, nutrients)	Water sampling and lab analysis	Seasonal

Table 67 Socio-economic indicators

Indicator	Description	Method	Frequency
Stakeholder satisfaction	Perception of risk reduction, aesthetics and land value	Interviews, perception surveys	Mid-term & final
Community involvement	Participation in monitoring, maintenance, or educational activities	Event logs, co-monitoring records	On-going
Educational use	Number of visits by schools and community groups	Event logs, visitor books	Monthly
Replication interest	Local demand for similar measures in other villages	Municipal reports, local discussions	End of the project

3. Data collection methods
   - Field sensors
   - Remote sensing
   - Biodiversity assessment
   - Stakeholder engagement
   - Socio-economic surveys/ interviews
   - hydrological monitoring

4. Monitoring schedule and evaluation approach

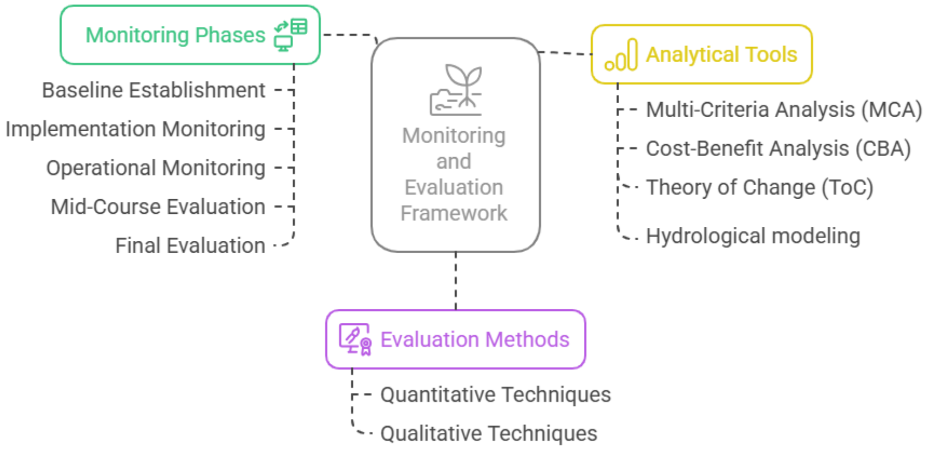


Figure 41 Monitoring and evaluation framework

5. Feedback loops
   - Continuous monitoring results will support evidence-based adjustments and be shared with stakeholders in real time.
   - Evaluation outputs will feed into institutional learning and support the co-design of future interventions.
   - Final findings can be translated into policy recommendations and integrated into capacity-building efforts

3.5.9 Summary of eligibility assessment

Table 68 Eligibility assessment of water retention ponds as NBS in Ronava Region

Water retention ponds	
Criterion	**Key justification**
Location	Sites were selected within the Roňava basin based on a combination of climate risk analysis (from WP1), expert site visits and stakeholder engagement. Most sites are in sub-basins categorized as high-risk flood contributors. Field observations confirmed issues such as flash flooding, erosion and drought on these lands.
Effectiveness	Interventions are designed to address specific hazards (flooding, drought, soil degradation) and are based on local hydrology, land type and runoff characteristics (e.g. CN curve analysis). NBS are tailored to maximize water retention and reduce runoff at site level.
Efficiency	The selected NBS are cost-effective, leveraging landowners' in-kind contributions and implemented through voluntary cooperation. Measures are simple and designed for high

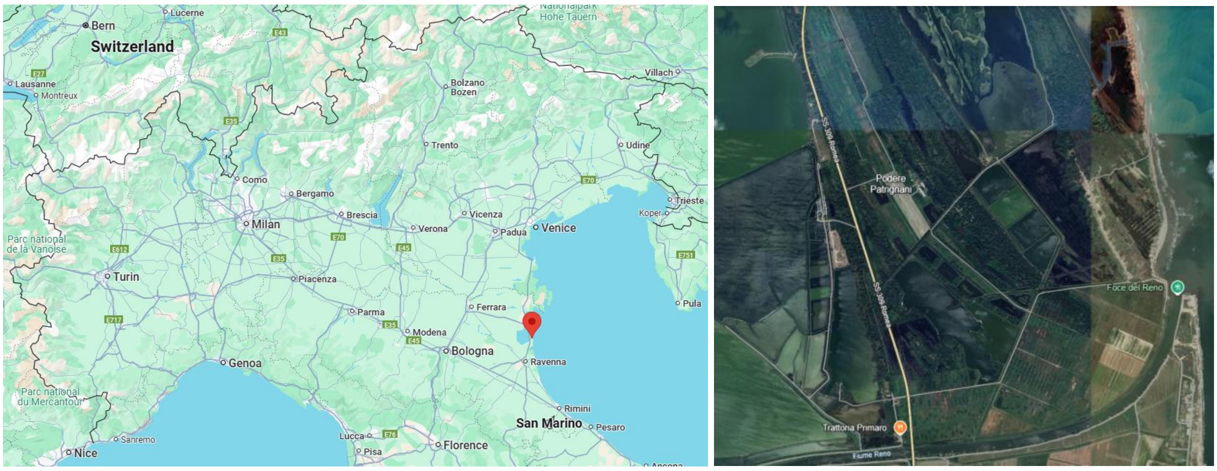
	impact at low-to-moderate cost, with expected long-term returns in terms of improved soil fertility and agricultural yield.
Legitimacy	A transparent multi-criteria process decided site selection. Landowners were directly involved through questionnaires, co-design and consultation. Participation was voluntary and agreements ensure shared responsibility for maintenance. No coercive instruments were used.
Justice	The approach is inclusive and non-disruptive: landowners retain ownership and benefit directly through improved productivity. There is no harm to surrounding landowners. Benefits extend to the broader community via improved flood control, biodiversity and landscape quality.

3.6 NBS strategy for Delta Po FRR, Italy

3.6.1 Regional context and climate challenges

In Emilia-Romagna, NBS strategy focuses on the varied environmental challenges posed by climate change in particular, flooding, drought, intrusion of salt into freshwater sources, cyclones and their resultant biodiversity loss. In its approach, this strategy joins ecological re-alignment with robust infrastructure resilience, so that both natural and human systems can thrive side by side across an area of differing landscapes along the Emilia-Romagna coast.

Table 69 Italian FRR brief description

Location  Figure 42 Italian FRR location maps https://maps.app.goo.gl/z7JTamQoRpprDhK17
Climate The climate of this region is conditioned by the presence of the Adriatic Sea, which mitigates temperatures. However, this sea is not very wide and, especially in the northern part, is shallow, so it can only partially soften temperatures, especially in winter, when strong winds blow from the north-east (Bora). The Adriatic region is characterized by average winter temperatures of around 5° C, also due to the Bora that blows over the area; autumn and spring are often rainy; summer is hot and sultry with frequently thunderstorms.
Soil The area features a lot of different habitats and soils due to the complexity of the landscape evolution since as these lands were formed by the sedimentation of debris carried by the Po River trough the

millennia. Most of the soil are made by sandy and silty sediments which, starting from the coast, become more and more developed and compact due to the presence of vegetation
Topography The area is mostly at sea level, but presents some area below that level due to subsidence issues, both natural causes and to past human activities of natural gas extraction that occurred in areas surrounding the NBS implementation area.
Land Use The NBS implementation site, which is a single private property, is predominantly rural with agricultural, fishery and hunting activities with only few buildings needed to run the activities mentioned above. There are also woodlands, mostly pine forests, especially in the northern and western area, more open areas with agricultural fields in the southern part and coastal habitats, natural beaches and coastal lagoon in the eastern part. Outside the private property boundaries there are a national natural reserve managed by Carabinieri Corp of Foresters, a military shooting range, a very important highway and an other private owned area.
Population Since the land is private, there are very few residents (mostly employees), but it is connect to the E55 - “S.S. 309 Romea” highway, a very busy and important road for Region economy and the tourist areas of Lidos of Comacchio and Casalborsetti.

To this end, the NBS strategy begins by meticulously studying Emilia-Romagna's ecological and hydrological systems. The strategy then draws on this fundamental reconnaissance to deploy a series of projects that marry natural systems inherent to ecosystems with technology for dealing out damage and winning sustainable benefits.

Key aspects of the strategy include wetland restoration and renewal efforts along river and coastal margins. Wetlands help in sponging up stormwater, reducing, reducing flood risks and filtering pollutants, thus maintaining water quality. Similarly, reforestation is aimed at stabilizing the soil, decreasing runoff water and enhancing biodiversity while also creating habitat for local wildlife or representatives of species that come here but do not stay permanently. These are especially needed downstream of the River Panaro and inside the Po Delta Region, where ecological function is at once flood defense and species conservation.

In coastal areas, the strategy is focused on restoring dunes and salt marshes, which are natural barriers against storm surges and coastal erosion. These features not only act as buffers from coastal storm damage but also serve as vital habitat for coastal and marine species. Vegetation, specifically ones that tolerate salty conditions, is to be introduced in an effort to reverse saltwater encroachment into freshwater habitats.

These include promoting sustainable agricultural practices, crop rotation, organic farming and tying in irrigation systems that reduce water demand and lessen reliance on freshwater sources.

Part of this strategy involves ensuring that community stakeholders receive the opportunity to be onboard so that they are actively engaged alongside their neighbors in the planning and implementation of projects. To enhance knowledge on the value of NBS, workshops and educational programs will be designed for local residents, farmers and landowners, focusing on how to practice sustainable land management.

Lastly, there will be a holistic monitoring and adaptive management system put in place that will help understand the success of implemented solutions and adapt to emergent environmental feedback. As new threats and new science emerge, the strategy must adapt to ensure sustainability and resiliency are possible over the long term.

With this broad NBS approach, Emilia-Romagna envisions its territory as a vibrant, inclusive and biodiversity-rich environment for people and the natural world to thrive.

Climate vulnerabilities

Following many years of focused development and use of its natural resources, the Emilia-Romagna region is facing a multitude of environmental challenges that impact both its riverine and marine-coastal environments. Such challenges not only jeopardize the fragile ecological stability of the region but also create significant threats to both natural and anthropogenic infrastructures. The ecological integrity and economic stability of the region depend on addressing these issues.

Flooding and drought are among the top five issues for Emilia-Romagna. These twin disasters hit with different magnitudes, but they have a similar effect: a grave disruption of the agriculture sector, the backbone of the region's economy and a huge amount of stress on the local communities and ecosystems. Flooding can cause soil erosion, a loss of agricultural productivity and damage to infrastructure and drought can stress water supplies, harming both human consumption and agricultural irrigation

Being located in the proximity of Adriatic Sea, the area faces the problem of saltwater intrusion (especially in the coastal areas). This process is amplified by climate change, tending to lower river flows (that often accompany droughts) and increasing sea levels (that can inundate freshwater systems and agricultural lands, salinizing them). Salt intrusion deteriorates drinking water quality, reduces soil quality and hampers the yield of crops and diversity.

Coastal defenses and infrastructure are immediately threatened by storm surges (often associated with severe weather events). Climate change-induced growth in storm intensity and precipitation has raised the vulnerability of coastal flooding, adding to the recent phenomenon of coastal erosion, at the expense of crucial environments in the nature reserves, especially in the Po Delta area. As coastal erosion washes away natural barriers for protection against the sea, it increases the inland threat of future surges while also destroying biodiversity.

Collectively, flooding, drought, salt intrusion and coastal erosion - all effects of climate change - have precipitated significant biodiversity loss across the region. Habitat destruction, mainly in natural reserves, causes the loss of species diversity and abundance. The decline of genetic diversity doesn't just alter the delicate balance of nature but it also erodes the present system's ability to adapt and recover from future disasters.

These issues leave both man-made and natural infrastructure extremely vulnerable to these environmental threats. Wetlands and coastal dunes that help to mitigate the effects of extreme weather, are gradually deteriorating. The outcome has been that those ecosystems are no longer able to absorb the shocks of heavy rainfall and flooding and the collapse of artificial infrastructure (roads, bridges and water management systems), which leads to economic losses.

To answer these challenges, it is required an integrated approach that should include measures based on increasing infrastructure resilience, restoring natural habitats and implementing green alternatives to water/land management. How the region responds to these challenges will be critical to maintaining ecological balance in the face of increasing environmental pressures while supporting a vibrant economy.

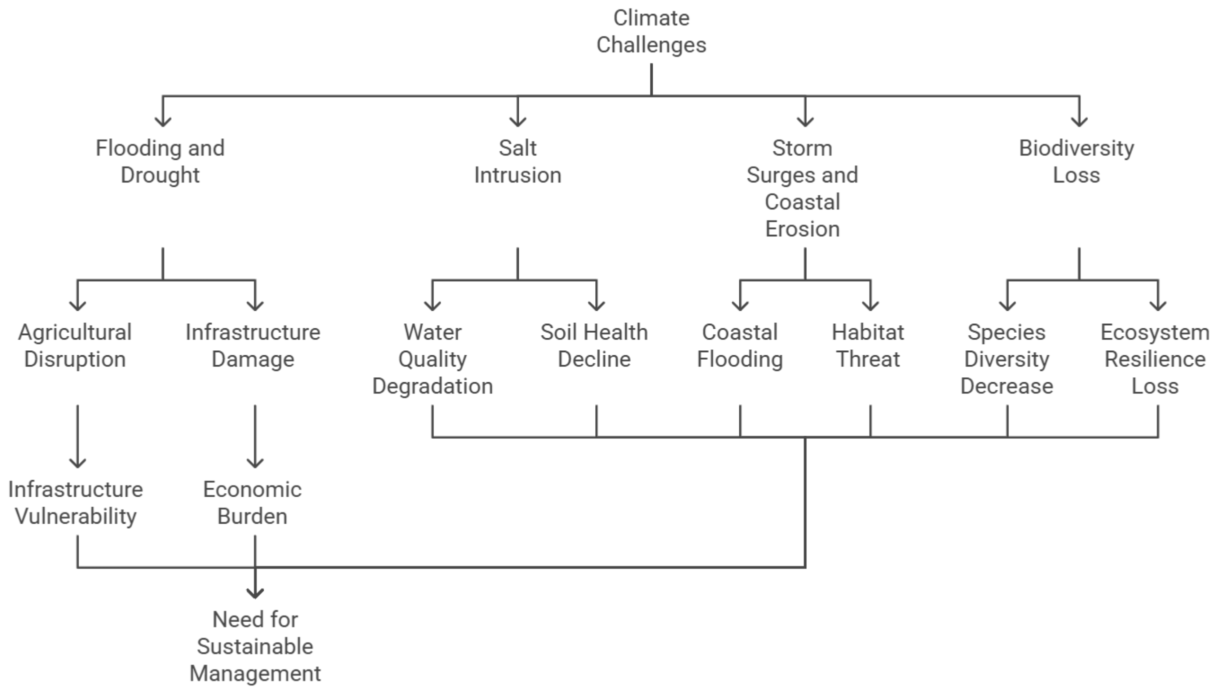


Figure 43 Environmental challenges and their impacts in Emilia-Romagna region

This figure outlines key challenges such as flooding, drought, salt intrusion, coastal erosion and biodiversity loss, along with their cascading effects on agriculture, infrastructure, ecosystems and economic sustainability, emphasizing the need for sustainable management.

Table 70 Climate risk assessment in Italian FRR

Hazard	Consequences		
	People	Assets	Environment
Flash floods			
Drought			
Urban heat			
Heat waves			

	No risk		Low risk		Moderate risk		High risk		Very high risk

Table 71 Summary of climate risks and main consequences in Italian FRR

Climate risks analysis and interpretation			
Flash floods	**Drought**	**Urban heat**	**Heat waves**
- Major threat in low-lying coastal areas and Po River settlements. - Vulnerable populations at risk due to rapid water accumulation and poor drainage. - Significant asset damage: agriculture,	- Water scarcity affects public supply and agricultural irrigation. - Health risks increase due to urban heat stress and reduced sanitation. - Agriculture suffers lower yields and economic instability.	- Health threats for vulnerable groups in densely populated areas. - Rising energy demands for cooling strain power systems and increase costs. - Infrastructure degrades under	- Frequent, intense heatwaves cause severe health issues and overload healthcare systems. - Extreme heat worsens drought, cripples crops and damages infrastructure.

urban infrastructure, frequent repair costs. - Environmental effects: runoff-driven soil erosion, habitat destruction, water contamination affecting ecosystems.	- Environmental impacts: desertification, increased soil salinity, declining biodiversity in wetlands.	prolonged heat exposure. - Ecosystem stress: urban green spaces and water bodies face reduced resilience and evaporation losses.	- Ecosystem degradation includes habitat loss and increased salinity intrusion in the Po Delta.

<u>Identified climate risk hotspots</u>

The area of East Emilia is part of the Po Valley, a primarily flat and densely populated region with intensive agricultural and industrial activity. This region has been identified as a climate risk hotspot since it is particularly susceptible to a variety of climate-related risks.

Several key climate risks are floods and pluvial events, water scarcity and drought, soil degradation and land subsidence.

Heavy precipitation (in an extensive soil sealing environment) results in a higher number and increased intensity of flooding episodes in cities and rural areas. The region also needs to face more and longer-lasting drought periods. These events add supplementary pressure on water resources. Rising temperatures and changing precipitation patterns are contributing factors that are exacerbating these risks

The urbanized areas like Modena and Reggio Emilia, with high sealing of the soil surface and poor green infrastructure, enhance the heatwave effect.

Land use changes and groundwater over-extraction lead to the degradation of soil and land subsidence, raising hydrogeological risks. Socio-economic pressures, including urban sprawl, density of infrastructure and competition for water resources, exacerbate these risks. Low-lying rural municipalities (particularly those close to river networks and urban edges) are the major climate risk hotspots according to spatial analyses.

3.6.2 Vision, goals and operationalization

The vision Emilia-Romagna region, stretching from the Panaro River to the Adriatic Sea, foresees a landscape based on nature and human activity harmoniously coexistence. An adaptive framework that anticipates and responds to future climatic challenges will lie at the base of this vision. This perspective aims to integrate ecological and economic aspects into a resilient approach that sustains both the region's biodiversity and the vitality of its communities.

Anchoring this vision are solid ecological corridors that unify the inland agricultural fields to the coastal natural reserves. These corridors are lifelines critical for biodiversity that allow migration and genetic exchange for many wildlife species. As natural buffers, they contribute to ecosystem health and resilience by preserving natural habitat and ecological processes.

The first step towards this goal is to understand how to build climate-resilient systems as one of the most critical adaptations required by the region. That includes strengthening defenses against increasingly common and severe flood and drought events and rising sea levels and coastal erosion. A regional strategy combining modern technological solutions with revived traditional practices will manage these challenges.

Water is a critical resource for Emilia-Romagna's agriculture and ecology. The most important aspect here would be integrated water resource management, where all the water uses should be maximally efficient and sustainable. Improvement of agricultural irrigation systems, encouragement of rainwater harvesting and rehabilitation of natural wetlands are just several measures that can support the sustainability of water resources dealing with the effects of climate challenges.

Agriculture is an important economic sector in the region and is changing to more sustainable methods. These changes include organic farming, reduced tillage, crop rotation and resilient varieties bred for local growing conditions. Such practices reduce agriculture's ecological footprint, enhance soil health and provide long-term viability to agricultural communities.

Figure 44 NBS strategy goals for Italian FRR

The community is central to this vision. Educating residents and including them in conservation initiatives helps to ground the conservation efforts in the knowledge and support of those whom the initiatives impact. Education programs that are customized for all ages enhance awareness of ecological issues and nurture a culture of sustainability and stewardship.

The region is also dedicated to sustainable infrastructure that retains the integrity of the natural landscape and can accommodate the environmental stressors. Innovative flood defenses simulating natural processes as well as energy-efficient structures, are all examples of what a holistic approach can deliver to infrastructure development.

These actions are not only addressing the present situation but are also preparing the ground for a sustainable future for Emilia-Romagna. It is a vision of an adaptable, resilient and harmonious landscape, which, if maintained, will leave the region alive and thriving for generations and set the benchmark for integrating both human development and environmental stewardship into a thriving region.

This figure outlines key goals including community engagement, flood and drought resilience, sustainable agriculture, biodiversity preservation, infrastructure adaptation, coastal erosion combat and monitoring and adaptive management to promote environmental resilience and sustainability.

Operationalization of NBS strategy in Italian FRR

Table 72 Key aspects of Land4Climate NBS strategy operationalization in Delta Po Region, Italian FRR

Activities	Topics
Mapping phase: identifying critical areas for effective interventions	Structured approach: enhancing resilience against environmental challenges
Stakeholder engagement: involving local groups for successful implementation	Tailor strategy to regional features: adapting plans to local geography and climate
Capacity building: equipping stakeholders with the necessary skills.	Identify environmental challenges: recognizing pressures that require NBS responses.
Project implementation: executing specific NBS projects.	

3.6.3 Location and NBS identification

Table 73 Overview of stakeholder-selected no-regret NBS measures for climate risk hotspots in the Italian FRR

How were priority hotspots identified?	multi-criteria CRA - Hazard data - Flood risk maps - Exposure analysis - Vulnerability indicators	Priority hotspots were identified through an integrated CRA combining hazard data, exposure mapping and vulnerability indicators, providing a robust evidence base for spatially targeted NBS planning
What is the justification for NBS location?	The location in part of the Po River Delta, a Natura 2000 site highly exposed to storm surges, saltwater intrusion, sea level rise and coastal erosion.	The area has experienced increasingly severe climate-related hazards, including the record-breaking 2022 drought and major regional floods in 2023–2024. The site was selected based on climate risk analysis, expert assessments and project requirements, particularly focusing on private land to ensure feasibility within Land4Climate.

What alternatives were considered for scale/ location?	- Several alternative sites—mainly on public land—were considered but ruled out due to ineligibility under the project's private-land focus.	- The final site was chosen for its exposure to risks, ecological sensitivity and ownership status.
Which NBS have been selected?	- Dune - Salicornia - Deep-rotted plants	

3.6.4 Effectiveness and efficiency

Table 74 Synthesis of integrated assessment methodology and indicators for Italian FRR

NBS	Addressed hazard	Evaluation process	Performance indicators
Dune	- Storm surges - coastal erosion - Saltwater intrusion	- CFD modeling (OpenFOAM) to simulate wave impacts and flood protection under severe maritime conditions. - ENVI-met simulations to evaluate the reduction in sea spray deposition, under different wind conditions (Umin/ Umax scenarios)	- Wave impact pressure reduction on inland areas. - Sea spray deposition: measured reduction behind the dune under varying wind intensities. - Vegetation health improvement due to reduced salt exposure

Table 75 Synthesis on NBS effectiveness, multifunctionality and expected co-benefits

NBS	how does the NBS mitigate the risks?	multi-functionality and expected co-benefits
Dune	- Acts as a physical barrier against high waves and sea spray. - stabilize the coastline, preventing erosion. - Protects biodiversity and agriculture inland by limiting salinization	- Enhances biodiversity by supporting salt-sensitive vegetation - acting as a coastal habitat - preserves agricultural productivity and land use - supports salt-tolerant crops (e.g., Salicornia).

<u>**Dunes: Co-benefits and trade-off analysis**</u>

In the Italian FRR, dune reconstruction was assessed as a key NBS to mitigate coastal erosion and saltwater intrusion, while supporting long-term shoreline stability.

Table 76 Dunes: co-benefits and trade-offs

Dimension	Co-benefits	Trade-offs
Environmental	- Prevents coastal erosion and storm surge damage - Reduces saltwater intrusion into hinterland during droughts - Enhances biodiversity and ecological connectivity - Provides natural buffer against sea level rise	- Requires space along coastal zones - Potential disturbance to existing land uses during construction

Social	- Preserves landscape aesthetics and cultural identity of coastal areas - Supports recreation and tourism opportunities - Contributes to local well-being and educational activities	- Possible conflicts with coastal development priorities (tourism infrastructure, settlements)
Economic	- Protects infrastructure and agricultural land from storm surges and salinization - Reduces long-term coastal protection costs (compared to hard infrastructure)	- High construction and maintenance costs - Limited direct economic return - Benefits are mostly indirect

For more details, please visit *Schindelegger, A., Thaler, T. (2025). Assessment of co-benefits and trade-offs of NBS (LAND4CLIMATE Deliverable 2.4).*

3.6.5 Land policy and implementation

Table 77 Assessment of alignment between proposed NBS measures and existing land use and spatial planning instruments in the Italian FRR

NBS	Policy/ planning tools used	Intervention type	Effect on land/ property values
Dune	- Implemented on privately owned land, accessed through voluntary cooperation. - Communication, negotiation and compensation mechanisms - Landowner retains ownership and will be supported by the national park and public authorities in both implementation and maintenance. - Formal contracts and agreements are planned to clarify responsibilities and ensure long-term upkeep	- Performance-based NBS, designed to reduce storm surge impact, coastal erosion and saltwater intrusion	- The impact on property value is unknown. - The expected benefits are anticipated to outweigh potential short-term constraints. - The NBS may enhance ecological and economic resilience

Implementation plans

Table 78 Implementation plan

Dune implementation roadmap	
Phase	**Activities**
Site selection & preparation	- Confirm final dune alignment and footprint based on hydrological modeling and historical storm surge data. - Conduct soil tests and elevation surveys. - Coordinate with local authorities and landowner to finalize access agreements.
Technical design	- Design the dune profile (height, width, slope) to resist storm surges and saltwater intrusion.

	- Integrate natural vegetation zones (e.g. salicornia) and reforestation buffers. - Incorporate native plantings and erosion control features.
Permitting and regulatory approval	- Obtain permits from local planning and coastal authorities. - Align with Natura 2000 conservation requirements. - Ensure compliance with private land ownership conditions and compensation agreements
Construction	- Shape the base dune structure using excavation and earthworks equipment - Install stabilization elements - Construct foredune and backdune segments as per modeling outputs
Vegetation planting	- Plant native dune vegetation in phases (e.g., salicornia and deep-rooted grasses). - Apply protective fencing if needed to reduce trampling and wind erosion.
Monitoring and adaptation	- Set up baseline indicators (wave impact, salt intrusion, biodiversity). - Schedule annual performance reviews (vegetation health, erosion control). - Adapt dune height or planting density based on observed climate or hydrological shifts.
Long-term maintenance	- Public authorities and national park staff to support erosion repair and invasive species removal. - Establish community co-monitoring and educational visits to enhance awareness and ensure long-term stewardship.

3.6.6 Legitimacy and justice considerations

Implementing NBS on private lands requires a legitimacy and justice analysis to secure long-term success and stakeholder support. Their design and execution required technical feasibility, strong social acceptability and procedural integrity. LAND4CLIMATE followed a participatory and transparent approach to maximize legitimacy from multiple angles.

This subsection evaluates the legitimacy of these interventions through three different dimensions:

- input legitimacy (how participatory and inclusive the stakeholders' involvement is)
- throughput legitimacy (about whether decision-making is procedurally fair and transparent)
- output legitimacy (assessing if the interventions are producing, or should produce, effective results)

These points of view together provide a nuanced picture of the extent to which the NBS interventions are just and accepted in the local context of the considered FRR.

Table 79 Overview of legitimacy and justice considerations in the implementation of NBS in the Italian FRR

Dune			
Dimension	**participatory**	**procedurally fair**	**effective results**
Evaluation	**Yes**	**Yes**	**Yes**
Explanation	The site was selected through a participatory process that involved direct consultation with the private landowner, collaboration with national park authorities and other public institutions, consideration of landowner preferences and voluntary cooperation, equal treatment	The process was guided by expert judgment, stakeholder involvement, alignment with Land4Climate project requirements and regional hazard modeling, transparent procedures in identifying the location and negotiating responsibilities, use of soft policy tools ensuring	The dune is expected to provide reduced risks from storm surges, saltwater intrusion and coastal erosion as well as multiple co-benefits, including enhanced biodiversity, landscape quality and long-term

	of all potential private landowners.	procedural fairness without coercion.	resilience for agricultural and natural systems.

3.6.7 Stakeholder engagement

LAND4CLIMATE initiative considers that meaningful stakeholder engagement is critical to the success of environmental projects. Overall, the approach taken by the regional project partners in the Emilia-Romagna area illustrates a strong awareness of the key priority to be inclusive of all relevant actors, including local authorities, private landowners, as well as sector-specific stakeholders, in the co-development and implementation of NBS.

Local authorities are key stakeholders in the LAND4CLIMATE initiative because they hold regulatory power, have the ability to implement policy and are agents for change in their communities. This ensures environmental projects are in line with local laws and have the required policy frameworks in place to be successful. Additionally, by including local authorities from the beginning, the project guarantees that the developed solutions can fold neatly into current and upcoming land-use plans. Additionally, local authorities have the ability to expedite the project through legitimizing the project and even providing funding.

The success of the NBS relies on land owned by private owners. Their engagement is vital, because a lot of the suggested measures (reforestation, restoring wetlands, sustainable agricultural practices) will take place on their land. The effect of this engagement is twofold; not only does the project gain access to the land it requires, but by engaging the owners of this land directly, the owners are ultimately vested in the success of the project. Landowners attended workshops and meetings designed to engage and inform them about the benefits of participating in the project: Not only are concurrent increases in the value and productivity of participating land evident, but landowners can contribute to the ongoing ecological health of the region.

Sustained communication is considered by project partners for a very good working relationship with above mentioned stakeholders. The purpose of this ongoing conversation is to keep all in the loop of progress, ensure continual feedback and to pivot when needed based on stakeholder input. This practice helps keep stakeholders engaged and invested long term, which is critical to the ongoing success of the project.

In order to build broad-based support and participation, spreading the word about the project's goals and benefits across the region is essential. Involving the wider community creates advocacy around the significance of protecting the environment and more people working to foster the success of the project.

In the course of the ongoing LAND4CLIMATE initiative, the regional project partners have been adjusting their approaches on stakeholder operations and engagement. It will focus on the long-term goal not just to satisfy the short-term needs of the project but also to establish a long-term relationship with all stakeholders to become an example for subsequent environmental projects. Emilia-Romagna also aims to promote a healthy, sustainable and economically viable living space for all its residents through these collaborative efforts.

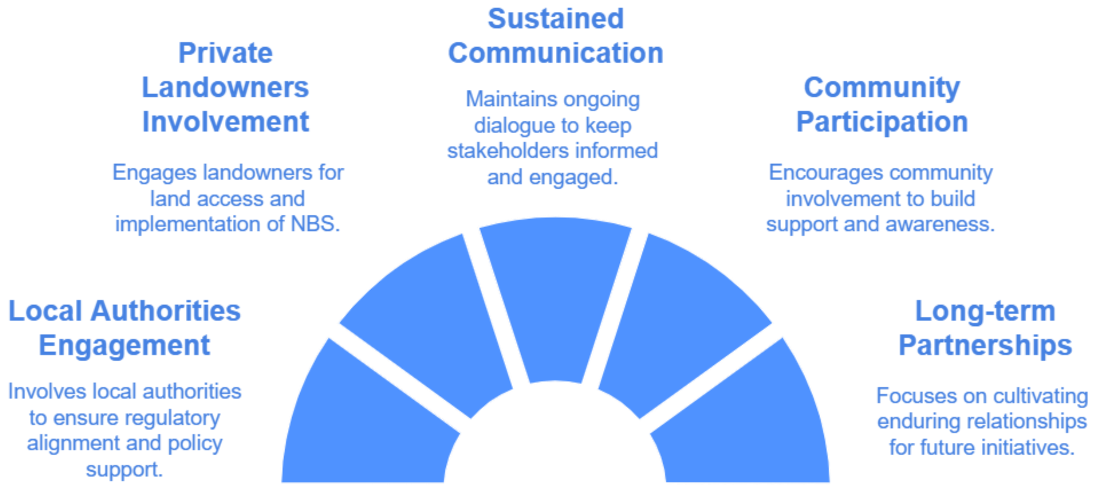


Figure 45 Key components including private landowner involvement, sustained communication, community participation, local authorities' engagement and long-term partnerships to support the implementation of NBS and climate resilience strategies

3.6.8 Monitoring, evaluation and learning

Even though the Land4Climate project does not foresee a monitoring and evaluation phase for the implementation of NBS measures, the team that developed this strategy considers that this phase is imperative in the event of identifying future sources of funding.

Therefore, the strategy includes for each NBS measure a brief monitoring, evaluation and learning plan, sufficiently versatile to be adjusted by the FRR in accordance with local needs and availability, at the appropriate time.

1. Objectives of MEL plan

- Assess the effectiveness of dune restoration in protecting coastal zones from storm surges, erosion and sea-level rise.
- Monitor ecological regeneration, especially dune vegetation and wildlife habitats.
- Evaluate social acceptability and institutional support for long-term maintenance.
- Generate evidence to inform institutional learning and scalability and replication.

2. Monitoring indicators

Table 80 Biophysical indicators

Indicator	Description	Method	Frequency
Dune morphology stability	Change in dune height, width and position	GPS surveys, drone-based DEM analysis	Annually
Vegetation cover	Growth and stabilization by native dune plants	Fixed-point photography, vegetation transects	Seasonal
Sediment movement	Aeolian and marine sediment deposition/erosion	Sand traps, LIDAR scans	Seasonal
Erosion control	Reduction in beach and backshore erosion	Shoreline position monitoring	Seasonal
Biodiversity increase	Flora and fauna recolonization	Transect surveys, nesting counts	Seasonal

Table 81 Socio-economic indicators

Indicator	Description	Method	Frequency
Visitor perception	Awareness and appreciation of dune benefits	Interviews, perception surveys	Mid-term & final
Land manager engagement	Local cooperation and support from park/rural stakeholders	interviews, co-management records	Annually
Use in education/tourism	Dunes used in guided walks, school programs	Event logs, visitor books	Monthly
Replication interest	Support for dune restoration in other coastal zones	Regional stakeholder workshops, interviews	End of the project

3. Data collection methods
- Field sensors
- Remote sensing
- Biodiversity assessment
- Stakeholder engagement
- Socio-economic surveys/ interviews
- infrastructure monitoring

4. Monitoring schedule and evaluation approach

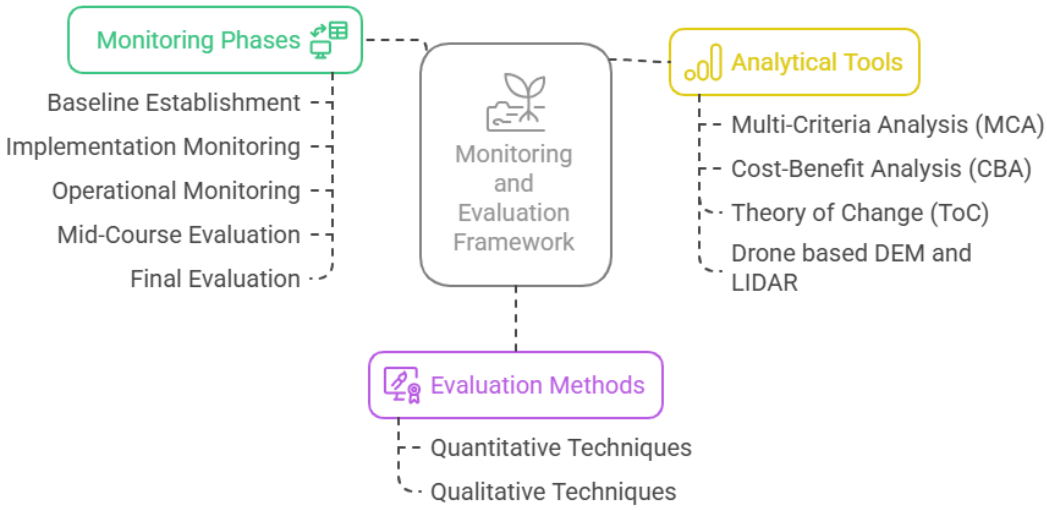


Figure 46 Monitoring and evaluation framework

5. Feedback loops
- Monitoring data and stakeholder feedback can inform institutional adaptation recommendations.
- Engagement outcomes can be shared via educational materials, workshops and policies
- Evaluation results can contribute to replication planning in other Mediterranean and Adriatic coastal zones.

3.6.9 Summary of eligibility assessment

Table 82 Eligibility assessment of dunes as NBS in the Italian FRR

Dune	
Criterion	**Key justification**
Location	The site is located in the Po River Delta, a Natura 2000 protected area highly exposed to storm surges, saltwater intrusion and coastal erosion. It was selected based on historical hazard data, hydrological and climate modeling and alignment with Land4Climate's focus on private land implementation.
Effectiveness	The dune acts as a natural barrier to mitigate marine flooding, reduce salinization and prevent coastal erosion.
Efficiency	The NBS is more cost-effective than hard engineering alternatives, particularly given the scale and ecological sensitivity of the site. It uses local materials and provides multiple ecosystem services, minimizing long-term maintenance costs.
Legitimacy	The process was participatory, involving the private landowner, experts and public authorities. The landowner agreed voluntarily and receives support from national park institutions for implementation and maintenance.
Justice	The intervention is fair and inclusive access to land was negotiated without coercion, all potential landowners were offered similar conditions and the long-term benefits (biodiversity, flood protection, soil health) extend beyond the individual property to the wider community.

Conclusions

Deliverable 4.1 demonstrates, through case-specific strategies in six European FRRs, that implementing NBS with targeted funding can provide valuable lessons and pathways for broader integration into climate risk management (e.g. floods, droughts, heatwaves, erosion, biodiversity loss). Although full mainstreaming remains a challenge, these experiences underscore both the potential of NBS and the conditions required to advance in that direction. The strategies and implementation plans developed in Germany, Austria, Romania, Czech Republic, Slovakia and Italy demonstrate that NBS can provide systemic, multi-functional benefits when carefully tailored to local ecological, social and institutional contexts.

Successful implementation requires combining technical design with participatory governance. Across all regions, stakeholder engagement – particularly the involvement of private landowners – emerged as decisive in strengthening the perceived legitimacy of NBS strategies. Although the implications for justice and long-term sustainability will require further empirical evidence as implementation progresses, insights from related projects suggest that early and inclusive engagement can create favorable conditions for these outcomes. Implementation plans consistently integrate voluntary agreements, co-design workshops and the results of collaborative NBS developments, supported by clear and open processes. These processes are designed to be documented, traceable and inclusive to strengthen local acceptance and support for the planned NBS interventions.

The selected NBS portfolios, ranging from tiny forests in Germany, agroforestry measures in Austria, reforestation in Romania, retention ponds in the Czech Republic and Slovakia, to dune restoration in Italy, highlight the importance of tailoring measures to site-specific climate hazards and vulnerabilities. These interventions were selected as “no-regret” options, able to deliver clear benefits regardless of future uncertainties.

Their multifunctionality is presented in a wide range of potential co-benefits identified by Land4Climate project deliverables, including contributions to biodiversity, water management, carbon sequestration, etc. Co-benefits differ in scope and mix across contexts, underscoring the complexity of outcomes and the limits of generalization. A particularly important dimension of these strategies is the role of private land. Public land can host NBS pilot projects, but large-scale resilience projects will require engaging private landowners, given that most European land is privately owned. The strategies acknowledge that private land is often characterized by fragmented ownership, diverse economic interests and regulatory uncertainties, thereby making engagement and coordination very challenging. Voluntary cooperation, trust-building and incentives therefore emerge as critical conditions for implementation.

The experiences documented across the six regions illustrate different governance approaches for involving private landowners, highlighting implementation pathways. First, the NBS were negotiated with landowners to address and include their’ concerns, and demonstrate clear benefits (such as soil fertility, flood protection, or improved property values) are more likely to secure participation. Second, integrating NBS measures into existing subsidy schemes, agricultural programs and local adaptation plans can reduce barriers to uptake. Third, it is critical to ensure fairness and transparency in decision-making to build legitimacy, particularly where land-use restrictions or opportunity costs are involved. Finally, framing NBS as shared assets (delivering public goods like biodiversity, cooling and water regulation while respecting private rights) has the capacity to create stronger acceptance and long-term commitment.

Implementation plans also emphasize efficiency and feasibility by aligning with existing land use and spatial planning instruments, mobilizing different available EU and national funding schemes, and integrating into larger climate adaptation policies. Monitoring, evaluation and learning frameworks have been included to enable adaptive management, replication and upscaling, even though project resources for this are limited.

Overall, the strategies and plans developed under Deliverable 4.1 present potential pathways for NBS operationalization in different socio-ecological environments. These strategies and implementation plans provide structured guidance and inspiration that can further support future planning and decision-making processes. They also show that considering inclusive governance, ensuring the alignment with policy instruments, securing adequate funding and capacity-building, NBS have the capacity to move beyond isolated pilots to systemic, catchment-wide and landscape-level solutions. These conclusions highlight the transformative potential of NBS to contribute not only to climate resilience, but also to broader goals of ecological restoration, sustainable land management and community well-being across Europe.

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