



NBRACER
Nature Based Solutions
for Atlantic Regional Climate Resilience

HORIZON Europe Research and Innovation actions in support of the
implementation of the Adaptation to Climate Change Mission
(HORIZON-MISS-2022-CLIMA-01)

Co-design of transformative systemic solutions in Rural landscape systems

Deliverable D4.1

Version n° 4

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About NBRACER

The impacts of climate change on people, planet and prosperity are intensifying. Many regions and communities are struggling to avoid losses and need to step up the effort to increase their climate resilience. Ongoing natural capital degradation leads to growing costs, increased vulnerability, and decreased stability of key systems. Whilst there has been noticeable progress and inspiring examples of adaptation solutions in Europe, the pressure to make rapid and visible progress has often led to a focus on stand-alone, easy-to-measure projects that tackle issues through either direct or existing policy levers, or sector-by-sector mainstreaming. But the dire trends of climate change challenge Europe, and its regions, needs exploration of new routes towards more ambitious and large-scale systemic adaptation. The European Mission on Adaptation to Climate Change (MACC) recognizes the need to adopt a systemic approach to enhance climate adaptation in EU regions, cities, and local authorities by 2030 by working across sectors and disciplines, experimenting, and involving local communities.

NBRACER contributes to the MACC by addressing this challenge with an innovative and practical approach to accelerating the transformation towards climate adaptation. Transformation journeys will be based on the smart, replicable, scalable, and transferable packaging of Nature-Based Solutions (NbS) rooted in the resources supplied by biogeographic landscapes while closing the NbS implementation gap. Regions are key players of this innovative action approach aiming at developing, testing, and implementing NbS at systemic level and building adaptation pathways supported by detailed and quantitative analysis of place-specific multi-risks, governance, socio-economic contexts, and (regional) specific needs.

NBRACER works with 'Demonstrating' and 'Replicating' regions across three different Landscapes (Marine & Coastal, Urban, Rural) in the European Atlantic biogeographical area to vision and co-design place based sustainable and innovative NbS that are tailor-made within the regional landscapes and aligned with their climate resilience plans and strategies. The solutions are upscaled into coherent regional packages that support the development of time and place specific adaptation pathways combining both technological and social innovations. The project is supporting, stimulating, and mainstreaming the deployment of Nature-Based Solutions beyond the NBRACER regions and across biogeographical areas.

Document information

Grant Agreement	n°101112836
Project Title	Nature Based Solutions for Atlantic Regional Climate Resilience
Project Acronym	NBRACER
Project Coordinator	Mindert de Vries, Deltares
Project Duration	1 st October 2023 – 30 th September 2027 (48 months)
Related Work Package	WP4
Related Task(s)	Task 4.1
Lead Organisation	VITO
Contributing Partner(s)	WUR, AAU, Klimatorium, Province of West-Flanders, Inagro, VLM, Nouvelle-Aquitaine Region, PNR Marais Poitevin, SMEAG, UC, FIHAC
Due Date	30 th September 2025
Submission Date	22 nd September 2025
Dissemination level	Public

History

Date	Version	Submitted by	Reviewed by	Comments
18/07/2025	V1	Catarina Baptista	Giulia Bussoletti	Formatting & content review
29/08/2025	V2	Catarina Baptista	-	-
05/09/2025	V3	Bastiaan Notebaert	Stefano Gamberoni	Formatting and content review
22/09/2025	V4	Bastiaan Notebaert	-	-
25/09/2025	V4	Approved by Stefano Gamberoni		

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Summary

Deliverable D4.1, *Co-design of Transformative Systemic Rural Solutions*, is a key milestone within the NBRACER project, which supports the EU Mission on Adaptation to Climate Change. The deliverable focuses on the co-design processes applied to Nature-based Solutions (NbS) in rural landscapes across four of the NBRACER Demonstrating Regions: Central Denmark, West-Flanders, Nouvelle-Aquitaine, and Cantabria.

The main objective of this deliverable is to document the progress and learnings from the co-design of 14 Rural NbS Demonstrators. These demonstrators address a range of climate challenges, such as flooding, drought, water quality degradation, and soil erosion, while targeting improvements in Key Community Systems (KCSs) like Water Management, Ecosystems, and Land use & Food Systems.

The co-design process is guided by five iterative steps: **issue framing**, **knowledge gathering**, **co-design of options**, **stakeholder validation**, and **decision-making**. The methodology combines participatory stakeholder engagement with technical assessments, including ecosystem service mapping and readiness level evaluations. The deliverable presents a comparative analysis of the demonstrators, highlighting the diversity of approaches, stakeholder constellations, and maturity levels. It also identifies enabling conditions and barriers to implementation, such as governance structures, data availability, and social acceptance.

Key findings show that while most demonstrators are still in early co-design stages, there is strong alignment between local needs, stakeholder engagement, and the potential of NbS to deliver climate resilience. The insights from this deliverable will inform the development of regional NbS portfolios and adaptation pathways for the rural landscapes in NBRACER.

This document for Deliverable 4.1 is structured as follows:

- Chapter 1 sets the scene within the scope of the NBRACER project;
- Chapter 2 introduces the objectives related to the demonstrators in Task 4.1 and this deliverable;
- Chapter 3 presents the Rural Demonstrators and reports the co-design process in a visual summary;
- Chapter 4 provides the mapping of landscapes and Ecosystem Services within the rural regions of NBRACER;
- Chapter 5 offers a comprehensive analysis of the co-design process and comparison of status among regions;
- Chapter 6 provides conclusions and recommendations for the way forward within the NBRACER Regional Resilience Journey.

Keywords

Co-design, Participatory process, Governance, Barriers, Enablers

Abbreviations and acronyms

Acronym	Description
CA	Cantabria Demonstrating Region
CICES	Common International Classification of Ecosystem Services
CRIC	Climate Risk Impact Chain
DK	Central Denmark Demonstrating Region
DR	Demonstrating Regions within the context of NBRACER: Central Denmark (DK), West-Flanders (BE), Nouvelle-Aquitaine (FR), Cantabria (ES), and Porto (PT).
D4.1	Deliverable of Task 4.1, corresponding to the present document: Co-design of transformative systemic solutions (due to in Month 24).
Dx.2	Deliverable of Task x.2: 'Lessons learnt from monitoring in local NbS demos', transversal to WPs 2, 3 and 4 (due to Month 36).
Dx.3	Deliverable of Task x.3: 'Regional portfolios of solutions and pathways', transversal to WPs 2, 3 and 4 (due to Month 40).
Dx.4	Deliverable of Task x.4: 'Lessons learnt from validating the portfolios', transversal to WPs 2, 3 and 4 (due to Month 44).
EEA	European Environment Agency
ES	Ecosystem Services
EU	Europe, European, European Union
EUCRA	European Climate Risk Assessment
INCA	Integrated Natural Capital Accounting
KCS	Key Community System
MACC	European Mission on Adaptation to Climate Change
MEL	Monitoring, Evaluation & Learning
NA	Nouvelle-Aquitaine Demonstrating Region
NbS	<i>Nature-based solutions (NbS) are inspired and supported by nature, they are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience; such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.</i> Source: Nature-based solutions - European Commission
P2R	Pathways2Resilience framework

RR	Replicating Regions within the context of NBRACER: Friesland (NL), East-Flanders (BE), and Cávado (PT).
SBA	Service Benefiting Areas
SOC	Soil Organic Carbon
SoS	System of Systems
SPA	Service Providing Areas
SRL	Societal Readiness Level
TRL	Technology Readiness Level
T1, T20, T1000	Event (respectively, drought, extreme heat, flood) with a statistical return period of 1, 20, and 1000 years. E.g., a T20 event is statistically expected to occur once every 20 years.
Tx.1	Task x.1 'Co-design of transformative systemic solutions', transversal to WPs 2, 3 and 4. Task to which the present deliverable refers to.
Tx.2	Task x.2 'Monitoring and prediction of KPIs', transversal to WPs 2, 3 and 4.
Tx.3	Task x.3 'Assessing the impact of solutions portfolios and pathways', transversal to WPs 2, 3 and 4.
Tx.4	Task x.4 'Transposing and validating solutions', transversal to WPs 2, 3 and 4.
VHA	Vlaamse Hydrografische Atlas – Flemish Hydrographic Atlas
WFL	West-Flandersss Demonstrating Region
WP	Work Package
WP1	Work Package 1 'Integrated stocktaking, visioning and prioritizing' led by Climate-KIC and mainly focused on the support to the transformational pathways towards climate resilience of the regions.
WP2	Work Package 2 'Demonstrations in Marine and Coastal Systems' led by Deltares.
WP3	Work Package 3 'Demonstrations in Urban Systems' led by Wageningen Research.
WP4	Work Package 4 'Demonstrations in Rural Systems' led by VITO.
WP5	Work Package 5 'Technical framework supporting the design and implementation of NbS' led by UCantabria.
WP6	Work Package 6 'Process framework enabling & transformative conditions for NbS implementation' led by Wageningen University.

1 Setting the Scene: the NBRACER Approach

The NBRACER Operational Climate Resilience Approach provides a flexible, co-designed framework to support regional climate adaptation using Nature-based Solutions (NbS). It responds to the growing need for transformative, system-oriented strategies that move beyond fragmented, project-level interventions. The approach views regions as complex Systems of Systems (SoS), integrating biophysical, socio-cultural, and governance domains to guide resilience-building in a way that is context-sensitive and community-driven. NbS serve as the core intervention, designed not in isolation but as part of multi-dimensional portfolios that align with local values, risks, and institutional landscapes.

The NBRACER operational framework equips decision-makers with adaptable tools and processes tailored to diverse regional contexts and scales. By employing an iterative, participatory approach and advanced spatial analysis, the framework helps regions build and sustain resilience that is adaptable to evolving risks. Emphasizing NbS and incorporating socio-ecological systems and ecosystem services dynamics, the framework supports comprehensive resilience planning, providing regions with a cohesive pathway to operationalize resilience strategies and prepare for climate uncertainties. This approach is applied across diverse regional landscapes - including Marine & Coastal, Urban, and Rural areas - within the Atlantic Biogeographical Region. NBRACER works directly with Demonstrating regions, serving as living laboratories for innovation, and Replicating regions, which test and adapt solutions for transferability. Regional pathways are rooted in participatory processes, while technical assessments - such as Climate Risk Impact Chains (CRICs), ecosystem service mapping, and multi-hazard risk profiling - help shape tailored NbS packages that respond to specific risks and local assets.

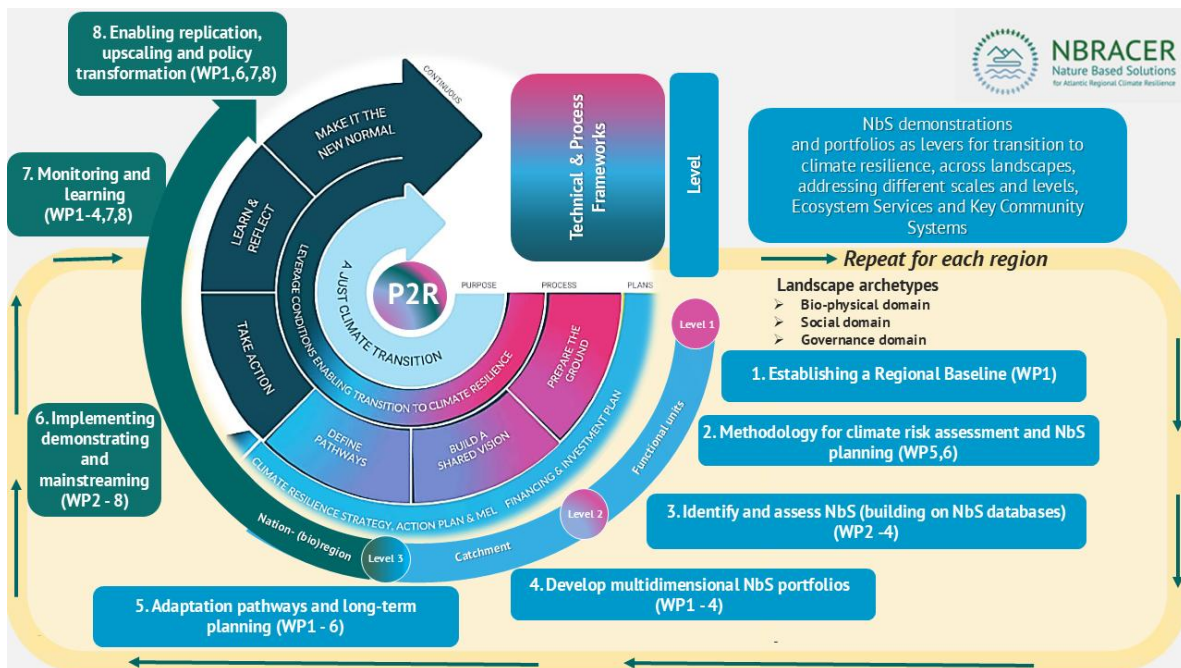


Figure 1: Overview of the NBRACER Approach with 8 steps, elaborating an iterative process for achieving a just climate transition through multi-level, multi-scale and multi-domain planning.

Structured around an eight-step operational process aligned with the Horizon Europe project **Pathways2Resilience (P2R) framework**, shown in **Figure 1**, NBRACER guides regions from system analysis and risk assessment to solution development, pathway design and implementation. A strong focus is placed on learning, monitoring, and iterative feedback, ensuring continuous adaptation and long-term transformation. The approach supports regions not only in deploying NbS but also in mainstreaming and scaling solutions beyond the project scope, contributing to policy transformation and enhanced resilience across Europe.

In this context, the co-design of transformative systemic rural solutions to which this deliverable is concerned supports the **NBRACER Approach** at different stages of the process. Specifically, within WP4, Task 4.1 lays the foundation for the identification of proposed NbS in consultation with stakeholders and according to the needs of the local landscape for **Step 3: Identify and assess NbS**, serving also as a start basis for further developing a place-based and context-specific portfolio of solutions in **Step 4: Develop multidimension NbS portfolios**. The co-design can cover not only the planning stage of an NbS demonstration but also its implementation and mainstreaming, contributing to **Step 6: Implementing, demonstrating and mainstreaming**. Stakeholders can also be closely involved in co-design of the monitoring protocols, contributing to **Step 7: Monitoring and learning**.

2 Introduction

Characterization of Rural Landscapes in the Atlantic Biogeographical Region

Rural landscapes in the Atlantic Region are diverse in topography and physical setting, biodiversity and human land use. They vary from the high peaks of the mountains of Northern Spain (including Cantabria) to the low plains of Denmark and the Low Countries. Due to the moderating influence of the Atlantic Ocean, this region has a temperate climate. This creates ideal conditions for agriculture, especially in the northern parts of the Atlantic region. Economic prosperity has led to significant urban centres throughout the entire Atlantic region, and as a result, the rural landscape is often intertwined with the urban. West-Flanders is certainly an extreme example of this, but the connection is undeniably present in other parts of the region as well. On the other hand, large areas of the rural zones are located in the lowlands along the coast and the major tidal rivers, where rural landscapes are often interwoven with coastal landscapes.

Nevertheless, there are also significant contrasts within the region, mainly driven by topography. The forested, mountainous areas of northern Portugal and northern Spain differ greatly from the flat, sparsely forested landscapes of West-Flanders and Friesland.

Climate change related challenges

Climate challenges in the region are diverse and vary between the demonstration areas. Nevertheless, water-related issues form a common thread. Changes in the hydrological cycle, combined with human land-use impacts, are increasing the risk of both pluvial and fluvial flooding. This plays a role in all demonstration areas. In low-lying regions, the problem is further exacerbated by sea level rise. At the same time, there is also an increase in the intensity and duration of drought periods, for example in West-Flanders and Nouvelle-Aquitaine. Due to intense economic activities – including industry, households, and agriculture – there are significant challenges related to water quality, such as nutrients, micropollutants, and water temperature. These are further intensified by climate change and more extreme hydrological events, as seen for example in Denmark, West-Flanders, and Nouvelle-Aquitaine. Heat stress also plays a role locally, for example in Nouvelle-Aquitaine.

Key Community Systems

In Section 6, we take a closer look at the Key Community Systems (KCS) involved in our demonstrators. Typical for rural areas is the importance of food production – the KCS of **Land Use & Food systems**. Food systems have relied on the temperate climate of the Atlantic region and are therefore coming under pressure from increasing flooding and drought periods. Heat stress can also play a role in this context.

In addition, **biodiversity** is crucial, particularly in this region where intense human activities already place significant pressure on the ecosystem as a KCS. Fragmentation of natural areas reduces their resilience and increases their vulnerability to climate change. Another KCS characteristic of the Atlantic region is **Water Management**. Over the centuries, humans have often

adapted and managed water systems to serve agriculture, industry, and settlements. Recent changes in drought and flooding are putting this system under pressure, making climate adaptation essential.

A key factor in the KCS of **Health & Wellbeing** in rural areas is landscape quality. Here, NbS offer a valuable opportunity: they can help restore landscape quality and revalorize rural areas as hubs for recreation and leisure, while also ensuring a healthy living environment for rural residents.

Nature-based Solutions in rural areas

NbS can help address the challenges mentioned above. In a landscape where nature and people have coexisted for centuries, there is already considerable experience with NbS. Traditional NbS are under pressure from more intensive agriculture and forestry, increasing economic activity, higher population density, and the resulting strain on available space and biodiversity. Nevertheless, many NbS remain part of the rural heritage. Some traditional ways of managing the landscape and water systems are clear examples of NbS. Restoring the natural system – such as the natural hydrological cycle – through NbS is therefore an important way to cope with floods and droughts, that can also help improving water quality.

The NBRACER Rural Demonstrators include mostly examples in which the natural system is being restored. Important considerations in this regard are the positive and negative impacts on both the climate challenges and the KCS (also referred to as co-benefits). The set of demonstrators represents only a subset of the possible solutions; these are solutions that still require an innovation step to increase their readiness level. In the same regions, other NbS focused on system restoration are also being implemented, for which that innovation step has already been taken. We will return to these in Task 4.3 and Deliverable 4.3.

3 Objectives

This deliverable reports for Task 4.1 on the **co-design of transformative systemic solutions and further development of the NbS demos in the Rural Landscape**. Task 4.1 aims to improve the proposed solutions by co-design based on the multiple vulnerabilities and identified risks for KCSs, identifying the enabling conditions (supported by WP6) and facilitated by the mapping of Landscapes and Ecosystem Services (ES) (developed in WP5). Local partners of each DR are closely engaged in a participatory approach, supported by the Monitoring, Evaluation & Learning (MEL) core connecting facility (T1.4 and supported by T6.4), to explore societal needs, benefits and trade-offs of the proposed solutions. The focus will be on increasing the TRL of NbS, through testing and demonstrating, status assessment, and requirements for enabling conditions.

The main objective of this report is to report on the progress on co-design of the demonstrators, experiences and findings, enablers, and barriers, while also registering its process of implementation. This builds further on several other activities carried out within NBRACER, such as the regional baseline reports (WPs 1 and 6), the regional workshops (WP1), the NbS questionnaire (WP5), and the technical framework for the mapping (and modelling) of landscapes and Ecosystem Services (WP5).

In order to **support the regions with co-design on their demonstrator cases**, WPs 2, 3 and 4 provided an aligned approach to actively and closely cooperate with the NBRACER DRs by means of setting up a **knowledge base**, including inspirations and examples for the regions, as well as providing **support services** on demand, to tackle the identified needs of each region. This task is operationalized in two main activities:

- (i) the **project demonstrators' MIRO board**, which includes a visual summary of all the information gathered so far regarding the demonstrators in each DR; and
- (ii) the **mapping (and modelling) of landscapes and ecosystem services**, which provides a translation of the technical framework provided by WP5 to the regional landscape context of each region.

A common template is made in the project demonstrators' MIRO board to serve as input for Deliverables 2.1, 3.1 and 4.1 (**Appendix B: Structure of the demonstrator canvas on MIRO**). This template aims to register the different demonstrators in the NBRACER DRs, with the objective to summarize the insights on the demonstrated NbS, including a brief description, the co-design process, their technical, governance and social aspects (positive and negative), their readiness level, the links to climate risks, KCS and ES, and their overall progress.

This template, now used for Deliverables D2.1, D3.1 and D4.1 (co-design), can be extended for Deliverables D2.3, D3.3 and D4.3 (portfolio of solutions), to build further on previous efforts and showcase progress over time. For D4.1, focus is on the sections: 'co-design process', 'description of demonstrator', 'insights', and 'summary'. The sections around 'monitoring and KPIs' are mainly preparing for D4.2 (lessons learned from monitoring, supported by the Regional Monitoring Team, executed in Tasks 4.2 and guided by Task 5.4).

4 Rural Demonstrators

Within its 5 Demonstrating Regions, NBRACER aims to demonstrate 19 NbS in total, distributed among the 3 landscapes. For the rural landscape, we focus on the following 14 demonstrators:

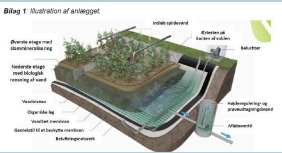
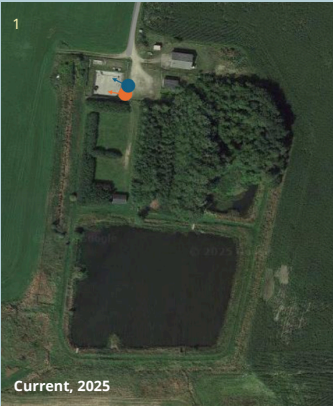
1. **Decentralized treatment of rainwater in Nr. Nissum** – Central Denmark
2. **Differentiated mowing of waterways** – West-Flanders
3. **Effect of raising water level on cropland agriculture** – West-Flanders
4. **Renaturalization of streams** – West-Flanders
5. **Riparian zones in the Machuitvallei** – West-Flanders
6. **Soil improvement practices in the IJzer catchment** - West-Flanders
7. **Sustainable farming practices** – West-Flanders
8. **Marais Poitevin** – Nouvelle-Aquitaine
9. **Artificial water recharge** – Nouvelle-Aquitaine
10. **Green filtering by riparian forest** – Cantabria
11. **Conservation of riparian forests** – Cantabria
12. **Conservation of hillside forests** – Cantabria
13. **Assisted natural regeneration of mountain wetlands** – Cantabria
14. **Floodplain restoration to reduce flood risk** – Cantabria

This chapter presents an overview of the Rural Demonstrators, according to the structured canvas from the project demonstrators' MIRO board. For detailed information on each demonstrator, consult the digital version of the MIRO board which can be accessed through: <https://miro.com/app/board/uXjVJMIU-AE=/>.

Decentralised cleaning of rainwater in Nr. Nissum

Authors: Martin Lehmann, Simon Wyke (AAU)

Summary	
Brief description and objectives Local cleaning/treatment of rainwater and potential combined sewage overflow (CSO) through constructed wetlands and the Rhizosph/Air technology [1]. Aim to evaluate cost and effectiveness of this NbS approach in the Danish context and under future climate circumstances.	Landscapes: Rural Landscape archetype subtypes: Peri-urban
Stakeholders involved and roles - Public: Klimatorium (PI), Lemvig Water (Utility company, plant owner), Lemvig Municipality - Private: Kilian Water (Consultant/ Construction) - Knowledge institutions: Aalborg University (AAU), Department of Sustainability and Planning (NBRACER partner) & Department of Chemistry and Bioscience (student intern at Klimatorium) - Society: Nørre Nissum, CSO (local partners, operation around the plant), local users of the recreational area neighbouring the plant.	Key Community Systems - Infrastructure - Water management
Climate risks - Pluvial flooding, cloudbursts - water quality	Main regulatory function - Urban water management - Stormwater overflow and treatment
Ownership and roles Lemvig Water A/S Local CSO (granted the permit to use and maintain the areas neighbouring the plant)	Co-benefits - Beautification - Recreational values - Biodiversity (sink) Enabling conditions - Municipal and utility company approval - Test wells in the new plant - Sensors and measurement equipment (NBRACER Monitoring)



Conceptual illustration of the aerated filtering plant



Conceptual site plan for the aerated filter plant, in the location shown in images 1- 3.

Description of Demonstrator

Keywords: Aerated filter, Rootzone plant, Diluted sewage, Stormwater management

The Nr. Nissum demonstrator is an aerated constructed wetland, incorporating the Rhizosph/Air technology [1]. The plant will be developed in an existing stormwater retention basin (as shown in images 1, 2 and 3). The wetland will be built by adding a membrane on top of the existing concrete slap, after which gravel and soil will be added, with aeration pipes laying within the gravel/soil mix. Finally, grasses will be planted in the substrate mix.

This aerated constructed wetland will be used to treat stormwater overflow from Nr. Nissum. The stormwater will be diluted when entering the plant, with rainwater infiltrating the sewage system during heavy storm events. The focus of the demonstrator will thus be on quality of the water exiting the plant, as well as the capability and efficiency of using aerated constructed wetlands as an alternative to grey infrastructure for stormwater management, retention and cleaning.

The NbS is furthermore of greater added value than the current concrete solution in Nr. Nissum, and will allow the solution to blend more easily with the surrounding nature and recreational area.

Co-design process and improvements needed

Until June 2025, the following stakeholders have participated in dialogue and co-design of solution:

- Klimatorium & AAU (partners in NBRACER)
- Lemvig Water Utility
- Technology providers, e.g. Kilian Water
- Nordenskov Community (<https://www.nordenskov.dk/>)

This is only a sub-section of the stakeholders identified with concrete interests in and/or responsibilities for adaptation/water management aspects of importance in the case-area (mapped in a separate Miro-board [LINK](#)).

An engagement design and process for implementation going forward has therefore been devised. This has a two-pronged approach:

- First, part (A) focusing on **engaging with more institutional and general stakeholders**, not necessarily based in the local community;
- Second, part (B) only **engaging with local stakeholders and community groups**.

For part A, there are concrete activities in August 2025 (National Climate Summit, Lemvig, with focus on overarching aspects of NbS, their implementation, and their functions and values; carried out by stop-n-go interviews), with a follow-up in August 2026 (National Climate Summit, Lemvig, and People's Climate Meeting, Middelfart). Potentially, repeated in August 2027.

Further, we will conduct **interviews with institutional stakeholders**, as well as continue **data collection** through stop-n-go interviews when participating in relevant, national, regional and/or local activities.

For part B, **dialogue sessions** will be initiated during the Youth Climate Summit in Klimatorium, Lemvig in October 2025, followed by an NbS workshop, held in December 2025 (also Klimatorium), and supplemented with open sessions with Nørre Nissum Borgerforening (<https://www.noerrenissum.dk/>), local schools (primary/secondary education), high schools and Folk High Schools (Folkehøjskoler).

This part of the co-design process enables engagement not only in the final stages of solution design, but also during the implementation and testing phases. This includes activities such as **Monitoring & Evaluation** (e.g., through citizen science), as well as learning opportunities for youth and the broader community (e.g., through specially designed activities integrated into primary and secondary school education).

Governance and other enabling conditions

Financial aspects:

- Cost of maintenance after 1, 5, 10 or 20 years?
- Longevity of solution, compared to grey solution?
- Who pays for what after construction?

Technical aspects:

- Who operates what after construction?
- The plant needs water to function, also during drought.
- Expertise is required to do systematic monitoring.
- Laboratory testing is required to analyse water quality.
- Space availability is a constraint - this type of NbS is currently mainly used in private systems.

Governance and social factors:

- Trust in the solution - institutional as well as community
- Limited uptake of NbS in public spatial plans.
- Engagement in designing solutions; ownership.

Monitoring and selected KPIs

Monitoring in Nr. Nissum will be concerned with the treatment efficiency of the aerated constructed wetland, stormwater quality and cleaning, biodiversity, and added value with respect to the neighbouring natural and recreational area:

- The **treatment efficiency** of the aerated constructed wetland will be monitored using monitoring wells in the plant, in which samples of inlet and outlet water can be taken. Water quality will be analysed in a laboratory.
- A **biodiversity** baseline has been initiated to audit the number of animal species living in the area, in and around the current plant in Nr. Nissum. We will continuously monitor species throughout the project period, to understand how the new solution affects the fauna in the area.
- As the area also has other water bodies affected by the current stormwater retention, we will also monitor water levels in those. Local stakeholder engagement is expected to be a key driver in obtaining water measurements. This will be further specified in the NBRACER Monitoring report.

As for specific KPIs used in Nr. Nissum, we will monitor the following:

- Volume of water inlet and outlet (L)
- pH, nutrients, pollutants, heavy metals and plastics (concentration)
- Number of animal species

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks - Water pollution (through CSO event) - Flooding	Key Community Systems - Ecosystem - Water System - Critical Infrastructure	Ecosystem Services - Provisioning: depending on design, biomass producer (e.g. carbon sink and for energy) - Regulating: Water purification, flood prevention - Cultural: recreation and learning - Supporting: Biodiversity sink	Co-benefits - Remove nutrients, reduce runoff - Carbon sequestration - Temporarily store stormwater that can be reused (sponge effect) - Recreational values, enhancing the existing area's benefits further - Learning opportunities for local schools (e.g. biology, chemistry, social sciences)
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How are KCS impacted:

The solution has the following benefits and impacts in respective Key Community Systems

- Robust in respect of fluctuating loads; internal water storage combined with recirculation of purified water ensure active microflora all year round
- Resilient and functions also in places with near-surface groundwater
- Minimising concrete and maximising plants/flora results in low carbon footprint
- Plants/flora support biological processes, attract wildlife and contribute to beauty and biodiversity (halting loss)
- Water resources kept locally
- It is functional under heavy precipitation events (regnbetegnede udløb) and can treat "first flush".
- Reduced drainage (retaining/delaying discharge) spares recipient for pollutants.
- Financial gain; simple construction makes it an inexpensive solution in both establishment, operation and maintenance.

References

[1] <https://www.life-intext.eu/documents/49914657/50162875/Rhizosph%27AIR.pdf/8c54cd1b-a882-908e-9c2c-35b1bc0da67b?i=1718193695080>

Differentiated mowing of waterways

Summary

Brief description and objectives: Differentiated mowing involves applying different maintenance practices (e.g., stop or mowing less regularly, block mowing, one side mowing, ...). Maintaining the vegetation in the banks can have a water purifying effect and provide habitat, reducing the workload and operation costs. Potential obstruction of the water (and flooding) is also considered.	Landscapes: Mainly rural, sometimes (peri)urban, coastal (polders)
Stakeholders involved and roles - Government: Province as manager of 2nd category water courses, polder waterboard as manager of water courses - Farmers/ landowners / businesses beside the waterway - VMM: regulatory agency for water quality - Mowing companies - Social initiatives (perform mowing) - Nature organisations - Municipalities - Sewage system manager (in case of overflows)	Key Community Systems - Water system - Ecosystem - To a less extent: critical infrastructure, health system
Climate risks - Flooding - Water quality - Drought (to investigate) - Biodiversity loss	Main regulatory function - Water purification - Effect on flooding (to be investigated)
Ownership and roles - Province W-FI, polder waterboard: responsible for 2nd category water courses - Mowing companies, social initiatives (mowing contracts)	Co-benefits - Biodiversity - Recreation - Carbon capture
	Enabling conditions - Cheaper - Less time-consuming - Uniform framework



Prov
WFI

Scale:
provincial

Authors: Els De Roeck (PWF); Florian Stragier (PWF);
Catarina Baptista (VITO); Bastiaan Notebaert (VITO)

Description of Demonstrator

Keywords: streams, differentiated mowing, reed, water purification

Within the Province of West-Flanders, there are over 3500 km of smaller watercourses (called '2nd order watercourses'). These are governed and maintained by the Province of West-Flanders and so called 'Polders' (Polder Waterboard), which is an other water management governance level responsible for specific areas [3]. Note that the same designation is used for a landscape type and specific areas with that landscape; however, for this demonstrator, this term is used to describe a governance level.

Currently, maintenance is performed at least once a year at most locations, including mowing soil and bank/riparian vegetation [1, 2]. The presence of vegetation along (the banks of) waterways can have a purifying effect through various mechanisms, including bacterial processes near the root zone and uptake by the plants themselves. Vegetation often consists of perennial plants (e.g. reed). Maintaining vegetation for longer periods can improve water quality, reduce the intensity of watercourse management (both in terms of workload and operating costs), and add value for biodiversity. However, reducing mowing can be sensitive for landowners due to a perceived higher risk of flooding, which is site-specific and sometimes has effects downstream.

We will use this demonstrator to co-design the transition to more functional watercourse maintenance by altering the mowing strategy (mow less frequently or in a different manner, where possible). We will conduct qualitative research (interviews, surveys, etc.) to examine the processes, opinions of landowners and other stakeholders, as well as governance and socio-economic aspects.

Monitoring and selected KPIs

This demonstrator is focused on the co-design process for identifying barriers and enablers, and establishing a process for mainstreaming this NbS.

As such, we will conduct qualitative research, focusing on:

- gathering opinions and perceptions of land owners and other key stakeholders e.g. through questionnaires, interviews, surveys, ...
- socio-economic, legal, organizational, and governance aspects

This demo will not focus on one specific NbS at one specific location but it will cover multiple applications of this measure, and assess aspects important for mainstreaming differentiated mowing practices.

Co-design process and improvements needed

Involved stakeholder groups:

- **Province of West Flanders:** As the works are the responsibility of the Province, phased mowing practices will take less time annually and, therefore, cost less. However, more obstructions may arise, requiring more ad-hoc responses.
- **Polder waterboards** (as a governance level): Within West Flanders, the polders are also partly responsible for the watercourses. There is an agreement where the Province financially supports the polders for management, making them responsible for these areas as well.
- **Residents/landowners/farmers:** For some residents, mowing and management are synonymous with order and tidiness. Phased mowing management might be negatively perceived by them.
- **Private companies:** contracted for mowing (in West-Flanders, they use the app 'WaterTalk' to know what should be mowed where and when)
- **Social work:** sometimes social workers perform mowing (by hand)
- **Nature organisations / ANB / regional associations ('regionale landschappen')**: when mowed area is next to nature domain.

Co-design steps:

1/ **Knowledge gathering**, in collaboration with VITO. Literature research indicates that removing (mainly non-perennial) plants by mowing at the end of the growing season prevents the release of nutrients and other pollutants they have absorbed back into the watercourse. Therefore, this practice should focus on watercourses with perennial plants. In many locations, reed is the predominant type of water vegetation. A more comprehensive literature study, including water quantity, will be conducted.

2/ **Gathering practical experience** and identifying enablers and barriers. For example, we will interview landowners along a stretch where differentiated mowing is performed (amongst others, Bollaertbeek). Additionally, we will interview key stakeholders, including project managers, governmental employees, and practical implementers.

3/ Use the gathered information to create a **process for mainstreaming**. Factors to consider include how to identify locations where differentiated mowing is applicable, how to involve and communicate with stakeholders, and how to mainstream the solution.

The goal is to **improve the readiness level of this solution** by: gathering technical knowledge on the effects for water quality and quantity (literature review), creating a process flow, identifying enablers and barriers through key stakeholders, creating a list of recommendations for practical implementation and follow up (e.g., existing app for mowing practices 'Watertalk'), and creating an information sheet.

Governance and other enabling conditions

The main barriers include the lack of scientific and practical knowledge about the effects of mowing on the system among policymakers, citizens, government, nature and agricultural organisations. Additionally, the feasibility of maintaining water vegetation without causing obstructions is location-specific. Each location has unique characteristics that influence vegetation (incl. water quality, water composition, type of vegetation, soil, etc.) and specific hydrological conditions (incl. risk of flooding). Another challenge is the difficulty in developing a uniform system for maintenance.

Technical barriers:

- More knowledge is needed to confirm the water purifying effect and how implementation practices influence this effect. This is, however, very difficult to monitor, since other factors also affect water quality. To perform such a detailed monitoring campaign is out of scope of NBRACER. We will determine if we can use existing monitoring data to deduct patterns (but causality is difficult to prove).
- Difficult to standardize for a larger area due to location-specific characteristics.
- Insufficient knowledge about the purifying effect of vegetation.
- Practical issues in implementing different mowing practices on a small local scale.

Governance and social barriers:

- Social acceptance: people might perceive/experience it as disorderly.
- Conflicting interests: not mowing upstream might have a positive effect downstream for flood prevention (but more chance for flooding upstream).
- Conflicting interests between land owners and nature organisations.
- Traffic safety: not mowing alongside crossroads or in a bend might reduce visibility.
- Interference between mowing and buffer strips (machines can be quite destructive).

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks - Water quality - Drought - Flooding	Key Community Systems - Water system - Ecosystem - Land use and food system - To a lesser extent: critical infrastructure, health system	Ecosystem Services - Water purification / effect on erosion - Cooling/ evapotranspiration - Biodiversity/ habitat creation - Aesthetics and tourism (landscape quality)
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How are KCS impacted:

- Not mowing can provide a necessary habitat for certain water birds that need multi-annual reed for nesting.
- It is expected that not mowing can influence water quantity in and around the waterway, sometimes positive for downstream flooding risk. However, mowing can reduce flooding risk right next to the area that is mowed, since the water flows with less obstructions.
- It is expected that mowing has an effect on water quality. For non-perennial plants, it might be better to mow for water quality (in order to prevent that the nutrients taken up by vegetation end up back in the waterway).
- Mowing can also have an effect on bank erosion (to be investigated).
- Mowing has an effect on the experience over the landscape (important for tourism e.g.), but also on safety of road traffic (high vegetation can obstruct the view).

References

- [1] Maintenance works framework by the Province of West-Flanders. [LINK](#)
[2] Watertalk: Onderhoudswerken | Provincie West-Vlaanderen
[3] Website of the organisation for Polders and Wateringen, VWPW; consulted 16/6/2025

Effect of raising water level on cropland agriculture

INAGRO

Prov
WFL

Authors: Nina Vanoverschelde (INAGRO);
Dominique Huits (INAGRO); Catarina
Baptista (VITO); Bastiaan Notebaert (VITO)

Summary

Brief description and objectives

The correct use of weirs can benefit agriculture during periods of droughts and support natural ecosystems. However there is still a lot of scepticism and uncertainty around the use and benefits of these weirs because poor placement and incorrect maintenance can result in damage to crops and soil structure.

Stakeholders involved and roles

- Citizens: farmers (maintenance)
- Government: Province West-Flanders (PWF), Polder managers (implementation, maintenance, regulation)
- Research: INAGRO (support)

Key Community Systems

- Land use and food system
- Water management
- Ecosystem

Main regulatory function

Water quantity

Climate risks

- Droughts
- Flooding
- Food and water security

Ownership and roles

- Farmers and polder (executors)
- INAGRO (research and support)
- PWF and Polder managers (regulation)

Co-benefits

- Soil quality

Enabling conditions

- Technical knowledge
- Financial incentives
- Maintenance support

Description of Demonstrator

Keywords: water level management, weirs

As a result of climate change, the duration and frequency of drought events is increasing, resulting in significant pressure on agricultural systems. At the same time, for historical water management reasons, many areas in Flanders are drained by an extensive network of ditches. This aggravates drought events as it limits the availability of water in the phreatic aquifer. The strategic placements of weirs in such ditches (or in small natural streams) can offer part of the solution. These weirs promote water retention and infiltration thus enhancing phreatic ground water recharge. Additionally they may reduce the risk of downstream flooding by reducing peak flows. When used correctly, weirs benefit agriculture and support natural ecosystems [2].

However when weirs are poorly placed or maintained incorrectly they can result in cropland flooding and waterlogging, causing damage to crops and soil structure. Additionally the need for regular inspection and maintenance adds to the workload. This has resulted in reluctance and scepticism from farmers towards the installation of weirs [3].

In Beverhoutsveld (West-Flanders) the installation of 15 weirs is planned. The effect of these weirs on soil structure and water quantity will be monitored within NBRACER.

Monitoring and selected KPIs

Monitoring will focus on **soil parameters**, since the main concerns of the farmers are often centered around the suitability of their land for traditional crops after the placement of weirs.

Possible change in soil structure will be monitored with bulk density, TAW, RAW, porosity, pF curves, soil compaction and infiltration speed.

The effect of the placement of these weirs on water quantity in the area will be monitored with groundwater and surface water sensors.

Co-design process and improvements needed

Involved stakeholders

- Farmers will feel the effects of the weirs the most. In current plans, they are also responsible for their maintenance.
- The Province of West-Flanders is responsible for facilitating the placement of weirs. This is conducted within the Water+Land+Schap project Beverhoutsveld.
- The water manager of the Oostkustpolder

The co-design aims to address farmers' concerns regarding the placement of weirs. Farmers fear that weirs will cause water logging and cropland flooding, leading to damage to crops and soil structure during wet periods. An important first step in the co-design process was **involving farmers in the placement plan of the weirs**. The Province of West Flanders effectively achieved this by first creating a mock-up of the placement plan and then discussing it with the farmers. As a result, several weirs were relocated based on the farmers' local knowledge to facilitate easier maintenance.

The placement of the weirs is planned the earliest in fall 2025, weather permitting. Monitoring before and after the placement of the weirs by INAGRO aims to map potential changes in soil structure from cropland to address farmers' concerns. This monitoring is conducted through on-farm experimentation, meaning it is carried out on commercial farms at a commercial scale in collaboration with farmers. Together with them, the effectiveness of these weirs will be monitored.

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks

- Droughts
- Flooding
- Food and water security

Key Community Systems

- Landscape and food systems
- Water management
- Ecosystem

Ecosystem Services

- Water retention and infiltration
- Groundwater recharge
- Enhancement of soil quality

How are KCS impacted:

- Landscape and food systems: food security is threatened by climate change causing longer and more frequent periods of drought. Weirs can be part of the solution if placed and used correctly. However, weirs can also have a negative impact if cropland fields become too wet.
- Water management: Weirs promote water retention and infiltration, thus enhancing groundwater recharge and limiting peak flows during flood events.
- Ecosystem: Weirs help to stabilize the (ground) water levels, restoring it to a more natural state.



Governance and other enabling conditions

Financial aspects:

- The placements of weirs are 100% subsidized [4]. However, maintaining them takes time.

Technical aspects:

- Depends on soil type and other regional factors, so it cannot be generalized [1]. The impact in different crops (management and yield) is also important for implementation by farmers [1].
- Requires long time for implementation and must be consistently monitored during and after implementation [1].

Governance and social factors:

- (Private) landowners and farmers have to be willing to collaborate [1].
- This NBS can be implemented by only changing management and do not necessarily includes a land use change or land exchange [1].
- The permitting process can be long and cumbersome.

References

- [1] NBRACER Internal Workshop Flanders - project kickoff and NBS factsheets (15/12/2023)
- [2] Boerenatuur factsheet stuw https://www.boerenatuur.be/pdf/Factsheets/20211022_Stuw.pdf
- [3] personal communication with farmers
- [4] INAGRO duurzaam waterbeheer <https://inagro.be/nieuws/investeer-duurzaam-waterbeheer#:~:text=Fen%20regelbare%20stuw%2C%20maar%20ook%20andere%20stuwen%20%28knijpstuw%2C,best%20enkele%20dagen%20op%20voorhand%20open%20worden%20gezet>.

Renaturalization of streams in West-Flanders

Prov
WFI

VLM

Authors: Fien Govaerts (VLM); Catarina Baptista (VITO); Bastiaan Notebaert (VITO); Lena Haesen (VITO); Els De Roeck (PWF); Florian Stragier (PWF)

Scale:
provincial

Summary	
Brief description and objectives Reshaping and restoring the natural stream by actively changing the course of a waterway (2nd category). The increased length and resistance slows down the water and reduces peak discharge downstream, significantly increasing infiltration and recharge of the groundwater table. Improved water quality is also expected.	Landscapes: Mainly rural, sometimes (peri)urban
	Landscape archetype subtypes: mainly valley and polders
Stakeholders involved and roles - Water managers (PWF, Polder waterboard, VMM) - Farmers and land users - Landowners, nearby residents, citizens and municipalities - Water quality and nature organizations (in nature areas) - Road and railway infrastructure authorities - Sewage organizations (in case of overflows) - Contractors - Researchers	Key Community Systems - Water system - To a lesser extent: critical infrastructure, health system, local economy and food system
	Main regulatory function - Reduced flooding (more room for water) - Slowing water current (more infiltration)
Climate risks - Flooding - Water quality - Drought	Co-benefits - Biodiversity - Recreation - Carbon capture
Ownership and roles - Rights over 2nd category waterways: PWF and Polders - No rights over waterway: landowners, citizens, farmers, ANB (nature areas), Natuurpunt, municipalities	Enabling conditions - Funding by projects - Governments / organisations buying parcels next to waterways



Description of Demonstrator

Keywords: re-meandering, micro-meandering, river channel restoration

Flanders has many rivers and streams that have been heavily altered in function of faster drainage of water and rationalization of agriculture and land use. This includes e.g. paving the river banks and bottom, changing river bed dimensions (widening, narrowing or deepening), straightening the stream, and putting it underground (in tubes). As a result, many streams have lost their natural (regulating) functions, like high and low water flow regulation and natural water quality improvement.

Stream restoration focusses on restoring the natural processes and functions of those streams that have been altered. This can include more impactful and large scale restoration, like large-scale re-meandering and restoring floodplain forests or floodplain meadows. However, in this demonstrator, we focus on small-scale landscape measures, such as micro-meandering. These small measures have also a more limited land and (financial/time) resources demand, and are less impactful on current land use, allowing continued agriculture in the floodplains. This demonstrator focusses on the enabling factors of such functional but smaller scales actions.

Co-design process and improvements needed

Involved stakeholders

- **Decision makers:** Farmers and land users; landowners; water course managers (PWF, Polder waterboard, VMM)
- **Involved:** nearby residents, business owners, citizens and municipalities; water quality and farming organizations; road and railway infrastructure authorities; sewage organizations (in case of overflows); contractors; researchers; nature organizations (in nature areas)
- **Informed:** emergency response and local works (e.g. for mowing)

We are investigating what is needed to scale up, out, and deep this NbS, the effective processes for co-design, recommendations for higher-level policy, areas requiring further investigation, and cost estimation methods.

We will focus on existing and ongoing projects (in the whole province West-Flanders). A specific case study is the renaturalization of streams in the demo "Riparian Zones in Agricultural Areas - Case Machuitvallei", where we will delve into greater detail - this is an other demonstrator in NBRACER. **Our goal** is to create a process design flow diagram and a sheet of recommendations for improving implementation. This includes identifying areas needing more research, providing recommendations to governance agencies, and outlining communication processes for stakeholders.

Co-design actions

We will test how **'Oeverzoneverkenner'** (translated: riparian zone explorer), a new tool developed in Flanders, can be used for co-design with stakeholders. This tool helps policymakers explore various riparian zone management options for chosen locations. Most importantly, it enables farmers, landowners, and watercourse managers to make collaborative decisions, providing them with guidelines and checking which management options have which impact at the parcel scale (see case Machuit).

We performed a **stakeholder mapping** exercise to identify key stakeholders for engagement.

In a stakeholder **workshop**, we gathered information from stakeholders professionally involved in stream renaturalization (e.g. via a SWOT analysis). **We will interview important stakeholders** (project managers, waterway managers, biologists, hydrologists, landowners-survey, etc.) involved in renaturalization projects to gather lessons learned, good examples, enablers, and barriers. We will examine technical, administrative, financial, legal, and organizational information and assess existing tools and potential improvements.

An **information sheet** will be made regarding the most important technical, organizational and socio-economic issues to consider when implementing the NBS, including barriers and enablers, including a list of recommendations.

Governance and other enabling conditions

Financial aspects:

- Could entail lower costs depending on the investment (construction of infrastructure and equipment) and maintenance (infrastructure and nature management) [1].
- The aspects of increased durability by adding technical structures or passages for monitoring also increase the investment costs. A balance between the added benefits, costs, impact on the waterway and initial goal of the project must be considered [3].

Technical aspects:

- Lack of knowledge on the benefits of renaturalization of streams (e.g., ecological benefits and water quantity).
- Applying a new tool made available by VMM ('Oeverzoneverkenner') could support the upscaling of this NBS.
- Soil transportation and excavation can lead to pollution. Avoiding transportation of soil must be considered in the design phase of the NBS [2].
- More natural water courses locally slow down water, resulting in increased flooding at site, but decreased flooding downstream [3].

Governance and social factors:

- A clear environmental policy framework, availability of appropriate flood risk models and active involvement of all stakeholders in an early phase could accelerate the co-design process and implementation [1].
- Because of high land demand, other valuable land uses might disappear [2]. (Private) landowners have to be willing to collaborate, and farmers may have to take more measures to comply with the regulations [2].
- Complicated administrative procedures must be followed in some cases related to waterway ownership (e.g. in case the riverbed is moved) [3].
- The ownership of the banks and who will be responsible for the long-term management is not always clear [2], which is crucial to deliver the benefits of this NBS.
- Good agreements must be made to make sure recreational use does not harm the natural environment or causes negative side effects like waste in the watercourse [2].
- The increase in the general heritage and environmental value of the water course can ensure more involvement of local residents [2].

Monitoring and selected KPIs

In this NbS, we focus on **qualitative data to identify enabling conditions**.

Our key areas of focus include:

- Aspects related to socio-economic, legal, organizational, administrative, and governance aspects.
- Interviewing and surveying stakeholders (one interview has already been conducted by VLM and VITO) to investigate the socio-economic and governmental aspects of re-meandering and other projects.
- Gathering opinions and perceptions of landowners, farmers, and other stakeholders.
- Exploring the usefulness of existing tools such as 'Oeverzoneverkenner.'

This demo will not focus on a single NbS in the field but will cover multiple NbS simultaneously, primarily examining aspects important for mainstreaming.

For specific cases, Natuurwaardeverkenner.be (a free to use, online tool to calculate ecosystem services) is used to quantify the ecosystem services.

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks Flooding Water quality Drought	Key Community Systems Water system Ecosystem To a lesser extent: critical infrastructure, health system, local economy	Ecosystem Services - Flood prevention - Infiltration - Water purification - Cooling/ evapotranspiration - Biodiversity/ habitat creation - Aesthetics, heritage and tourism
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How are KCS impacted:

- Water system: More natural water streams restore the natural processes and functions. This includes: restoring the natural water purification capacity (water quality improvement); regulating high discharge flows and slowing down water; decreasing downstream flooding (depending on the exact solution, local flooding risk can increase); regulating low discharge flows and restoring base flows.
- Ecosystem: Positive effect on biodiversity and habitat creation.

To a lesser extent:

- Critical infrastructure: Better water quality has a positive impact on the production of drinking water. However, renaturalization can require necessary adjustments in terms of mobility.
- Health system: The improvement of water quality and the creation of more natural zones has a positive impact on well-being and perception of the landscape.
- Local economy: Depending on the space needed for the exact implementation, these solutions can have a negative effect on food production as farming as a local economic system due to loss of land.

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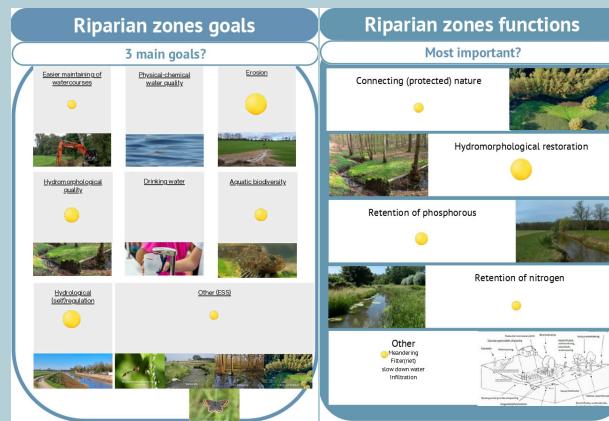
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VLM

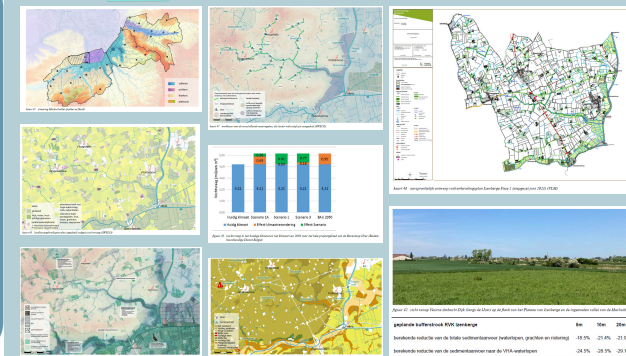
Authors: Fien Goovaerts (VLM); Bastiaan Notebaert (VITO); Catarina Baptista (VITO)

Scale:
regional

Brief description and objectives In the Machuit valley of West-Flanders, research is being conducted on how bank restoration with riparian zones (alongside/compared to the damming with automatic sluices) can contribute to the various needs and landscape restoration for the area and help build up climate resilience.	Landscape: rural, Landscape archetype subtypes: valley and flank, (polder)
Stakeholders involved and roles - Government representatives and water managers (VLM, Provincie West-Flanders, Westkustpolder, VMIM) - Land-owners - Farmers and farming organizations - Water and agricultural policy - Citizens and municipalities - Nature managers - Researchers	Key Community Systems - Water management - Land use & Food systems - Ecosystems & NBS - Health & Wellbeing - Critical Infrastructure
Climate risks - Pluvial Flooding (local) - Fluvial flooding (IJzer) - Water quality - Drought - Heat	Main regulatory function - Water management, water quality, erosion, hydro-morphological quality, drinking water, aquatic biodiversity
Ownership and roles - Westkustpolder (polders) (incl. most of the water courses) - Municipality (small ditches) - Private land owners and VLM (part of the land)	Co-benefits - Ecological corridors, structural restoration of riverbanks, phosphorus captation, nitrogen captation, meandering, infiltration
	Enabling conditions - available land - governance, policy and financing (implementation & maintenance) - engagement and understanding of ESS by key stakeholders



Stakeholders indication of their main goals and functions of riparian zones for the Vlaamse Ardennen regio, as part of the NBRACER Regional Workshop *East-Flanders* [6]. Larger yellow dots indicate the goal/function has been indicated as more important by the stakeholders.



Maps showing the setting of the site (copied from [3])

Keywords: micro-meandering, river channel restoration, hydromorphology, biodiversity

In the Machuit valley in West-Flanders, the projects Water-Land-Schap Bovenloop-IJzer and PRO Boven-IJzer [1] focus on how to manage riparian zones. Where today often intensive agriculture is practiced up to the edge of the stream banks, those projects aim at creating semi-natural riparian zones as a buffer along those streams. The potential of those zones is not fully understood, both in terms of added value (e.g. for climate resilience, landscape quality, biodiversity, water quality and quantity, farming production), as well as governance (e.g. policy, land owners, land availability, implementation methods with distance rules, agreements/compensation, land acquisition, long-term maintenance).

This NBRACER pilot is focused on **enabling factors for supporting riparian zone restoration**, through connecting to ongoing projects, land owners and other possible financing sources. This is done in collaboration with the Horizon 2020 project MERLIN [2] on mainstreaming ecological restoration of freshwater-related ecosystems. Governance and policy of this NbS is also looked at by bringing together governmental stakeholders and creating a space for dialogue. Given VLMs the governmental advisory role, we will also assess how public land (and lease contracts with farmers) can be a lever, taking into account social conditions. Replicability within NBRACER is also assessed as a collaboration between NBRACER regions West- and East-Flanders.

- Water managers (Province West-Flanders, Westkustpolder, VMM)
- Land-owners, incl. farmers and others (AWV, civilians, vzw de passage)
- VLM: landscape designer, ecologist, soil scientist, hydrologist, farmer contact point
- Water and agricultural policy (VLM, ALZ, ...)
- Citizens and municipalities (Lo-Reninge, Alveringem)
- Nature managers (Natuurpunt, milieudienst gemeente, ANB, ...)
- Farm organisations (Inagro)
- Research (WITO, Ugent)
- Consultant design (Sweco)

Stakeholders are reached through **regular interactions**. NBRACER supports this project in organizing **field visits and workshops with local governments, and identifying enablers and barriers to implementation**. We link to other existing projects in the region [1,2], incl. Integrale Waterstrategie IJzer & Handzameveelje [3] (coordinated by the Province of West-Flanders). For this pilot, there is a close link to the replication region of East-Flanders.

Co-design actions

By joining the team of PRO Boven-IJzer project, NBRACER investigates and stimulates the implementation of this NbS in order to give advice to key stakeholders and better understand their vision of the region, focusing on the enabling factors of 'finances and resources' and 'governance and engagement'.

Enabling factor: 'finances and resources'

- (1) We support the Working Group Mactcheutbeek in the visioning and design of NbS for the area. We see if we can replicate some examples in the project portfolio of VLM for design and later implementation of riparian zones and sustainable agricultural practices. The regional NBRACER team will join the meetings of the local stakeholders to discuss their vision on opportunities and barriers for these NbS. This is done by providing knowledge and guidance towards these NbS, and organizing stakeholder workshops to go discuss more in-depth and map locations with high potential for these NbS. The NBRACER team will also support the local stakeholders to better understand the effect and benefits of these NbS.
- (2) Create a technical sheet that will be developed about riparian zones and general river restoration to be provided to the stakeholders to support practical implementation.
- (3) The tool 'Overzevonevkenner' [7] will be used to assess co-benefits and ecosystem services, as well as explain the cost-benefits of the suggested riparian zones.

Enabling factor: 'governance and engagement'

- (1) Investigate existing important regulation and documents regarding this NbS on a Flemish level (e.g., afwegingskader overzevones, natuurherstelwet, MAP7, ...)
- (2) Discuss NbS with governmental institutions, interview some of them to understand their position towards the NbS, and make a complete overview of the stakeholder mapping.
- (3) The results will be written in a report, that gives policy recommendations on knowledge gaps and governance setup.
- (4) Determine the barriers and enablers together with demo case province of WFL 'renaturalisation of streams in West-Flanders' to scale up and with RR Flemish Ardennes to scale out.

- NB-RACER supports in answering the following questions:
 - What is the knowledge level about riparian zones with different stakeholders?
 - Can riparian zones in the Machuit contribute to climate resilience of the area? If yes, how?
 - What are the ecosystem services (ES) that riparian zones (can) provide?
 - How can we quantify these ES? Are there tools to support this?
 - What type of riparian zones are best fitted for the Machuit (incl. width and placement)?
 - Who should be involved in the implementation? Who can maintain it in the long-term?
 - How is the current (Flemish) policy supporting (or not) implementation of riparian zones?

This pilot will involve a compilation of existing literature on the implementation of riparian zones, as well as a qualitative study to better understand the socio-economic impact of this NBS. The barriers and enablers will be harvested by stakeholder consultation (through workshops and interviews). Testing of tools such as the 'Oeverzoneverkenner' [7] will also allow quantification of ecosystem services.

The gathered lessons learnt can be incorporated in a document with best practices, perceptions and how to improve implementation of riparian zones in Flanders.

Climate Risks	Key Community Systems	Ecosystem Services	Riparian zones can support farming systems by decreasing the loss of nutrients to the water courses, creating barriers for pesticides or sediment (in erosion prone zones), thus allowing more intensive farming within the limits of acceptable water quality impact. They can also contribute to heat reduction for cattle, increased infiltration and recharge of the water table in dry periods, and local flood prevention in wet periods. Floods are impacted by decreased connectivity between overland flow and the rivers, in some cases also increasing channel roughness. As a result, on site flooding might increase or decrease, depending on conditions, while downstream flooding will decrease. Sometimes the soil quality can be an issue for earth works in a riparian zone, for instance when soil are polluted with PFAS.
Flooding (peak discharges) Water quality Drought (local) Heat	Water management Land use & Food systems Ecosystems & NBS Health & Wellbeing Critical infrastructure	Water purification (incl. nutrient removal) Water infiltration Erosion control and hydro-morphological quality Improve aquatic biodiversity Ecological corridors and structural restoration of riverbanks	

How are KCS impacted:

- Water management: bank management (mowing or pruning); sediment removal and stabilisation. Positive effect on water quality.
- Land use & food systems: by using space, a negative impact on food production on private fields. Can also impact the risk of flooding (positive or negative, also on site and downstream) and thus on floodplain food production.
- Ecosystems: forest; grasslands; biodiversity. Positive effect due to habitat creation.
- Critical infrastructure: less important; some smaller roads and private houses. Land use changes might interfere with existing infrastructure.
- Health and well-being: Recreational; heat reduction; sense of being.

Higher variety of habitats alongside the river increases **soil, water and land biodiversity**. Riparian zones (depending on the type and location) also provide connection for species, serving as a **ecological corridors**. Riparian zones provide **cooling** alongside rivers. They increase the overall positive experience of the landscape, contributing to health and **wellbeing**. In some cases, riparian zones can contribute to the protection of critical infrastructure (e.g., blocking sediment and runoff before it goes to roads/gardens/houses). Also by decreasing the local (pluvial) flooding risk and providing a larger buffer for high discharges. However, riparian zones sometimes compete for space with other forms of landuse and infrastructure.

- Could entail lower costs depending on the investment (construction of infrastructure and equipment) and maintenance (infrastructure and nature management) [1].
- Structured agreement and financing for long-term maintenance [4].
- Combining riparian zones with a productive function is often more difficult (e.g. close by natural zones can hinder production for larger farms with intensive practices).

Technical aspects:

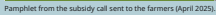
- Design of riparian zones based on the local context and needs (incl. width, type, ...).
- Lack of knowledge on the benefits of renaturalization of streams (e.g. ecological benefits and water retention in land riparian zones) [5].
- Applying a new tool made available by VMM ("Oeverzoneverkenner") [7] could support the upscaling of this NbS.

Governance and social factors:

- Although there are opportunities in governance to upscale riparian zones, regulation is too complex and creates lack of trust. The governance structure is too fragmented to efficiently support this NbS.
- A clear environmental policy framework, availability of appropriate flood risk models and active involvement of all stakeholders in an early phase could accelerate the co-design process and implementation [4].
- There is a competition in land use in forests, but the area required for riparian zones is smaller than larger scale re-meandering and rewetting of rivers.
- Although natural systems need less maintaining, sometimes the need for management increases (e.g., riparian zones with grass buffer strips), and it is hard to agree on who is responsible for the maintenance.

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- [7] Online tool "Overzeeverkenner" (Riparian zone explorer). Available at: <https://geoloket.waterinfo.be/overzeerverkenner/>

Summary Brief description and objectives: Carbon farming and non-illage are agricultural practices based on natural processes. Additional knowledge and good examples are needed to widespread this practice among farmers and to better understand its impact. This pilot specifically tests if and how governmental land can serve as a lever for sustainable farming.	Landscapes: rural andscape archetype subtypes: valley and flank, polder
Stakeholders involved and roles - Farmers, land-owners and implementers - Province West-Flanders: responsible for the local coalitions of the regional programme (Weerbaar Water-Land-Schap) - VMIM: policymaker for water environmental regulations - VLM, ALZ: water and agricultural policy, government support - Research support (WTO, UGent, ILVO, Inagro) - Nature organizations (Natuurpunt, Milieudienst gemeente, ANB, ...) - Citizens and municipalities (Lo-Reninge, Aalst)	Key Community Systems - Water management - Land use & Food systems - Ecosystems & NbS - Health & Wellbeing - Critical Infrastructure Main regulatory function - Soil quality improvement (infiltration, reduction of pollution and sediment runoff, reduced use of chemical fertilizers)
Climate risks - Drought - Flooding - Water quality and soil erosion	Co-benefits - Biodiversity - Food production - Water regulation (less runoff and pollution with pesticides/nutrients)
Ownership and roles VLM is responsible for this case	Enabling conditions - Technical knowledge - Behavioural change - Policy incentives, time and finances - Risk predictions and management



VLM

Prove
WELL

INAGRO

Scale:
regional



Procedure and timeline for the subsidy call sent to the farmers (April 2025).

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Sustainable farming practices

Summary

Brief description and objectives: Non tillage and carbon farming are sustainable practices aimed at better and more natural soil management resulting in a more climate robust agriculture. Evaluation of the long-term benefits of carbon farming and the benefits of non tillage in polder landscapes are crucial in helping farmers to implement these practices.	Landscapes: Rural; Coastal
	Landscape archetype subtypes: Polders
Stakeholders involved and roles - Citizens - farmers (implementation) - Research - INAGRO (support) - Government - PWF, local municipalities (regulation)	Key Community Systems - Landscape and food systems - Ecosystem - Water management
	Main regulatory function - Improved soil quality
Climate risks - Extreme weather events, erosion, loss of biodiversity, soil degradation, food and water insecurity	Co-benefits - Biodiversity - Carbon capture - Water infiltration
Ownership and roles - farmers (executors) - INAGRO (research and support) - PWF (regulation)	Enabling conditions - Technical knowledge - Financial incentives - Time management

Scale:
local



INAGRO

Prov
WFI

Authors: Nina Vanoverschelde (INAGRO); Dominique Huits (INAGRO); Catarina Baptista (VITO), Bastiaan Notebaert (VITO)

Description of Demonstrator

Keywords: carbon farming; non-tillage agriculture, sustainable farming, soil management practices

In this demonstrator, we focus on two sustainable **farming practices**: carbon farming and non-tillage agriculture. These practices result in a more natural and healthier soil system. This should make farmers less susceptible to climate effects, especially drought and (to a lesser extent) flooding, as the natural soil water system (availability of water for crops in the unsaturated zone, infiltration, ...) is restored.

Carbon farming involves measures that sequester carbon dioxide in the soil by enhancing soil organic matter. Increased soil organic matter improves overall soil quality, benefiting farmers through higher yields and reduced nutrient and water demands. It also enhances soil biodiversity and health. By capturing carbon in the soil, CO₂ emissions are mitigated, addressing both adaptation and mitigation simultaneously [2].

Non-tillage farming is a technique that avoids intensive turning or mixing of the soil. This results in more crop residues remaining on the soil surface, protecting the soil against erosion and increasing soil moisture content. Reduced soil compaction leads to better water infiltration. For farmers, this technique saves time and fuel costs [3].

Monitoring and selected KPIs

Different soil parameters will be monitored, including:

- Chemical soil analysis (CF&NT)
- CEC and HWC (CF)
- Aggregate stability (CF)
- Infiltration rate (CF&NT)
- Soil compaction (CF&NT)
- Bulk density, TAW, RAW, porosity and pF curves (CF&NT)
- Soil moisture content (NT)
- Soil microbial analysis (CF)

Crop parameters will also be monitored:

- Yield (NT)
- Crop emergence (NT)

For this KPIs, NT stands for non-tillage and CF for carbon farming.

Co-design process and improvements needed

Involved stakeholder groups:

- Farmers play the most important role as they are responsible for the implementation of these practices
- Local/regional governments: the municipality of Beernem and the Province of West-Flanders are also involved; they offer a support base for the implementation of carbon farming techniques by offering a financial incentive.

Sustainable farming practices encompass two separate demonstrations: **non-tillage agriculture** and **carbon farming**. Both of these demonstrations involve on-farm experimentation, meaning they are conducted on commercial farms at a commercial scale in collaboration with farmers.

The aim is to understand farmers' preferences regarding these NbS and to identify enablers and barriers. This will help determine what is needed to upscale and mainstream these NbS. Already quite a lot of information has been gathered on the potential of these techniques, the co-design process within NBRACER will be mostly focused on mainstreaming these techniques.

Non-tillage agriculture

There is already considerable experience with non-tillage on sandy and loamy soils, but not for heavy clay soils in the coastal polders. To mainstream this technique and increase its implementation in different soil contexts, scientific evidence of the effects of non-tillage compared to the traditional practice of plowing before winter in the polders needs to be gathered. This demonstration is located on several fields at different locations in the polders of West Flanders.

Carbon farming

The storage of carbon in the soil is a work of generations. Although this increase in soil organic carbon content is a slow process, other benefits are expected and may not take as long to realize. Further scientific evidence of the benefits obtained after a shorter term (+/-5 years) on a local scale might be the convincing factor for some farmers. In this study we plan to evaluate the effects these measures have had after they have been practiced since 2020-2021. This demo is located in Beverhoutsveld in West-Flanders. For this, we collaborate with an ongoing project Water-Land-Schap Beverhoutsveld, funded by VLM.

Governance and other enabling conditions

Financial aspects:

- Combining sustainable agricultural practices (carbon farming, organic manure, non-inversion tillage, agroforestry) can bring multiple benefits for investment [1].
- A sharing system for agricultural machines could help de-risk individual transition investments and upscale implementation (new market creation) [1].
- Consumers or governments might be willing to pay for the carbon sequestration in a carbon credit market system [2].
- Non-tillage leads to lower fuel costs and saves times [3].

Technical aspects:

- The effectiveness depends on soil type and other regional factors [1]. The impact on different crops (management and yield) is crucial for farmer implementation [1].
- Requires long time for implementation and must be consistently monitored during and after implementation [1].
- Difficult to measure and quantify carbon uptake as this is a work of generations.
- When not correctly maintained, the carbon can be released again [1].
- Potential negative effect on water quality: depending on the method of building up carbon in the soil, there is a risk for increased phosphate, nitrate and pesticide pollution [1].

Governance and social factors:

- (Private) landowners and farmers have to be willing to collaborate [1].
- These NbS can be implemented by only changing management and do not necessarily include a land use change or land exchange [1].

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Climate risks, Key Community Systems, Ecosystem Services

Climate Risks

- Extreme weather events
- Erosion
- Soil degradation
- Loss of biodiversity
- Food and water insecurity

Key Community Systems

- land use and food system
- Ecosystem
- Water management

Ecosystem Services

- Improved soil quality
- Biodiversity
- Carbon capture
- Water infiltration

How are KCS impacted:

- Landscape and food system: Our food security is threatened by the changing climate. Carbon farming and non-tillage agriculture can help make agriculture more climate robust. These measures tackle climate adaptation and, in the case of carbon farming, climate mitigation.
- Ecosystem: Non-tillage and carbon farming aid in building a more natural and healthier soil system. This includes a richer soil biology.
- Water management: Both techniques support a better water infiltration and water retention in the soil.

Artificial water recharge - Ramage

SMEAG

Bordeaux
INP

Région
Nouvelle-
Aquitaine

Authors: Cardot Nicolas (SMEAG);

Summary

Brief description and objectives

Study the feasibility of recharging the Garonne aquifer, during bad recharge years, to help support the flow rates at low water levels. The final objective of this project is to infiltrate between 8-10 hm³ into the Garonne aquifer in the Tonneins sector.

Stakeholders involved and roles

- Institutional levels with:
 - Local communities: social acceptance
 - Government: legal aspect
 - Adour-Garonne water Agency: funding aspect
- Economic actors: share knowledge
- Land owners: provision of their land for experimentation
- Research: Bordeaux INP - modelling and technical support
- NBRACER partners Design monitoring protocol
- Region Nouvelle-aquitaine : NBRACER regional coordinator

Climate risks

- Drought: reduction of low flow in aquatic and wetland ecosystems
- Risks to population and economic sectors due to water scarcity

Ownership and roles

Land is still owned by local authorities or private owners (they agree to make their land available for free for artificial water recharge). The infrastructure and its installation are paid by SMEAG. Local authorities can participate in operational management.

Landscapes: Rural

Landscape archetype subtypes: Garonne valley; alluvial plain with irrigated land arable and some wetland

Key Community Systems

- land use and food system
- water management
- ecosystem and nature-based solutions

Main regulatory function

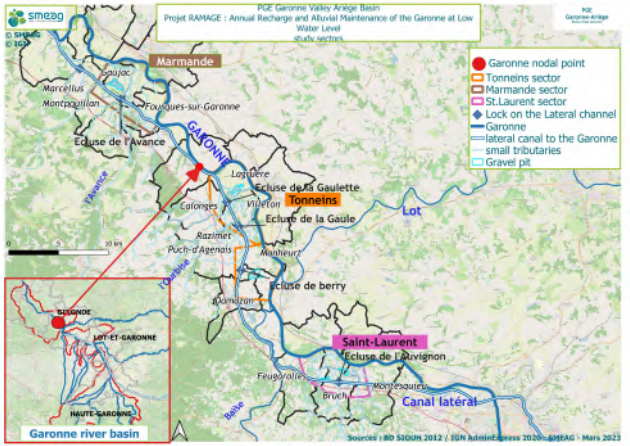
- Groundwater recharges and soil water storage
- Natural and thermally tempered low flow support

Co-benefits

- Maintain water in existing wetlands
- Reduction in water deficit at the gates of the estuary
- Increase knowledge on the functioning of the alluvial aquifer

Enabling conditions

- Social acceptance
- Legal framework



Description of Demonstrator

Keywords: water recharge, low water flow support

The Garonne basin experiences significant low water levels every year [1]. For +30 years, SMEAG has supported the Garonne's flow from hydroelectric dams in the Pyrenees and Massif Central to preserve the river's ecological, hydraulic, and landscape features while maintaining economic activity, including the irrigation of around 100,000 ha of farmland[2]. In the context of climate change, solutions for artificial recharge are being explored [3]. This hybrid solution combines NbS with human intervention to activate the recharging system.

The project, located in Lot-et-Garonne, focuses on the section of the river bordered by the Garonne Canal on the left bank. The three main study sectors are located upstream and downstream of the nodal point of Tonneins (between Agen and Marmande), in which the geological characteristics make artificial recharge an effective strategy to support the river flow during low water periods, with infiltrated water returning to surface flows. Groundwater recharge is crucial in years of rainfall deficit to naturally support the river's low water levels.

The aim is to infiltrate 8-10 hm³ into the Garonne aquifer in the Tonneins sector. Three test campaigns are planned to refine the model and select infiltration sites. The model, currently being calibrated, will test different hydroclimatic scenarios to simulate recharge operations. Various methods, such as infiltration ditches, old gravel pits, and flooding of poplar plots, will be tested. This experiment aims to determine if this solution can support the Garonne's flow in summer. The goal is to increase the inflow by 1-2 m³/s, with a flow rate of around 100 m³/s. If effective, this solution could be replicated along the entire Garonne to achieve a greater impact on the river's flow rates.

Co-design process and improvements needed

Involved stakeholder groups

- **SMEAG**: territorial authority managing the Garonne River. SMEAG leads the project, providing political leadership and funding. It identifies aquifer recharging sites, secures owner approvals, and requests administrative authorizations for the project's implementation.
- **Bordeaux INP**: provide scientific support and develop the hydrogeological model.
- **Landowners, gravel pit operators, and farmers**: involved by providing access to wells to determine water table levels and offering land for recharge experiments.
- **Municipalities**: act as intermediaries between citizens and SMEAG, crucial for operational support and explaining the project to residents to avoid opposition.
- **State representatives**: provide authorizations and facilitate administrative procedures, while the **Supra-regional Water Agency** finances part of the project.
- **Région Nouvelle-Aquitaine**: regional coordinator providing support to bring stakeholders together and organize common events; contact point with NBRACER partners and other EU projects
- **NBRACER partners** support SMEAG with their expertise: **AcclimaTerra** aids in social acceptance and connects with researchers, while **MEOSS-AtoS** handles satellite monitoring, focusing on soil moisture and drought indicators and **Sorbonne Univ** help in modelling effects of climate change on the water cycle, focusing on punctual events like flooding.

The project, built with a multidisciplinary approach, has involved numerous watershed partners since its experimental phase launch in 2021 through various agreements: Voie Navigable de France, Mazière national nature reserve, Départemental Fishing Federation, and nature and environmental protection associations. **A sociological study [4] was conducted at the project's start to engage local stakeholders and identify obstacles and levers for implementation.** This led to local presentations and collaboration with municipalities and economic stakeholders (farmers and gravel pit operators) to gather data on the water table.

Key discussion points included:

- Vigilance on water quality regulations prohibit water compartment degradation).
- Flood risk concerns, as the solution might increase flooding.
- Ensuring "additional" water does not increase agricultural use.

The project began in 2019 with an initial reflection phase (TRL 4) to transfer results from the European SISENAS project and review bibliographic data. This data helped adjust the model and validate the principle, leading to the first experiments in 2021 and 2022 (TRL 6). The next step, integrated into the NBRACER project, involves **testing the experiment in an operational environment** (TRL 7), planned to end in 2026.

The characteristics of the Garonne Valley make artificial recharge a viable strategy to support the river's low water levels, and are the main criteria for replication. However, the complexity of the river water table requires significant awareness and explanation efforts. As such, the co-design approach in NBRACER is focused on **gathering of knowledge and lessons learnt** during the implementation action.

Communicating measured values from **residents' wells** fosters local engagement and supports **citizen science** for involvement of the local population. Annual meetings [5] with partners (local officials, farmers, nature protection associations, state representatives) are organized to present progress and discuss future directions. Decisions are made upon consultation.

The experiments aim to **demonstrate the benefits** of this hybrid NbS in reducing regional vulnerability to climate change. Experimental sites will showcase the solution for replication along the Garonne River.

The technical parts of the project are funded by public money (department members of SMEAG and the Supra Water Agency) and Garonne River users (around 30 %).

Governance and other enabling conditions

Financial aspects:

- It costs the community around €3.5 million annually for maintaining the Garonne's water level [6] (SMEAG low water management budget). Seeking alternative low-tech solutions aims at reducing these costs and sustain the river's flow.
- The project is financed by SMEAG through fees (users and member communities) and co-financing from the Adour-Garonne Water Agency, covering up to 50 %. Current costs, excl. implementation, are estimated at €900,000 over the 6-year experimental phase. These costs will need revision for the operational phase, particularly to include work expenses.

Technical aspects:

- The alluvial plain of the Garonne have geological characteristics that are favorable to infiltration.
- The project is part of a comprehensive approach to improve knowledge of the functioning of the Garonne. It builds up on the previous EU SISENAS project (hydrological model) and on the expertise of Bordeaux INP (hydrogeology and hydrochemistry).
- Requires infrastructure to transport water to infiltration sites (here the lateral canal of the Garonne is used).

Governance and social factors:

- In this area of the Garonne, risk of flooding is very present (particularly following the 2021 floods). Local officials are careful to ensure that this solution does not increase the risk of flooding. Water quality also raises concerns, both for environmental associations and for communities using groundwater for drinking water supply.
- Since SMEAG does not own land in this sector, one of the main difficulties is the access to properties and acceptance by owners. The first chosen sites are owned by partners or individuals with a strong interest in the project. The search for other sites is time-consuming, and SMEAG is considering possible compensation for owners for the use of their plots.
- There is another large-scale groundwater recharge project in the Garonne (R'Garonne)[9]. Discussions with the project leaders (BRGM and Réseau31) take place regularly to share experiences and lessons learnt, particularly on the regulatory aspects. One of the main differences lies in that Réseau31 manages the canal and several nearby plots of land, thus facilitating their use for the experiment (first test in 2023).

Legal aspects:

- Groundwater recharge projects must not degrade the quality of the receiving environment, as required by the EU Water Framework Directive.
- Currently, there is no clear regulatory framework for this type of experimentation. Temporary authorization files are submitted annually to obtain yearly permissions for infiltration test. Efforts are underway to simplify the regulatory framework for these experiments, ensuring minimal environmental impact. A permanent authorization file will be required for the replication phase.
- For water quality monitoring, one-off measurements and an alert system for pollution are accepted during the experimental phase. Coordination with the R'Garonne project ensures consistent treatment between the two initiatives.

Monitoring and selected KPIs

We monitor the impact of the recharge on the Garonne aquifer and use a model to observe the propagation of the recharge bubble from the infiltration site to the Garonne. The **hydrological model** also estimates the recharge's impact on the Garonne River. We track indicators on **water quality and quantity** and gather data on **soil properties** to feed the model and simulate the recharge bubble's propagation.

Main KPIs:

- Groundwater table levels in 40 wells or piezometers.
- Soil type, parameters, and percolation rate (infiltration site).
- Water quality for groundwater and surface water (temperature, conductivity, pH, nitrates, oxygen, major ions).
- Metal concentration (two field campaigns per year for groundwater, canal water, and surface water).
- Surface water level at one point (Tonneins on the Garonne River).
- Effective drought index and moisture index (via satellite imagery) to assess impact on local wetlands.
- Monitoring of stygofauna (aquatic fauna in groundwater) with limited existing data.
- Drought vulnerability and flood hazard (indicator not yet implemented).
- Socio-economic KPIs to understand levers and barriers for replication and upscaling in the Garonne watershed (support needed from NBRACER consortium).

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks

Drought
Reduction of low flow in aquatic and wetland ecosystems
Water quality (temperature)

Key Community Systems

Water system
Local economic system
Land use and food systems

Ecosystem Services

Soil properties to store water to slow down the water cycle
Natural and thermally tempered low flow support

How are KCS impacted:

- During low-water periods, the Garonne's flow is naturally supported by contributions from the alluvial aquifer. This project aims to enhance winter recharge of the aquifer to increase the Garonne's low flow and mitigate drought impacts.
- The Garonne and its aquifers secure several thousand hectares of irrigated land, enabling crop diversification and the development of high-value crops. The project seeks to reduce the hydrological deficit at the Tonneins station, contributing to the Garonne's good ecological status and minimizing restrictions on water abstraction for irrigation and drinking water.

Co-benefits

- Recharging the water table will help maintain water levels in local wetlands.
- Confluences, backwaters, and wetlands are crucial for species diversification in these ecosystems.
- The area's classification as an N2000 site highlights its rich biodiversity, including eight large migratory fish species.
- Water inputs from the aquifer, at around 14-15 °C, help cool the river, creating favorable conditions for fish species.

References

all document (except [1]) are in french

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- [9] Exchange with the R'Garonne project (similar groundwater recharge project on the upper Garonne) with the BRGM (French geological research institute) and Réseau31 (local authority)

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Development and restoration of riparian forests functioning as green filters to control the delivery of sediments into the river network. Relevant in landscapes dominated by productive land uses, where erosion is exacerbated by two major factors in the Cantabrian region: wildfires and logging in plantation forests.

- Spanish State: ownership of the Hydraulic Public Domain (DPH)
- River Basin Authority (Confederación Hidrográfica del Cantábrico): management of the Hydraulic Public Domain.
- Regional Governmental institutions: General Directorate of Forests and Biodiversity (planning and design)
- Private land-owners: ownership of margins beyond the Hydraulic Public Domain
- Neighbourhood Council of Treceño: Lead promoter and implementer of the NbS initiative.
- Primary sector (e.g., farmers, livestock producers, fishermen,...): expressing needs and concerns

- Wildfire
- Soil erosion

DPH, owned by the State, includes channel and shores, which are managed through river basin organizations. ~70% of the 364,000 ha of forested land in Cantabria is publicly owned (almost entirely belonging to local councils and government associations). 2/3 of the eucalyptus area is privately owned. [2,3]

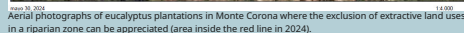
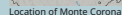
Landscape archetype subtypes: Mountainous hillslopes

- Ecosystems: Protection and regeneration of riparian zones
- Downstream critical infrastructure: Safeguarding water intakes and quality in river systems serving nearby communities
- Food and materials provision system

- Sediment retention through vegetated riparian strips, which filter runoff and prevent sediment-laden flows from reaching streams and rivers

- Biodiversity enhancement
- Reduced soil erosion
- Aesthetic and cultural landscape value
- Improve water quality
- Recreational value

- Active engagement of forest owners who benefit directly from the intervention by reducing management costs and protecting their own lands.
- Downstream beneficiaries (e.g., water utilities) are incentivized by improved water quality, fostering cross-scale cooperation.



Keywords: Riparian forest, green filter, sediments, silvicultural and livestock uses

This demonstrator focuses on development and restoration of riparian forests acting as green filters. The green filters established in Monte Corona are essentially spontaneously regenerating riparian forests composed of a wide diversity of native tree species. These forests have been allowed to re-establish naturally through the exclusion of extractive land uses in riparian zones.

These vegetated buffers serve multiple purposes:

-Sediment filtering: After logging activities, rainfall events can trigger soil erosion on bare slopes. The riparian forests intercept sediment-laden runoff, preventing it from reaching stream channels.

- Biodiversity conservation: The restoration of native riparian vegetation supports habitat complexity, creating a mosaic of different forest types and preventing the dominance of monocultures.

- Operational zoning: Riparian buffers also function as natural boundaries between forest exploitation parcels, reducing the continuity of intensive management areas.

These systems can be extended to livestock-dominated areas, where ground cover is often degraded by trampling and grazing, leading to compaction and increased erosion. These zones are also frequently subjected to burns, used to reopen shrub-invaded pastures. In such contexts, establishing or conserving riparian green filters can significantly reduce runoff and sediment delivery while contributing to fire risk mitigation and pasture quality recovery.

The monitoring strategy for this NbS focuses on **evaluating its effectiveness in reducing soil erosion and conserving biodiversity** in silvicultural and pastoral production systems. No extensive infrastructure is required, as the approach relies on comparative analyses and targeted field sampling. Other areas across the region will be selected as part of a control-implement approach to include in the monitoring different productive areas in order to compare the effectiveness of the NbS according to the origin of sediment mobilization (plantations, logging and forest fires).

Monitoring approach

- Risk mapping: FIHAC at UC have developed fire risk maps and post-logging deforestation maps based on satellite data and field verification.
- Water sampling: A control-implement sampling design is employed. Water samples are collected from streams with and without riparian forest buffers that drain hillslopes with varying silvicultural and grazing pressures (e.g., mature plantations, recently logged areas, burned pasture zones).
- Physicochemical analysis: Parameters such as turbidity, sediment load, and nutrient concentration will be monitored to quantify the filtering effectiveness of riparian vegetation.

Key Performance Indicators (KPIs) (focused on soil erosion and biodiversity)

- Reduction in suspended sediment concentration (mg/L): Indicates the capacity of riparian vegetation to reduce sediment transport from hillslopes into streams.
- Reduction in turbidity (NTU): Serves as a proxy for improved water quality and reduced erosion.
- Presence and abundance of indicator riparian species: Used to assess biodiversity conservation and ecosystem health.
- Increase in vegetated buffer strip width (m): Reflects spontaneous or assisted regeneration success.

The Hydraulic Public Domain (DPH), which includes channels and shores, is owned by the State.

Administration. Management is through river basin organizations, also known as Hydrographic Confederations. Riparian zones, which are land adjacent to riverbeds and located above the water level, may be privately owned but are subject to conditions that restrict their use [1]. Of the 364,000 hectares of forested land in Cantabria, approximately 70% is publicly owned, almost entirely belonging to local councils and local government associations. The majority (82%) are Public Utility Forests (MUP). The Regional Government's Forestry Service can establish consortiums with the owners of these lands (local authorities, local councils, and local government associations), allowing for the management tasks at the initiative of the Regional Government. 28% of the forest area is privately owned by smallholders. However, two-thirds of the eucalyptus area is privately owned, and only one-third is publicly owned. [2] [3]

Involved stakeholders

The co-design process for this NbS has been **informal but organically developed** through long-term land-use practices and local knowledge. The Neighbourhood Council of Treceño, as the forest owner and land manager, has played a central role in initiating and implementing this approach in Monte Corona, supported by the acceptance and awareness of various user groups.

Apart from that, other stakeholders could be involved at a regional scale as the riparian areas are located along the Hydraulic Public Domain (DPH):

- Spanish State: ownership of the Hydraulic Public Domain.
- River Basin Authority (*Confederación Hidrográfica del Cantábrico*): management of the Hydraulic Public Domain.
- Regional Governmental institutions: General Directorate of Forests and Biodiversity (planning and design)
- Private land-owners: ownership of margins beyond the Hydraulic Public Domain.
- Primary sector (e.g., farmers, livestock producers, fishermen,...): expressing needs and concerns

Climate Risks

- Wildfire
- Soil erosion

Key Community Systems

- Ecosystems
- Downstream critical infrastructure (e.g. water captations in the river)

Ecosystem Services

- Sediment filtering
- Biodiversity enhancement
- Improved water quality
- Reduced soil erosion
- Aesthetic and cultural value
- Recreational value

How are KCS impacted:

- Soil erosion due to the absence of vegetation and extractive activities in hillsides during erosive rainfall events may lead to runoff and sediment transport processes into the river. In this case, the absence of riparian vegetation that prevents the retention of mobilized sediments, has an impact on water quality. The alteration of the suspended solids in the water produces a negative impact on river ecosystems and the communities that inhabit them, as well as on human water use systems (treatment plants, water abstractions) due to high turbidity.
- In parallel, erosion and the lack of sediment deposition on the riverbank can change the morphology of the slope, making the lower part more active and promoting hillslope erosion. The subsequent soil loss has negative impact on the productivity of the livestock-forestry operation itself.

Financial aspects:

- Low-cost intervention, especially when relying on natural regeneration of riparian vegetation.
- No direct financial incentives have been required in this case; however, benefits are perceived by upstream forest landowners, who recognize the ecological and economic value of maintaining vegetated buffers to reduce erosion.
- Downstream water users (e.g., treatment facilities or public administrations) also benefit, suggesting the potential for developing payment for ecosystem services schemes or compensation mechanisms.

Technical aspects:

- It does not require heavy civil engineering works, as it mainly relies on excluding extractive or productive land uses in riparian zones to allow for natural regeneration of native vegetation. In this case, implementation is based on passive restoration (land-use exclusion), with minimal technical intervention.
- Although design and construction challenges are negligible, performance depends on the integrity of the surrounding landscape, particularly the intensity of silvopastoral activities on nearby slopes.

Governance and social factors

- The intervention is promoted by local councils, such as the Neighbourhood Council of Treceño, which facilitates local acceptance. There is a clear understanding among landowners and forest users of the function and benefits of riparian buffers, particularly in historically managed forests such as Monte Corvino. The intervention is mainly by small-scale farmers, farmers, ecotourism users) and is compatible with the traditional multi-use management of the area.
- No major legal or institutional barriers have been reported; the action aligns well with existing land management and water protection policies.
- Knowledge about the role of riparian vegetation in sediment retention is well accepted by land managers, and local administrations, fostering replication potential.
- This intervention can serve as a reference example for other regions, especially where forest and pastureland use coexist, and sediment control is a concern.
- Further institutional support could involve long-term monitoring and procees scaling through pilot programs or forest agency partnerships.

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Conservation of riparian forests

FIHAC

UC

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Summary

Brief description and objectives: Riparian forests constitute areas of provision of multiple ES, e.g. thermal regulation and bank erosion control. The conservation of this habitat is crucial for maintaining an adequate thermal regime in rivers and preserving hydromorphological dynamics in fluvial landscapes. In this demo, we identify drivers and barriers in order to mainstream this NbS.

Stakeholders involved and roles

- Spanish State: ownership of the Hydraulic Public Domain (DPH).
- River Basin Authority (Confederación Hidrográfica del Cantábrico): management of the Hydraulic Public Domain.
- Regional Governmental institutions: General Directorate of Forests and Biodiversity, Water, and Land Use (planning and design), Public Works, and Environment (development and implementation).
- Private land-owners: ownership of margins beyond the Hydraulic Public Domain.
- FIHAC/UC: project coordinator, scientific or technical advisors, research collaboration.
- NGOs: facilitating stakeholder engagement, translating science and transferring knowledge.
- Primary sector (e.g., farmers, livestock producers, fishermen, ...) & citizens: expressing needs and concerns

Climate risks

- Changing temperature, Heat stress, Temperature variability
- Water stress, Flood
- Soil erosion, Landslide

Ownership and roles

DPH, owned by the State, includes channel and shores, which are managed through river basin organizations. ~70% of the 364,000 ha of forested land in Cantabria is publicly owned (almost entirely belonging to local councils and government associations). 2/3 of the eucalyptus area is privately owned. [2,3]

Landscapes: Rural

Landscape archetype subtypes: floodplains (Land cover CORINE: Forest and seminatural areas > Forests > Broad-leaved forest)

Key Community Systems

- Ecosystems

Main regulatory function

- Thermal regulation
- Erosion control

Co-benefits

- Provision of biodiversity: habitats and species
- Climate regulation: Carbon sequestration.

Enabling conditions:

- Environmental and biodiversity legislation
- Recent European, national and regional strategies on biodiversity and green infrastructure

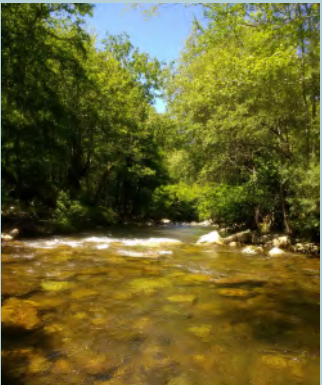


Figure 1. View of a river with well-preserved riparian forest (Cantabria, Northern Spain).

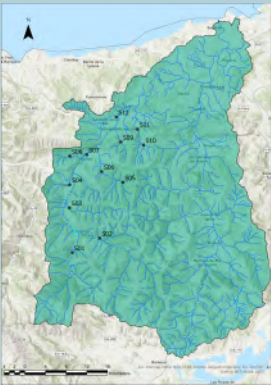


Figure 2. Monitoring sites for the thermal regulation effect of riparian forests.

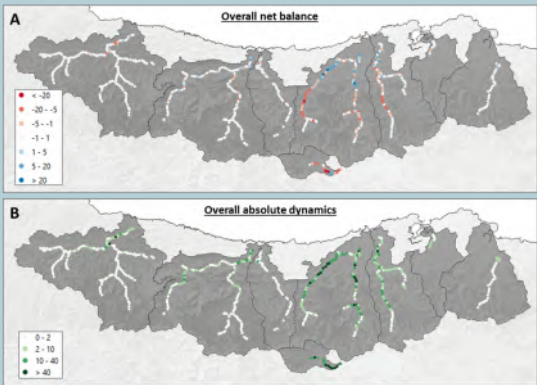


Figure 3. A: Global net balance (m2/m) between 2016-2023. B: Cumulative absolute value change (m2/m). Negative: net erosion; Positive: net accretion/vegetation development

Description of Demonstrator

Keywords: Riparian forest; Erosion; Thermal regulation; Habitat creation; Flooding

Strips of native riparian vegetation, primarily habitat 91E0* ("Alluvial forests of *Alnus glutinosa* and *Fraxinus excelsior*", Fig. 1) [4], have been preserved along the river network to maintain the thermal regime of the rivers and enhance bank protection against erosion. These forests regulate channel and air temperatures through shading [5] and play a crucial role in bank erosion dynamics by stabilizing riverbanks [6]. They also contribute to habitat creation and the formation of various channel features (e.g., bars, pools, rapids) through the production of large woody debris and leaf litter, thereby sustaining river biodiversity [7]. Additionally, riparian forests increase floodplain roughness, potentially reducing the specific energy of streams during flood events [8]. In this demonstrator, we focus on the preservation and restoration of these forests. We do this in a co-design process that aims at mainstreaming this solution, and resulting in the identification of drivers and barriers.

Co-design process and next steps

The Hydraulic Public Domain (DPH), which includes channel and shores, is owned by the State. This means that any use or activity in these areas requires authorization from the Water Administration. So, although it is state-owned, its management and protection are the responsibility of the river basin organizations, also known as Hydrographic Confederations. Margins, which are land adjacent to riverbeds and located above the water level, may be privately owned but are subject to conditions that restrict their use [1].

Of the 364,000 hectares of forested land in Cantabria, approximately 70% is publicly owned, almost entirely belonging to local councils and local government associations. The majority (82%) are Public Utility Forests (MUP). The Regional Government's Forestry Service can establish consortiums with the owners of these lands (minor local authorities, local councils, and local government associations), allowing for the management tasks at the initiative of the Regional Government. 28% of the forest area is privately owned by smallholders. [2] [3]

This demonstrator aims to engage stakeholders in mainstreaming this solution by quantifying the costs and benefits of conservation measures more concretely compared to alternative solutions. It includes the development of a co-design process with local and regional governments to plan subsequent actions.

Stakeholders involved

- Spanish State: ownership of the Hydraulic Public Domain.
- River Basin Authority (Confederación Hidrográfica del Cantábrico): management of the Hydraulic Public Domain.
- Regional Governmental institutions: General Directorate of Forests and Biodiversity and General Directorate of Water and General Directorate of Land Use (planning and design), General Directorate of Public Works and General Directorate of Environment (development and implementation).
- Private land-owners: ownership of margins beyond the Hydraulic Public Domain.
- Scientific or technical advisors: Research collaboration (e.g., data sharing, experience exchange) to improve evidence quantification or monitoring methods through scientific programs or *ad-hoc* meetings.
- Intermediary organizations (NGOs): Facilitating stakeholder engagement, translating science and transferring knowledge through the participatory process.
- Primary sector (e.g., farmers, livestock producers), fishermen and land-owners: Expressing needs and concerns through surveys and participatory events.
- Citizens: Expressing needs and concerns through surveys and participatory events
- FIHAC/UC: Project coordinator, sampling design, baseline and monitoring through project development

Next steps

Evidence gathering about the functions of riparian forests. This aims at:

- knowledge transfer to regional government via reports and meetings
- scientific articles in preparation

Gathering info on funding schemes to share with farmers (e.g., funding to preserve/restore riparian belts).

As part of the evaluation of this NbS and aligned with the participatory process of **NBRACER** in Cantabria, key stakeholders in the region will be informed of the results obtained during the monitoring through workshops or surveys, and their opinions and perceptions will be gathered to make the necessary adjustments to the action.

Governance and other enabling conditions

Financial aspects:

- Public local authority's budget and regional EU funds (calls for grants funded by the Recovery and Resilience Facility, EAFRD).

Technical aspects:

- Literature contains extensive information on the cause-effect relationships regarding riparian ecosystems and their environmental and social benefits (e.g., regulation, provision and cultural ecosystem services), as well as biodiversity conservation.
- Implementation requires a low intervention degree. The high degree of naturalness of the implementation area facilitates the conservation of this system.
- The identification of priority conservation areas requires scientific evidence and, thus, research development, which is often time demanding.

Governance and social factors:

- The inclusion of conservation areas in national and regional conservation planning requires the agreement of multiple environmental organizations operating at multiple scales.
- Riparian forests provide a range of regulation (e.g., bank erosion control), provision (e.g., clean water, wood, latex, mushrooms) and cultural ecosystem services (e.g., recreation, aesthetic value, cultural heritage, therapeutic benefits), facilitating social support.
- Pressure from alternative land uses (e.g. livestock, agriculture, linear infrastructure) can pose a challenge to the conservation of riparian forests.
- Working on private land and bureaucracy can also play a role as barriers.

Monitoring and selected KPIs

FIHAC and UC have collected water and air temperature measurements in sites with a range of riparian forest cover (Fig. 2), and developed a temperature model for riparian areas using AI (deep learning models) and global data (e.g., climate models). Also, FIHAC and UC are developing AI-based models to map erosion-accretion maps (Fig. 3) and will evaluate the effects of riparian forests on bank erosion control with advanced statistical techniques (e.g., structural equation modelling).

KPI's:

Referring to the KPI code from EU 2021 Handbook when possible [9]

Changing temperature:

- Air temperature (Daily/Seasonal temperature mean)
- Air temperature (2.14 - Daily temperature range)
- Water temperature (4.38 - Water quality: basic physical parameters various)

Soil erosion:

- Catchment sediment yield (6.29 - Total predicted soil loss)
- Bank erosion

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks

Changing temperature
Heat stress
Temperature variability
Water stress
Flood
Soil erosion
Landslide

Key Community Systems

Ecosystems:
- Forests
- Freshwater ecosystems

Ecosystem Services

Water provision
Biodiversity provision
Climate regulation
Air quality regulation
Water flow regulation
Erosion control
Water quality regulation

How are KCS impacted:

- Freshwater habitat: Creation of habitats and regulation of temperatures.
- Forests: Conservation of terrestrial processes, functions and species.
- Nature based Solutions: constituting a source of social and environmental benefits from natural elements (riparian forest).
- Riparian forests, being located at the interface between terrestrial and aquatic ecosystems, provide a disproportionate amount of ecosystem services, taking into account their small extension. Likewise, their structure along the river network allows these services to be offered in large areas of the territory.

Co-benefits

- Provision of biodiversity: refuges for mammals, nesting sites for birds, corridors and refuge for bats and fish
- Regulation of natural hazards: attenuation of the specific energy of water in flood events.
- Educational value: dissemination of information on the relationship between terrestrial and aquatic ecosystems
- Aesthetic value: ecosystem of great beauty.
- Recreation/Tourism: hiking activities, bird watching, sport fishing
- Sense of place: part of activities of local importance (e.g. "10,000 del Soplo" race and Cocio Montañés festival)

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Conservation of hillside forests

Scale:
several sites
spread over
the region

FIHAC

UC

Authors: Ayanta Velasco Martínez (FIHAC),
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Summary	
Brief description and objectives Forests, in general, and hillside forests, in particular, constitute areas of provision of multiple ES, e.g. thermal regulation by temperature buffering through shading. In this demo, we identify drivers and barriers in order to mainstream this NbS.	Landscapes: Rural Landscape archetype subtypes: hillside (Land cover CORINE: Forest and seminatural areas > Forests > Broad-leaved forest)
Stakeholders involved and roles - Regional Governmental institutions: General Directorate of Forests and Biodiversity, General Directorate of Land Use, General Directorate of Environment (planning, design, development and implementation) - FIHAC/UC: Project coordinator; scientific or technical advisors: Research collaboration - Intermediary organizations (ONGs): Facilitating stakeholder engagement, translating science and transferring knowledge - Primary sector (e.g., farmers, livestock producers) and land-owners & citizens: Expressing needs and concerns	Key Community Systems - Ecosystems
Climate risks - Changing temperature - Precipitation/hydrological variability, Water stress, Drought, Flood - Soil degradation, Soil erosion	Main regulatory function - Hydrological regulation - Thermal regulation
Ownership and roles Of the 364,000 hectares of forested land in Cantabria, approximately 70% is publicly owned, almost entirely belonging to local councils and local government associations. The majority (62%) are Public Utility Forests (MUP). The Regional Government's Forestry Service can establish consortiums with the owners of these lands (minor local authorities, local councils, and local government associations), allowing for the management tasks at the initiative of the Regional Government. 26% of the forest area is privately owned by smallholders. However, two-thirds of the eucalyptus area is privately owned, and only one-third is publicly owned [1] [2].	Co-benefits - Provision of biodiversity: habitats and species - Climate regulation: Carbon sequestration.
	Enabling conditions: - Environmental and biodiversity legislation - Recent European, national and regional strategies on biodiversity and green infrastructure



Figure 1. View of a native mature beech forest (Cantabria, Northern Spain).

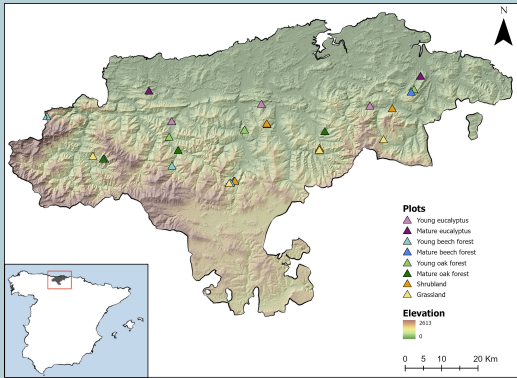


Figure 2. Monitoring sites for the hydrological and thermal regulation effect of hillside forests.

Description of Demonstrator
Keywords: ecosystem services, hydrological response, erosion control, thermal regulation, hillside forests, integrated watershed management.
Native forests, such as oak and beech forests in Northern Spain (fig. 1), play a crucial role in regulating hydrological processes because they influence water quantity [3] and quality [4], regulate thermal regimes at multiple scales [5], act as carbon sinks [6], and protect soil from erosion [7]. Conservation of native forests in hillside areas aims to maintain and enhance the ecosystem functions and services they provide. This includes carbon sequestration, regulation of hydrological processes to ensure water availability and quality, biodiversity conservation, soil protection against erosion and temperature buffering. This demonstrator focuses on the preservation and restoration of these native forests and the climate resilience benefits this brings. We do this in a co-design process that aims at mainstreaming this solution, and resulting in the identification of drivers and barriers.

Co-design process and improvements needed
This demonstrator aims to engage stakeholders in mainstreaming this solution by quantifying the costs and benefits of conservation measures more concretely compared to alternative solutions. It includes the development of a co-design process with local and regional governments to plan subsequent actions.
Stakeholders involved: - Regional Governmental institutions: General Directorate of Forests and Biodiversity, General Directorate of Land Use, General Directorate of Environment (planning, design, development and implementation) - Scientific or technical advisors: Research collaboration (e.g., data sharing, experience exchange) to improve evidence quantification or monitoring methods through scientific programs or <i>ad-hoc</i> meetings. - Intermediary organizations (ONGs): Facilitating stakeholder engagement, translating science and transferring knowledge through the participatory process. - Primary sector (e.g., farmers, livestock producers) and land-owners: Expressing needs and concerns through surveys and participatory events - Citizens: Expressing needs and concerns through surveys and participatory events - FIHAC/UC: Project coordinator, sampling design, baseline and monitoring through project development
Next steps: Evidence gathering about the functions of riparian forests. This aims at - knowledge transfer to regional government via reports and meetings - scientific articles in preparation
Gathering info on funding schemes to share with farmers (e.g., funding to preserve/restore hillside forests).
As part of the evaluation of this NbS and aligned with the participatory process of NBRACER in Cantabria, key stakeholders in the region will be informed of the results obtained during the monitoring through workshops or surveys, and their opinions and perceptions will be gathered to make the necessary adjustments to the action.

Governance and other enabling conditions
Financial aspects: - Public local authority's budget and regional EU funds (calls for grants funded by the Recovery and Resilience Facility and EAFRD [9]).
Technical aspects: - The scientific literature contains extensive information on the cause-effect relationships regarding hill-side forests and their environmental and social benefits (e.g., regulation, provision and cultural ecosystem services), as well as biodiversity conservation. - The implementation of this NbS requires a low intervention degree. The high degree of naturalness of the implementation area facilitates the conservation of this system. - The identification of priority conservation areas requires scientific evidence and, thus, research development, which is often time demanding. - The inclusion of conservation areas in national and regional conservation planning requires the agreement of multiple environmental organizations operating at multiple scales.
Governance and social factors: - Hill-side forests provide a range of regulation (e.g., erosion control), provision (e.g., clean water, wood, latex, mushrooms) and cultural ecosystem services (e.g., recreation, aesthetic value, cultural heritage, therapeutic benefits), facilitating social support. - Pressure from alternative land uses (e.g. livestock, agriculture, linear infrastructure) can pose a challenge to the conservation of hill-side forests.

Monitoring and selected KPIs
To monitor this solution, different variables and/or indicators related to hydrological variability, extreme events such as floods and droughts, and temperature changes will be measured in Northern Spain (Fig. 2). These indicators include: - Soil organic matter - Soil water storage - Soil moisture - Infiltration rates and hydraulic conductivity - Evapotranspiration rates, using remote sensing - Air temperature above and below the canopy - Soil temperature - Surfaces occupied by each type of habitat and % of forest cover - Carbon storage in biomass - Forest biomass above ground - Water supply in the basin
KPIs Referring to the KPI code from EU 2021 Handbook when possible [8] - Water infiltration (4.1 & 4.2 - Infiltration rate / Infiltration capacity) - Soil moisture (6.15 - Moisture index) - Soil temperature (2.5 - Soil Temperature / 2.18 - Land surface temperature) - Evapotranspiration (2.17 - Rate of evapotranspiration) - Air temperature (2.10.3 - Thermal Storage Score / 2.14 Daily - Temperature range)

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks Changing temperature Precipitation or hydrological variability Water stress Drought Flood Soil degradation Soil erosion	Key Community Systems Ecosystems: - Forests	Ecosystem Services Water provision Biodiversity provision Climate regulation Air quality regulation Water flow regulation Erosion control Water quality regulation	Co-benefits - Provision of biodiversity: Refuges and corridors for mammals, nesting sites for birds, high soil biodiversity - Regulation of natural hazards: Attenuation of the specific energy of water in precipitation events - Educational value: Dissemination of information on the relationship between terrestrial and aquatic ecosystems - Aesthetic value: Ecosystems of great beauty. - Recreation/Tourism: Hiking activities, bird watching - Sense of place: Part of activities of local importance (e.g. "10,000 del Soplo" race and Cocio Montañés festival)
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How are KCS impacted:

- Forest habitat: Creation of habitats and regulation of temperatures.
- Forests: Conservation of terrestrial processes, functions and species.
- Nature based Solutions: Constituting a source of social and environmental benefits from natural elements (hill-side forest).

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Assisted natural regeneration of mountain wetlands

FIHAC

UC

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Pepe Barquín (UC)

Summary

Brief description and objectives: Seasonal livestock exclusion to restore aquatic habitats and improve the capacity of mountain wetlands to adapt to changing temperature, precipitation/hydrological variability, drought and soil degradation. This action avoids the soil and vegetation degradation caused by cattle grazing and trampling on raised bogs and mires and fens, which are declared Sites of Community Importance (SCI).

Landscapes: rural

Landscape archetype subtypes: mountain (Land cover CORINE: Agricultural areas > Pastures, Wetlands > Peat bogs)

Stakeholders involved and roles

- Picos de Europa National Park: technical/scientific advisor.
- Regional Governmental institutions: General Directorate of Forests and Biodiversity (coordination)
- Local authorities (landowners and ongoing maintenance): local government and neighbourhood association (Junta Vecinal)
- Livestock farmers: planning and compensatory measures.
- Residents
- NGO (Red Cantabria): participatory process, awareness and citizen participation campaigns.
- Non-profit entity (Fundación Camino Lebaniego): ongoing maintenance in Cantabria region.
- FIHAC/UC: project coordination, design, baseline and monitoring.

Key Community Systems

- Ecosystems

Main regulatory function

- Green filtering (water quality regulation, biological control)

Climate risks

- Soil degradation

Ownership and roles

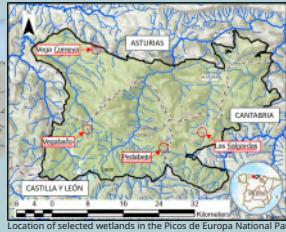
- Picos de Europa National Park, Special Protection Area for Birds – Liebrana (ZEPA ES0000198)
- Ayuntamiento de Camaleño: municipality of implementation
- Junta Vecinal de Espinama: to manage, conserve, and defend the communal pastures.

Enabling conditions:

- LIFE DIVAQUA project (already finished) was the promoter of the installation of the temporal fences (first installation in summer 2023). There have been to recent botanical descriptions (2021 and 2024).
- LIFE TREMEDAL project: Previous permanent enclosures (2013-14) in the National Park but in Asturias and Castilla y León.



Location of Picos de Europa National Park.



Location of selected wetlands in the Picos de Europa National Park.



Salgardas wetlands protected by fencing from cattle that graze in the surrounding area in summer.



Detail of the electric fences.



Compensatory measures: drinking trough repair (above) and cattle pens repair (below).



Volunteers during the day for the dismantling of the fences (left) and example of information boards (right).

Description of Demonstrator

Keywords: wetland protection, mires and bogs, livestock exclusion, soil degradation

One of the priority actions of the recently completed LIFE DIVAQUA project [1] carried out in Picos de Europa National Park (PENP) was to restore and maintain the natural conditions of the wetlands by installing fences to prevent livestock from entering. Following the botanical characterization of the PENP wetlands in 2021, certain wetlands were prioritized for protection based on the presence of Sites of Community Importance (SCI) across the three regions within the PENP (Cantabria, Asturias, and Castilla y León). Consequently, 11 fences—mostly seasonal—were first installed in the summer of 2023. Additionally, three permanently fenced wetlands, established during the previous LIFE TREMEDAL project (2013-14), are located in Asturias and Castilla y León. The seasonal fencing involves setting up and dismantling temporary solar-powered electric fences each June and October, respectively, during the grazing season when cattle are present in the high pastures/lands.

Livestock exclusion aims to restore aquatic habitats and enhance the wetlands' capacity to adapt to changing temperatures, changing rainfall patterns, hydrological variability, drought and soil degradation. This action reduces the degradation caused by extensive livestock grazing or trampling, and avoids organic enrichment of the water. This contributes to the appropriate development of vegetation associated with these wetlands.

Co-design process and improvements needed

Involved stakeholder groups

DIVAQUA's actions were focused on achieving functional links between aquatic environments through the restoration and ecological improvement of the territory and the wildlife that inhabit it. Since the LIFE DIVAQUA project involved both public and private entities, and did not aim to develop market-oriented products or services, it sought to establish a balance between human activity in the various social spheres of the Picos de Europa and the conservation of natural spaces, such as riparian forests and peat bogs. Based on the presence of habitats of community interest identified in a prior botanical characterization (2021), a zonification and prioritization of wetlands was performed.

Through a participatory process, **local representatives** (local governments and neighbourhood associations) were informed about the environmental status of the area, as well as possible solutions to reconcile the socioeconomic use of the land (extensive livestock farming) with the preservation of biodiversity. The involvement of local stakeholders continued with visits to the area. Prioritized areas were proposed to be temporally protected by means of fences and their installation were consulted and agreed with the **landowners** (local authorities) whose approval was essential. To establish the fencing perimeter for the exclusion of livestock in the wetland, the most advantageous proposal for all parties was agreed.

Livestock farmers were also consulted to know their needs and to design and propose interesting compensatory measures for them:

- cattle pens repair
- drinking trough repair
- clearing of scrubland for the recovery or expansion of grazing land

Red Cantabria, responsible of the participatory process, established a citizen awareness and participation program, including a day for the dismantling of the fences with volunteers [2] and the installation of information boards [3].

Environmental agents of the **Picos de Europa National Park** were present during the installation of the fences and during the citizen participation sessions to ensure the correct development of the actions.

The Juntas Vecinales (**neighbourhood councils**) have the power to limit the number of livestock that may access pastures if strict reasons of conservation, maintenance, and natural regeneration so require. This is to ensure that the principle of equally governing collective use of communal land is not violated. The spatial and temporal delimitation of the use of communal pastures is determined and approved by each neighborhood councils, which may which may determine important differences in the landscape.

The **residents** of the corresponding municipalities have the right to use the communal pastures in accordance with the provisions of the laws and local Ordinances.

The respective **regional governments** are responsible for coordinating and maintaining the fences through the participation of environmental agents. In the specific case of Cantabria, the **Fundación Camino Lebaniego** (non-profit entity as an instrument of co-participation of Cantabrian society with public authorities), through a Steps for LIFE project, will also collaborate with the installation and uninstallation of the fences in the wetlands of the Cantabria region (Salgardas) from 2025 onwards.

As part of the evaluation of this NbS and aligned with the participatory process of NBRACER in Cantabria, key stakeholders in the region will be informed of the results obtained during the monitoring through workshops or surveys, and their opinions and perceptions will be gathered to make the necessary adjustments to the action. The replicability of this action in similar mountain wetlands will depend on the ability to demonstrate its effectiveness to agents in the territory.

Some improvements of the co-design process will be identified during the ongoing regional participatory process.

Governance and other enabling conditions

Financial aspects:

- LIFE DIVAQUA project was a great opportunity providing the necessary funding for the implementation of this measure.
- Commitment of the Fundación Camino Lebaniego to collaborate from 2025 onwards in the context of a Steps for LIFE project.
- Public funds from the National Park Picos de Europa allocated to Cantabria [10]
- Regional public funds (EU regional EARDP) [11]

Technical aspects:

- Onsite conditions are identified as enabling conditions, since neither the physical characteristics of the place, nor the lack of available space have been observed as obstacles to the development of the intervention.
- Maintenance and performance challenges could be barriers for the correct functioning of the intervention, as it requires short- and medium-term commitment to assemble and disassemble the fence, organize field work teams, and provide a place to store materials during the rest of the year.

Governance and social factors:

Many enabling conditions are associated with institutional and governance capacities, such as:

- Clear leadership
- Inter-agency & Inter-institutional cooperation
- Long-term vision
- Legislation & regulation
- Climate Change policies

Knowledge aspects:

Most enabling conditions are associated to previous experience of involved stakeholders, such as:

- General knowledge on NbS
- Institutional experience
- Technical guidance
- Previous successful stories
- Past experiences
- Clear cause-effect relationships

Monitoring and selected KPIs

Preparatory actions by FIHAC/UC:

- literature review (previous botanical reports, similar experiments).
- design of a control-impact experiment (fenced vs unfenced areas) in some protected wetlands.
- identification of KPIs to assess the effectiveness of this NbS mainly focused on soil degradation (CC challenge), carbon sequestration and biodiversity conservation (co-benefits).

Upcoming monitoring by FIHAC/UC:

- Referring to the KPI code from EU 2021 Handbook when possible [9]
- **wetlands:** 1 in Cantabria region (Salgardas), 1 in Asturias region (Vega Comeya) and 2 in Castilla y León region (Vegabaño and Pedabajo).
- **treatments:** fenced areas (impact) and unfenced surrounding areas (control) in each wetland.
- **time:** early summer (June), midsummer (July-August) and late summer (September).
- **habitats of interest:** 7110 Active raised bogs [5], 7120 Degraded raised bogs still capable of natural regeneration [6], 7140 Transition mires and quaking bogs [7], 7230 Alkaline fens [8]
- **parameters:** KPI code from EU 2021 Handbook [9] is provided when possible:
 - > water: conductivity (4.35), pH (4.34), T (4.38), TDS, TSS (3.3), NH3 (3.4), PO4 (3.4), coliform bacteria content (3.6)
 - > soil: bulk density, texture, OM (7.3), salinity, bare ground cover (8.13)
 - > gas: CO2 (1.1), CH4 (1.1)
 - > vegetation: plant species abundance (8.9/10.22/9.3.1/9.2/10.7.1/10.16/10.17), moss cover, above-ground biomass (1.1)

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks

- Soil degradation

Key Community Systems

- Ecosystems:
 - > Freshwater habitats
 - > Natural and semi-natural grassland formations
 - > Raised peatlands, lowland peatlands (fens and mires) and swampy areas

Ecosystem Services

- Biodiversity provision
- Erosion control
- Water quality regulation
- Biological control
- Educational value
- Aesthetic value
- Recreation / Tourism
- Soil formation
- Biogeochemical cycles
- Habitat creation
- Genetic diversity maintenance

How are KCS impacted:

Livestock exclusion contributes to restoring aquatic habitats and improves the capacity of wetlands to adapt to changing temperatures, changing rainfall patterns, hydrological variability, drought and soil degradation.

This action reduces the degradation caused by extensive livestock grazing and trampling, and organic enrichment of the water. This contributes to the appropriate development of the vegetation associated with these wetlands.

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Floodplain restoration to reduce flood risk

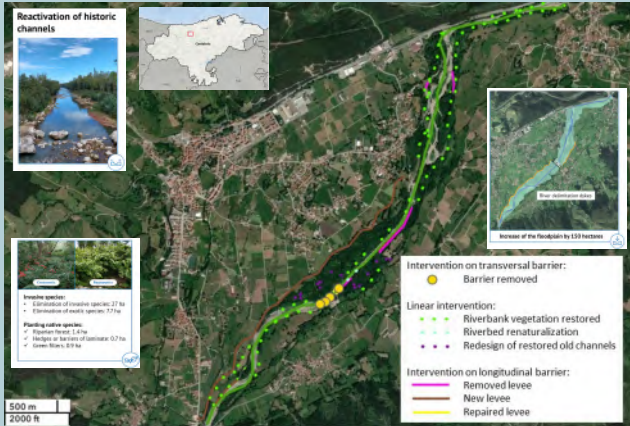
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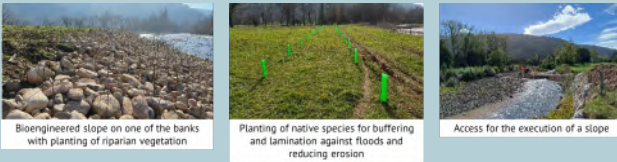
Authors: Ignacio Pérez-Silos (UC),
Alberto Vélez Martín (FIHAC), Pepe Barquín (UC)

Summary

Brief description and objectives: Environmental recovery of 6 km length of Saja river by expanding the floodplain, reactivating historic secondary channels and planting native species will provide effective protection against flooding and will improve river habitats.	Landscapes: rural
Stakeholders involved and roles - Cantabrian River Basin Authority (Confederación Hidrográfica del Cantábrico): project design and execution of the works. - Consulting Company Eptisa, Engineering Services, S.L.: Technical Assistance - Local authorities (Cabezón de la Sal and Mazcuerras): local government - Landowners: expropriations and stewardship agreements - Farmers: land users - Residents: exposed to flood risk - Environmental NGOs: consultation in the participatory process	Landscape archetype subtypes: floodplain
Main regulatory function - Lateral connection between the river channel and its floodplain for temporal water storage and energy dissipation	Key Community Systems (incl. socio-econ impacts) - Ecosystems - Urban infrastructure (exposed to flooding) - Roads and bridges
Climate risks - Extreme precipitation events - Fluvial flooding	Co-benefits - Biodiversity - Erosion control - Aesthetic value - Water quality - Recreational value
Ownership and roles The intervention area is mostly located within public hydraulic domain, which falls under the jurisdiction of the national government. However, part of the land used to open up the floodplain belongs to private landowners.	Enabling conditions This action was declared of general interest by Law 26/2009 of the General State Budget for 2010 and forms part of the programme of measures of the Flood Risk Management Plan (PGRI) of the Western Cantabrian Hydrographic Demarcation. The project was awarded on 05 June 2023 with a budget of €5,230,504.21 and a completion period of 31.5 months.



Map with the location and the main interventions of the project.



Description of Demonstrator

Keywords: flooding regulation, floodplain restoration

This project aims to address the problems affecting a stretch of 6.3 km of the river Saja between the bridges of Virgen de la Peña and Santa Lucía, in the municipalities of Cabezón de la Sal and Mazcuerras, both in Cantabria. This section of the river Saja is identified in the Flood Risk Management Plan (PGRI) of the Western Cantabrian Hydrographic Demarcation [1] [2] as being extremely dangerous and at extreme risk (Area of Significant Potential Flood Risk - ARPSI: E5018-CAN-22-1), since the population affected is high and/or the damage to economic activities is very important. Furthermore, from an environmental point of view, this section is particularly degraded by hydromorphological pressures, basically defense structures (dykes and breakwaters), canalisations, flow regulation (weirs and deflectors), which have caused alterations in the geomorphological processes of the riverbed and the degradation of river habitats.

The work to be carried out is divided into the following groups of actions:

- Hydromorphological restoration** consisting of the elimination of longitudinal and transversal barriers, stabilisation of slopes using bioengineering techniques, reactivation of secondary river channels, control and mitigation of invasive exotic species, improvement of the state of health of the existing autochthonous vegetation, increase in the surface area for flood control, among others.
- Improvement of water quality** through the installation of green filters (vegetated buffers serving multiple purposes such as sediment filtering and biodiversity conservation) and the collection and management of existing waste in the section of the riverbed affected.
- Promotion of biodiversity** with different initiatives aimed at promoting and protecting birds, amphibians and phytophagous insects, as well as the creation of a network of island habitats.
- Socio-economic integration** of the project through social participation, the improvement of knowledge in society about the river ecosystem and the promotion of ecotourism by means of a communication plan.

Monitoring and selected KPIs

The effectiveness of this NbS, focused on floodplain restoration along a 6.3 km stretch of the river Saja, will be primarily assessed through a **model-based approach** rather than direct field monitoring. The Cantabrian River Basin Authority (Confederación Hidrográfica del Cantábrico), as the promoter and implementer of the intervention, has developed a hydrodynamic model of the site. This model will be used by FIHAC to evaluate the performance of the intervention in terms of fluvial flood regulation. The monitoring will consist of **pre- and post-intervention simulations** using the same hydrological boundary conditions. These simulations will allow comparison of key hydrological variables to quantify the mitigation effect of the NbS on fluvial flood risk.

Main lines of monitoring

- Run the hydrological model under equivalent storm and flow conditions before and after the intervention.
- Assess changes in flood peak discharge at critical points of the river stretch.
- Compare flood extents and depths in populated or flood-prone areas adjacent to the river.
- Evaluate the temporal delay of peak flow reaching downstream settlements (attenuation effect).

Key Performance Indicators (KPIs)

- Reduction in peak flow (m³/s): Quantifies the ability of the floodplain to attenuate flood waves.
- Reduction in maximum flood depth (cm): Particularly in high-risk urban or infrastructure areas.
- Increase in floodplain storage capacity (m³): Volume of water the restored area can temporarily retain.
- Reduction in flooded surface area (ha): In vulnerable or built-up zones.
- Delay in time to peak (min): Indicates improved flood wave attenuation and regulation.
- Increase in active floodable area (ha): Due to removal of barriers and reconnection of secondary channels.

These indicators are intended to evaluate the hydrological functionality of the restored floodplain and its contribution to mitigating climate-related fluvial flood risks. Although no direct field measurements are planned, model calibration will rely on existing hydrometric data from the Confederación Hidrográfica del Cantábrico and past flood events.

This monitoring strategy ensures a cost-effective yet robust assessment of the NbS, focusing on its core objective: reducing flood hazard in a critical area with both high risk and high ecological degradation.

Co-design process and improvements needed

This project has been drafted by the **Cantabrian Hydrographic Confederation** with the technical assistance of the **Consulting Company Eptisa**, Engineering Services, S.L.

The implementation of this restoration project included a series of **social integration and participatory activities** promoted by the Cantabrian River Basin Authority, aiming to increase **public awareness** and foster community involvement in river restoration efforts. These activities, although valuable, represent a relatively basic level of co-design, focused more on awareness and engagement than on true collaborative planning or decision-making.

- As part of the project, several volunteer and **environmental education activities** were organized, such as:
- Environmental volunteering days for planting native vegetation, removing invasive species, and cleaning riverbanks.
 - Educational workshops on biodiversity, including the construction of bird boxes, amphibian ponds, and insect hotels.
 - Citizen science actions such as "bioblitz" species identification events.

These activities targeted a broad audience, including school groups, environmental associations, and interested individuals. Their purpose was mainly to raise awareness, build a stronger connection between the public and the river ecosystem, and promote a sense of stewardship.

Additionally, the project foresaw the establishment of **land stewardship agreements** to secure the long-term conservation of restored areas. These voluntary agreements are designed to engage **landowners** and local actors in the sustainable management of ecologically valuable sites. The agreements included mapping of the stewardship areas, identification of key ecological values to be protected, the drafting and signing of contracts, and the development of associated action plans. In this regard, it is important to note that while most of the interventions have taken place on public land, the actions involving floodplain restoration have required the expropriation of some privately owned parcels near the river channel. These flood-prone lands are mainly used for livestock grazing and hay collection, particularly when animals are kept in stables.

Although flooding of these areas might initially appear to be a **trade-off** with respect to their current agricultural use, this is not necessarily the case. Under an adequate early warning and flood prevention system, there should not be a simultaneous occurrence of flood mitigation (i.e., intentional inundation of the parcels) and active livestock grazing. In fact, the natural flooding dynamics may even provide nutrient-rich sediment that helps fertilize these meadows, thereby maintaining or enhancing their productivity for agricultural purposes. On the other hand, the setback of flood protection levees introduces the risk of a perverse incentive: if a floodplain is at risk of flooding during a 1-in-100 or 1-in-500-year event, urban development is typically restricted. However, if a levee is built to eliminate the risk, the land could potentially be reclassified as developable, opening the door to urban expansion.

While these participatory elements added value to the implementation of the intervention, they remained peripheral to the core decision-making process. Key design choices—including site selection, intervention type, and hydrological modeling—were led by technical experts without structured input from local stakeholders during the planning phase.

Therefore, improvements are needed to move from stakeholder involvement to actual co-design. This would require **early-stage engagement of local communities, landowners, and relevant institutions** in identifying objectives, setting priorities, and evaluating trade-offs. Such an approach would ensure a stronger alignment of the intervention with local needs and knowledge, enhance social ownership, and increase the long-term sustainability of the intervention.

Improvements needed:

- Organizing participatory planning workshops during early phases.
- Integrating local ecological knowledge into the technical assessments.
- Establishing multi-stakeholder governance structures to guide design and monitoring.
- Including co-benefits and land use synergies as part of stakeholder-led discussions.

These improvements would help transform public participation from supportive engagement to shared responsibility and collaborative design. In this sense, as part of the evaluation of this intervention and aligned with the participatory process of **NBRACER** in Cantabria, key stakeholders in the region will be informed of the results obtained during the monitoring through workshops or surveys, and their opinions and perceptions will be gathered to make the necessary adjustments to the action.

Governance and other enabling conditions

Financial aspects:

- Civil works funded by the Public National Budget [3] and the Regional ERDF 2021-2027 [4].
- This action was declared of general interest by Law 26/2009 of the General State Budget for 2010 and forms part of the programme of measures of the Flood Risk Management Plan (PGRI) of the Western Cantabrian Hydrographic Demarcation.

Technical aspects:

- This type of intervention requires substantial civil works, incl. earthmoving, the construction of levees, and various bioengineering measures. While such actions demand appropriate design and machinery, they no longer pose significant technical challenges (except for the challenge in this case posed by the spread of *Reynoutria japonica* -an invasive plant species), as extensive experience has been gained in this field.
- Onsite conditions, design and construction challenges, maintenance & performance challenges.

Governance and social factors:

- This kind of NbS implementation has been widely tested across Europe, particularly in the late 20th and early 21st centuries, with a large body of supporting evidence available.
- These interventions are typically led by public authorities, which ensures strong institutional backing during both the implementation and long-term maintenance of the NbS.
- A complete list and explanation of these barriers & enablers is available in [5].

References

- [1] Update of the flood risk maps of the Western Cantabrian Hydrographic Demarcation. <https://www.chcantabrico.es/actualizacion-mapas-de-peligrosidad-y-riesgo-demarcacion-hidrografica-del-cantabrico-occidental>
- [2] Flood Risk Management Plan for the Western Cantabrian Hydrographic Demarcation 2022-2027 (page 312). https://www.chcantabrico.es/documents/2014/3/1169804/63ef646a10962e0.0476494401_DHCoc ANEJO_1_2C_RD.pdf/6bf711-8ed6-9645-c8fc-c591c75b0f3671e1676044485505
- [3] Public Tender for Project implementation
- [4] Cantabria ERDF 2021-2027 (page 62)
- [5] Deely, J., Hynes, S., Barquín, J., Burgess, D., Finney, G., Sillo, A., ... & Ballé-Béganton, J. (2020). Barrier identification framework for the implementation of blue and green infrastructures. *Land Use Policy*, 99, 105108.
- [6] Habitat 91E0: *Alluvial forests with Alnus glutinosa and Fraxinus excelsior*

5 Mapping Landscapes and Ecosystem Services

This deliverable addresses also mapping of Rural Landscapes which will support the co-design process and further development of demos towards portfolios at regional level and across landscapes. Following the guidance of WP5, we have focused on existing maps and data, with some new maps and analysis for the Demonstrating Regions of **West-Flanders**, **Nouvelle-Aquitaine** and **Cantabria**. For the Central Denmark Demonstration Region, maps are not available at this moment, but will be developed in Task 4.3, later during the project. The further operationalization of the technical and process framework in the regions still has to be further discussed and developed, which will be implemented in the following Task 4.3, building on an integrated balanced portfolio and adaptation pathways, supported by WP5 and WP6.

The maps and sources incorporated below are addressing a selection of the following: **location of the current demo(s)**, **climate hazards and risks**, **land use**, **Key Community Systems**, relevant **ecosystems** and **Ecosystem services**.

5.1 West-Flanders

The West-Flanders mapping of landscapes and ecosystem services is focused on two focus areas, representative of the rural landscape in the Province: **Male-Lieve** and **Boven-IJzer**. Figure 2 provides an overview of the rural demonstrators, followed by the different maps of landscape archetypes, climate hazards, and biodiversity and ecosystem services.

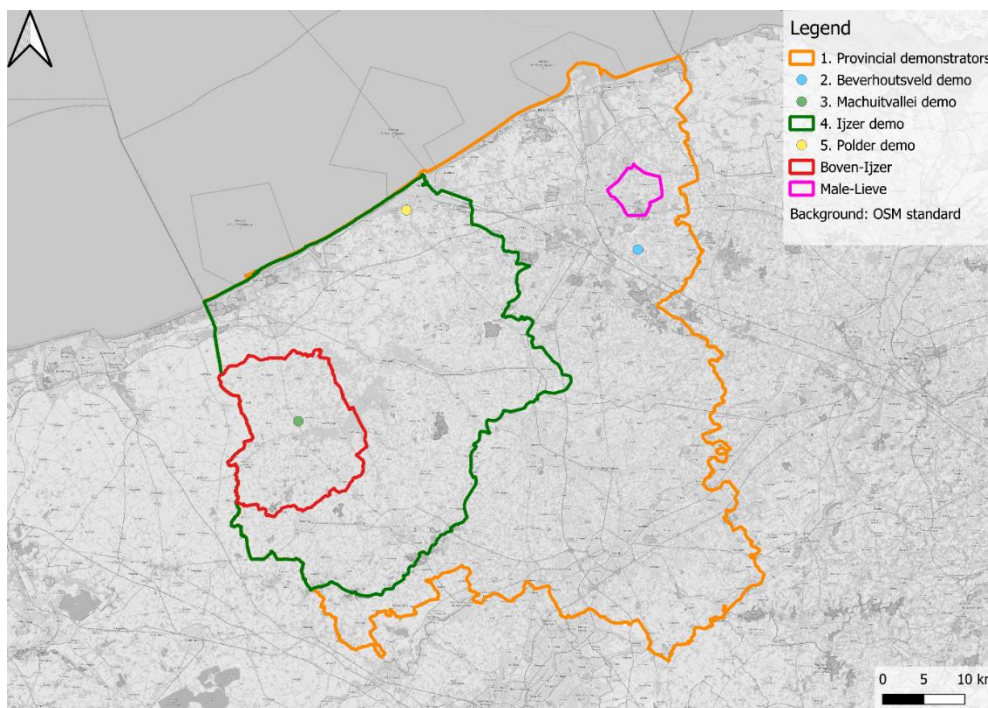


Figure 2: Location of the Rural Demonstrators in West-Flanders: differentiated mowing and renaturalization of streams - entire Province (1); raising water level on cropland - Beverhoutsveld (2); riparian zones - Machuitvallei (3); soil improvement practices - IJzer catchment (4); sustainable farming practices - Beverhoutsveld (2) and Polders (5); the focus areas Male-Lieve (pink) and Boven-IJzer (red).

1.1.1 Male-Lieve

Landscape archetypes

Land use

Figure 3 shows the land use at 10-meter resolution within the Flemish region for the reference year 2022¹. The concept of 'land use' refers to the actual use of the land for specific human activities (e.g., housing, industry and services, recreation, etc.), for cultivation (e.g., arable farming, grassland, etc.), or for natural vegetation (e.g., forest, shrubland, etc). Within the Male-Lieve focus area, the most prevalent land uses are **arable land**, followed by **grassland under agricultural use**, and subsequently **residential areas**, including houses and gardens.

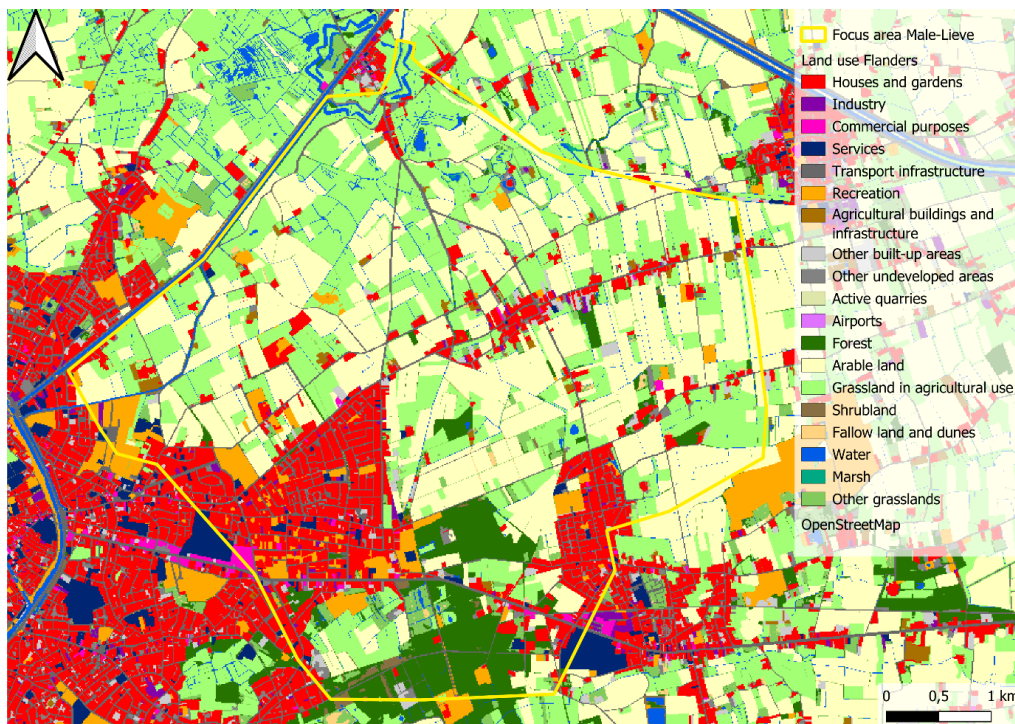


Figure 3: Land use in the focus area Male-Lieve.

Ecoregion

An ecoregion is an area that is relatively homogeneous in terms of its physical-geographical (soil characteristics, topography) and ecological (nature and environment) conditions². Climate, topography, and soil are particularly influential in determining the types of natural habitats that can occur within a given ecoregion. Within the Male-Lieve focus area, two ecoregions are present: (i) the **polders and the tidal Scheldt**, and (ii) the **Pleistocene river valleys** (Figure 4). The ecoregion of the *polders and the tidal Scheldt* is a low-lying, flat area with a subsurface composed of quaternary geological formations, deposited during repeated marine inundations caused by post-glacial sea level rises. It is further characterized by a history of artificial land reclamation and clay soils lacking distinct profiles. The ecoregion of the *Pleistocene river valleys* is a low-lying

¹ [Landgebruik - Vlaanderen - toestand 2022 | Vlaanderen.be](https://landgebruik.vlaanderen.be/toestand/2022)

² [Ecodistricten en ecoregio's als instrument voor natuurstudie en milieubeleid](#)

sandy plain where the tertiary geological substrate was deeply eroded by Pleistocene rivers and subsequently filled with a thick layer of sandy aeolian and fluvial deposits. Furthermore, a permanent groundwater table is present almost everywhere.

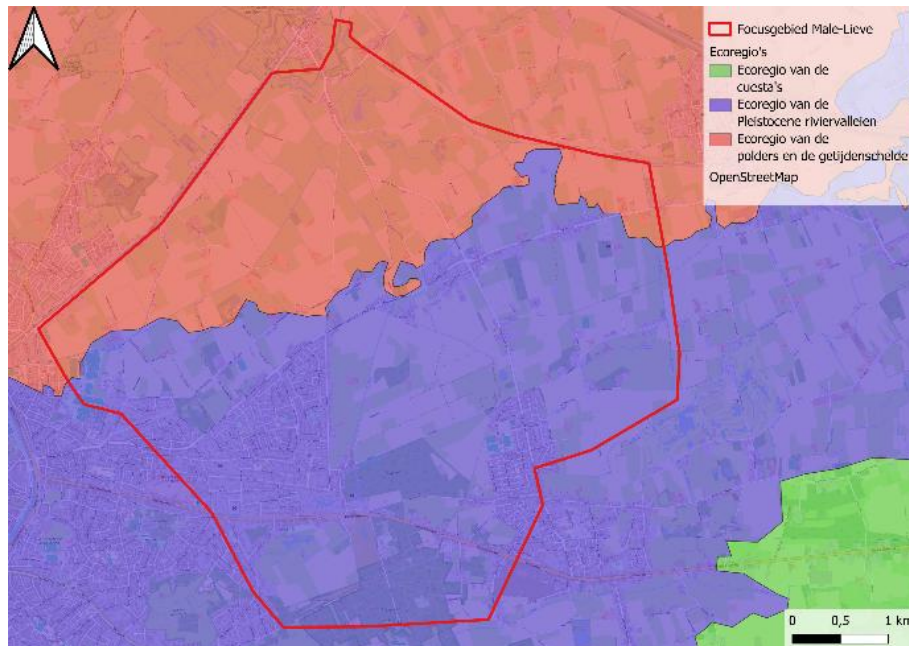


Figure 4: Ecoregions in the focus area Male-Lieve: polders (red), Pleistocene valleys (blue) and cuesta's (green).

Watercourses

The Vlaamse Hydrografische Atlas (VHA), or Flemish Hydrographic Atlas, provides detailed data on surface water systems in the region of Flanders in Belgium (Vlaamse Milieumaatschappij, 2025)³. The VHA maps all categories of watercourses, including navigable and non-navigable watercourses, public ditches, and some private and roadside ditches. Within the Male-Lieve focus area, a **total of 83 watercourses** have been identified, comprising 51 public ditches, 17 second-category classified watercourses, 14 non-classified watercourses, and one first-category classified watercourse (Figure 5).

³ [Vlaamse Hydrografische Atlas - Waterlopen, toestand 10/01/2025 | Vlaanderen.be](https://vlaanderen.be/vlaamse-hydrografische-atlas-waterlopen-toestand-10-01-2025)

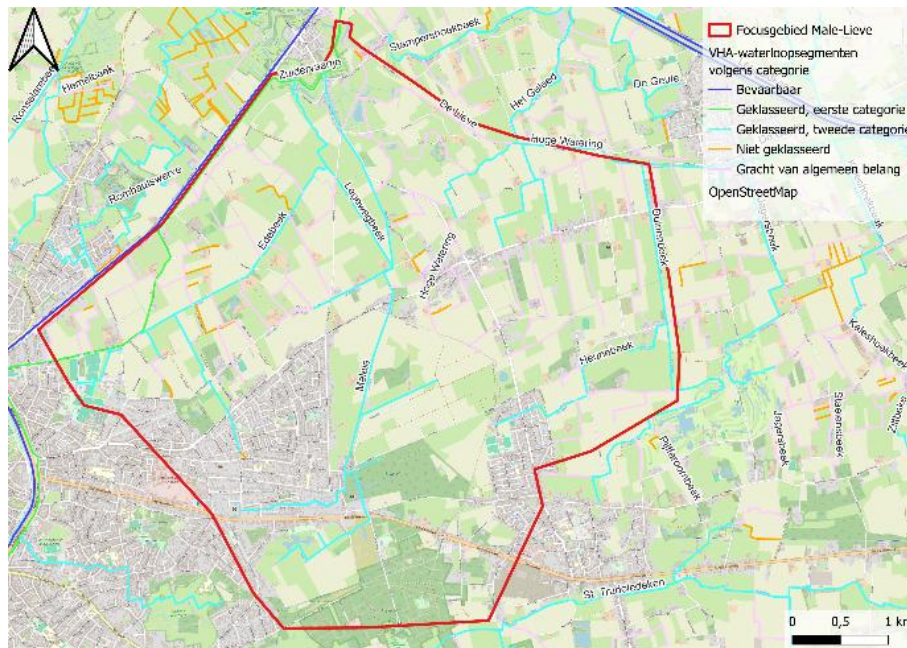


Figure 5: Watercourses in the focus area Male-Lieve, with their official classification: navigable (blue), first category (green), second category (turquoise), not classified (orange) and ditches (pink).

Climate hazards

Climate hazards and their impacts on KCS, including vulnerable people, buildings and health infrastructure are investigated based on information publicly available at KlimaatPortaal⁴.

Heat stress

A heat event with a return period of 20 years (T20) was used for all presented maps and figures. Spatial patterns in heat are visualized by means of the multi-year average of the **number of tropical days per year** (Figure 6). A tropical day is a day with a maximum temperature of 30°C or more. There are little to no spatial differences within the focus area, but a clear increase in the number of tropical days over time: mean of 4 tropical days/year (current climate) vs. 12 tropical days/year (future climate 2050).

Vulnerable individuals are defined as those aged 0 to 4 and 65 and older. More specifically, this concerns vulnerable individuals for whom the daily maximum and minimum apparent temperatures during an extreme heat day (T20) are exceeded to such an extent that serious adverse health effects are anticipated. The **number of vulnerable residents exposed to heat stress** (Figure 7) increases from 0 (current climate) to 780 (future climate 2050). Exposed residents are mainly located within the urbanized zone east of Bruges.

Vulnerable institutions (including childcare facilities, pre-primary, primary and special education, hospitals and nursing homes) are those where, during an extreme heat day (T20), the threshold values for maximum and minimum daily apparent temperature are exceeded beyond which

⁴ [IMPACTtool - Klimaatportaal Vlaanderen](#)

severe health impacts are expected. The **number of vulnerable institutions exposed to heat stress** (Figure 8) increases from 0 (current climate) to 2 exposed childcare institutions in Sijsele (future climate 2050).

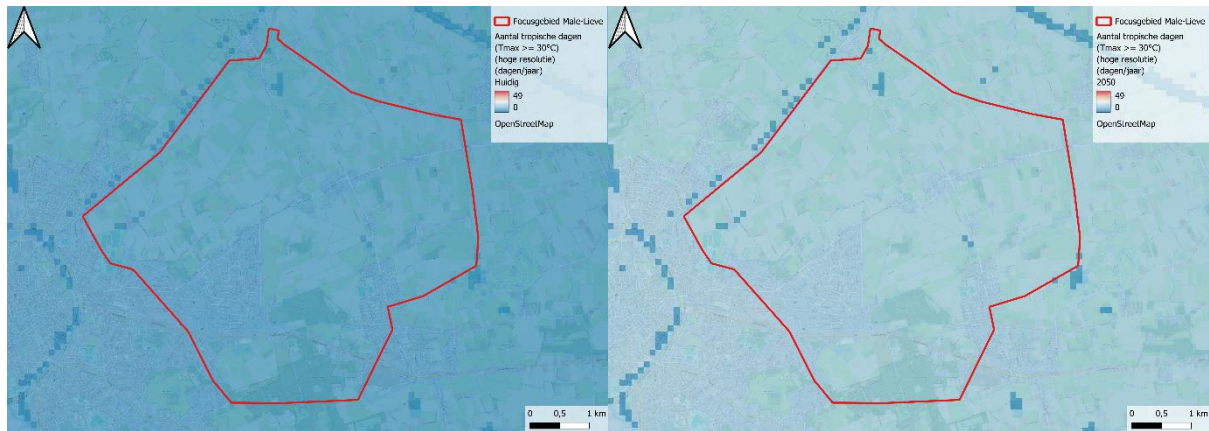


Figure 6: Number of tropical days ($T_{\max} \geq 30^{\circ}\text{C}$) in the focus area Male-Lieve (high resolution: 100 m): current climate (left) & future climate (2050) (right).

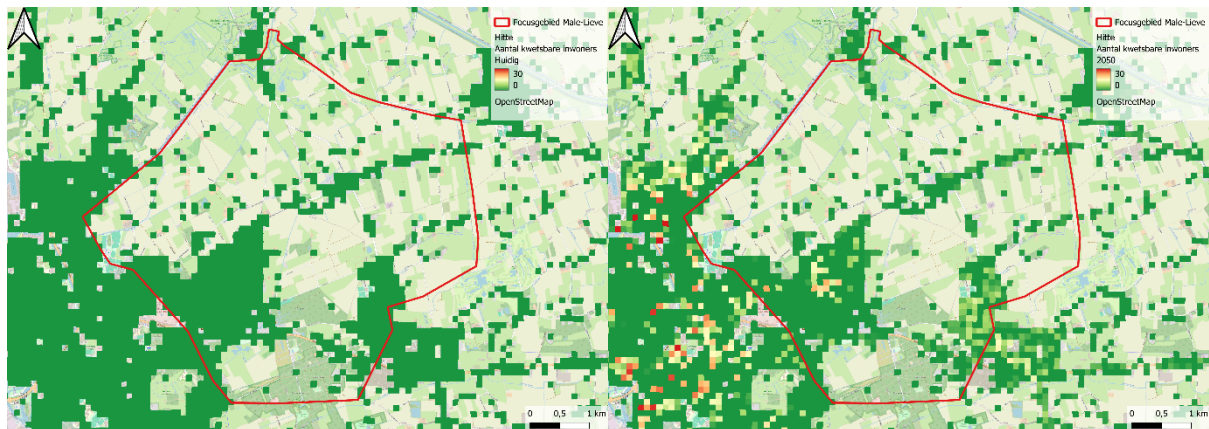


Figure 7: Number of vulnerable residents exposed to heat stress in the focus area Male-Lieve: current climate (left) & future climate (2050) (right).

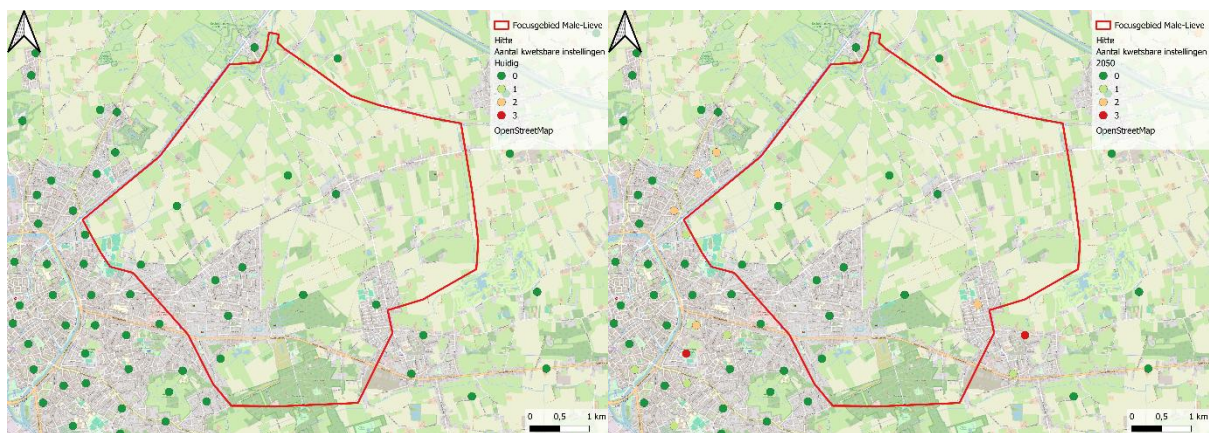


Figure 8: Number of vulnerable institutions with heat stress in the focus area Male-Lieve: current climate (left) & future climate (2050) (right).

Drought

Drought-related climate risks and impacts on KCS were considered with a return period of one year (T1). For **drought duration (meteorological)** (Figure 9), the number of days per year with little or no precipitation (less than 0.1 mm/day) increase: mean of 169.5 days/year (current climate) vs. 202.4 days/year (future climate 2050). There is little to no spatial variation within the focus area.

The evaluation of **agricultural parcels with significant drought stress** (Figure 10) is based on the drought-intensity. The intensity of drought is quantified as the total cumulative volume deficit of soil moisture on an annual basis, expressed in the cumulative volume of water deficit per volume of soil (cumulative m^3/m^3 year). This annual drought intensity is modelled for the current and future climate for a given return period (here T1). Agricultural crops experience significant drought stress when a given threshold is exceeded. This threshold is defined as the moment when the total water shortage exceeds the permanent wilting point and plants experience reduced plant growth and lower crop yields. This threshold was determined at a drought intensity of $1 \text{ m}^3/\text{m}^3$ for agricultural crops in Flanders.

For the current climate, 22 parcels (2.3% of the agricultural parcels in the region) and 44.8 ha (0.77% of the total area of the region) are identified; whereas for the future climate (2050), 66 parcels (6.9%) and 141 ha (2.4%) (assuming current crops). Agricultural drought stress is evaluated based on current crops and environmental factors like soil texture. The spatial patterns therefore reflect the effects of both factors, with a slightly higher number of parcels affected by drought in the southern part of the focus area, which is characterized by sandy soil (Figure 4). Especially crop vulnerability to drought impacts the pattern.

Vulnerable ecotopes with significant drought stress (Figure 11) correspond to natural parcels vulnerable to desiccation that are exposed to extreme drought conditions (with a drought intensity exceeding 1) (T1). For the current climate, 27 parcels and 20.8 ha (0.36% of the total area in the region) is identified; whereas for the future climate (2050), 67 parcels and 48.0 ha (0.83%).

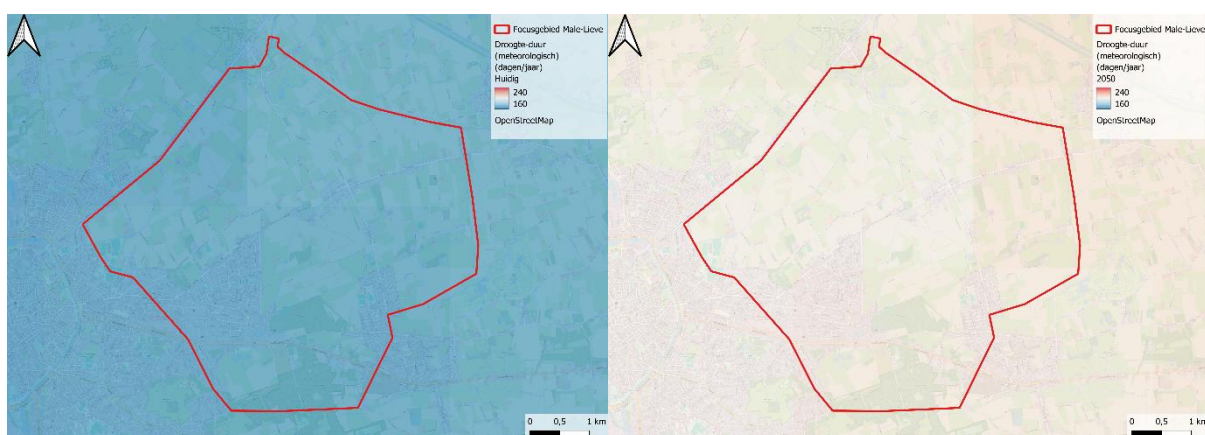


Figure 9: Drought duration (meteorological; days/year) in the focus area Male-Lieve: current climate (left) & future climate (2050) (right).

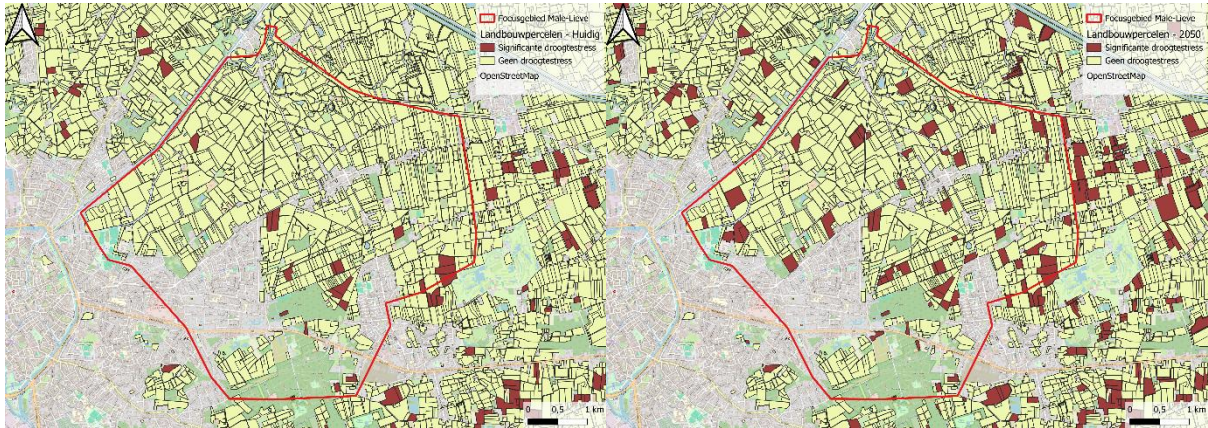


Figure 10: Agricultural parcels with significant drought stress in the focus area Male-Lieve: current climate (left) & future climate (2050) (right). Red parcels have significant drought stress.

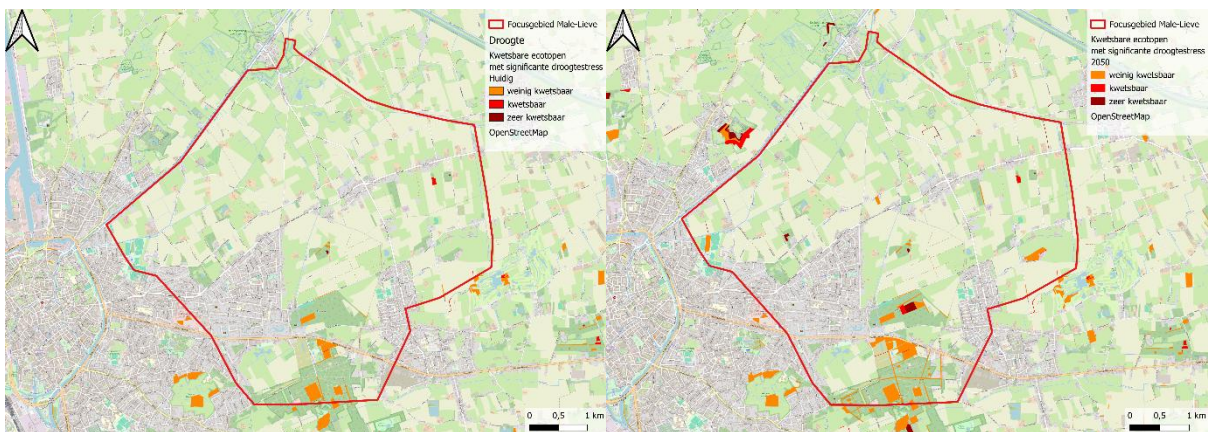


Figure 11: Vulnerable ecotopes with significant drought stress in the focus area Male-Lieve: current climate (left) & future climate (2050) (right). The legend indicates limited vulnerable (orange), vulnerable (red) and very vulnerable (dark red) ecotopes.

Fluvial flooding

Water depth during a flood with a probability of once every 1000 years (T1000) (Figure 12) under current climate was identified especially in the northern part of the region around Damme: water up to 257 cm deep and a mean water depth of 46 cm.

The **number of buildings by statistical sector with a probability of flooding** once every 1000 years (T1000) (Figure 13) under current climate was identified especially in the northern part of the region around Damme and Vivenkapelle: at least 41 buildings were flooded in 2017, considering only statistical sectors fully contained within the perimeter.

Vulnerable institutions at risk of flooding (Figure 14) (including childcare facilities, pre-primary, primary and special education, hospitals, and nursing homes) for T1000 were not identified under current climate.

Although the impact of these climate risks was not modelled for this region under future climate (2050) conditions, an increase is expected.

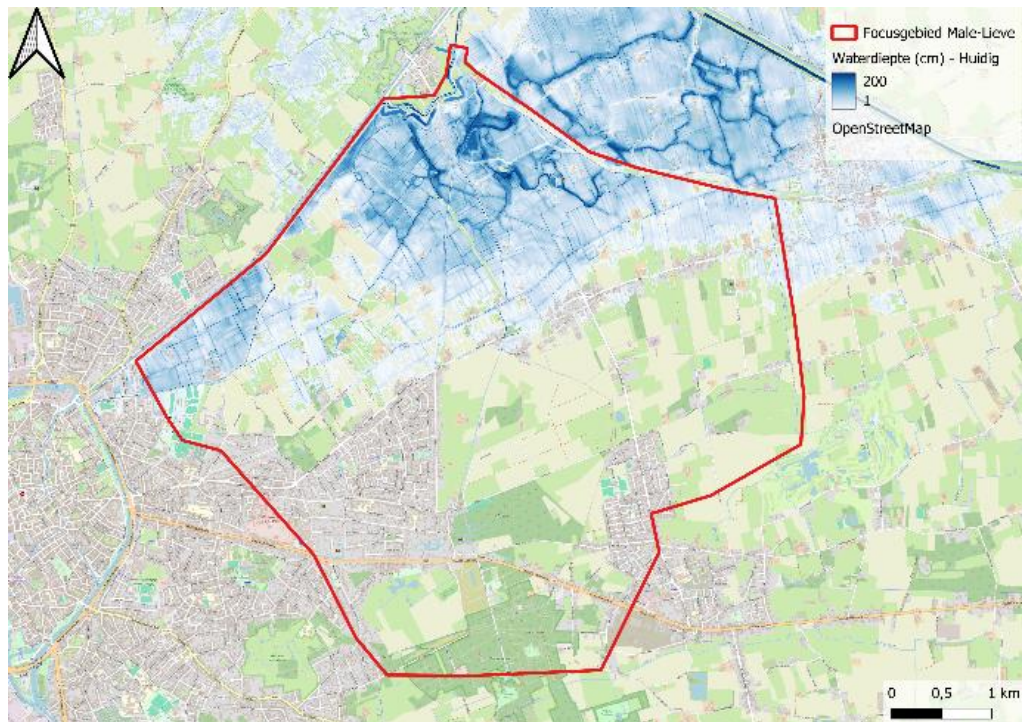


Figure 12: Water depth (cm) due to fluvial flooding (T1000) in the focus area Male-Lieve: current climate.

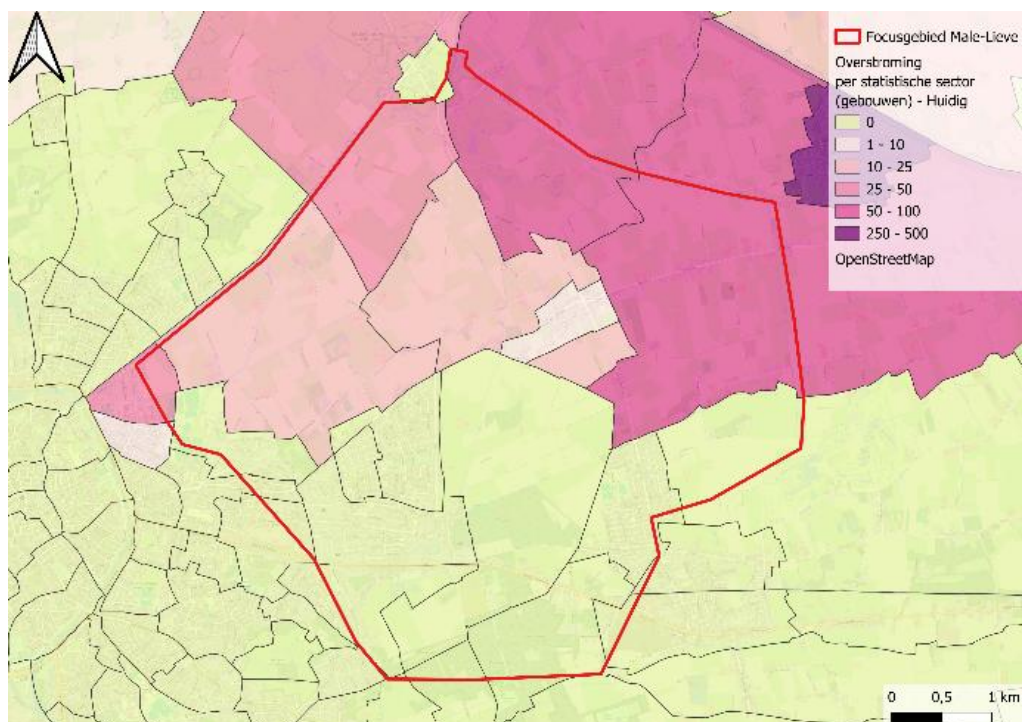


Figure 13: Fluvial flooding by statistical sector (buildings) (number) in the focus area Male-Lieve: current climate.

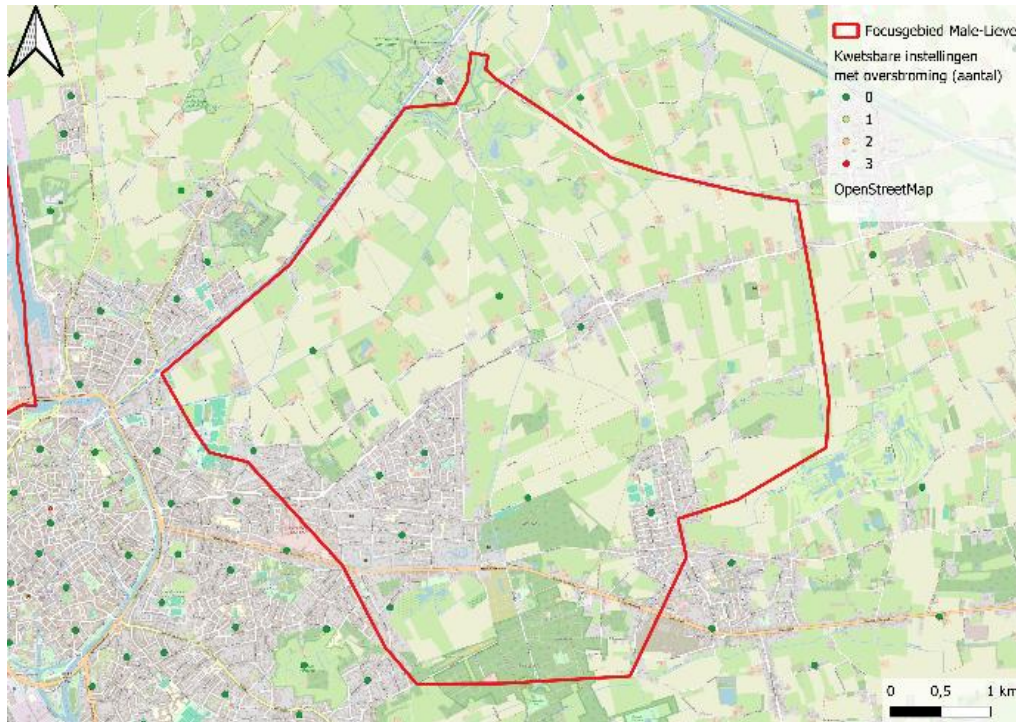


Figure 14: Vulnerable institutions at risk of fluvial flooding (number) in the focus area Male-Lieve: current climate.

Pluvial flooding

The **maximum water depth resulting from pluvial flooding** due to intense precipitation associated with a T1000 event (Figure 15) present slight variations when comparing both climate scenarios. Under current climate, water up to 173 cm deep with an average water depth of 33.49 cm is identified, especially affecting the regions of north of Damme (Lieve, Edebeek, Legewegbeek), valley of Heunebeek (Sijsele), neighbourhood of Engelendalelaan, and south of the Maleleie. For future climate (2050), water up to 222 cm deep with an average water depth of 32.63 cm affects the same regions but more extended and with varying depth, mostly 10–30 cm.

The **number of buildings by statistical sector with a probability of pluvial flooding** for a T1000 intense precipitation event (Figure 16) were analysed considering only statistical sectors fully contained within the perimeter. Under current climate, at least 66 buildings were exposed (mainly in Malehoek and Sijsele); whereas in the future climate (2050), at least 123 buildings exposed (mainly in Malehoek, Sijsele and Sint-Kruis).

Vulnerable institutions at risk of pluvial flooding (Figure 17) (including childcare facilities, pre-primary, primary and special education, hospitals, and nursing homes) due to intense precipitation (T1000) showed no difference. In both climate scenarios, 2 childcare institutions were exposed (Sijsele and Assebroek).

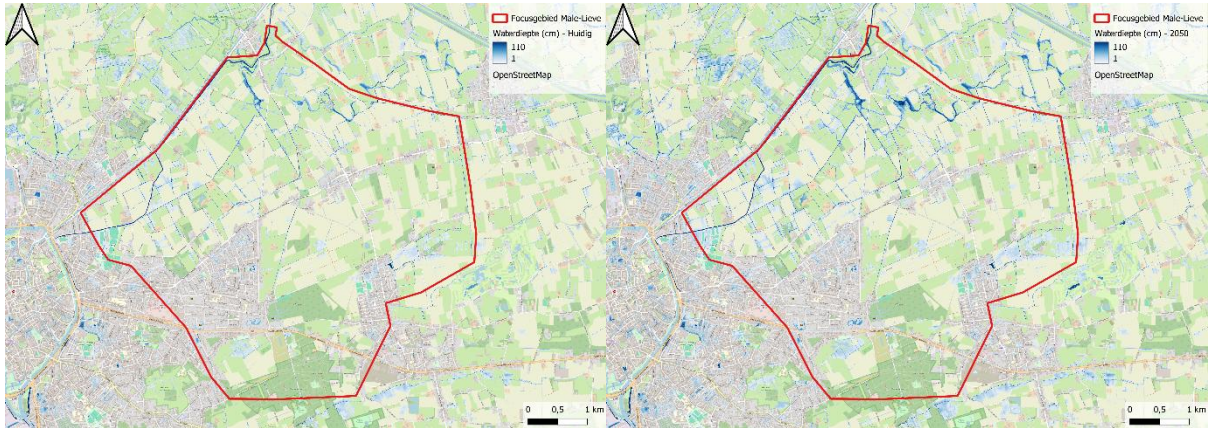


Figure 15: Water depth (cm) by pluvial flooding in the focus area Male-Lieve: current climate (left) & future climate (2050) (right).

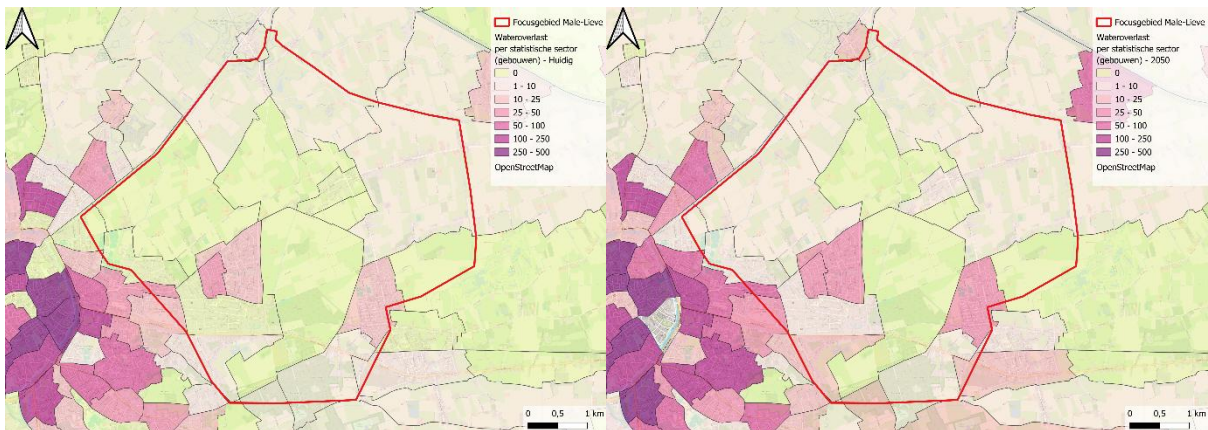


Figure 16: Pluvial flooding by statistical sector (buildings) (number) in the focus area Male-Lieve: current climate (left) & future climate (2050) (right).

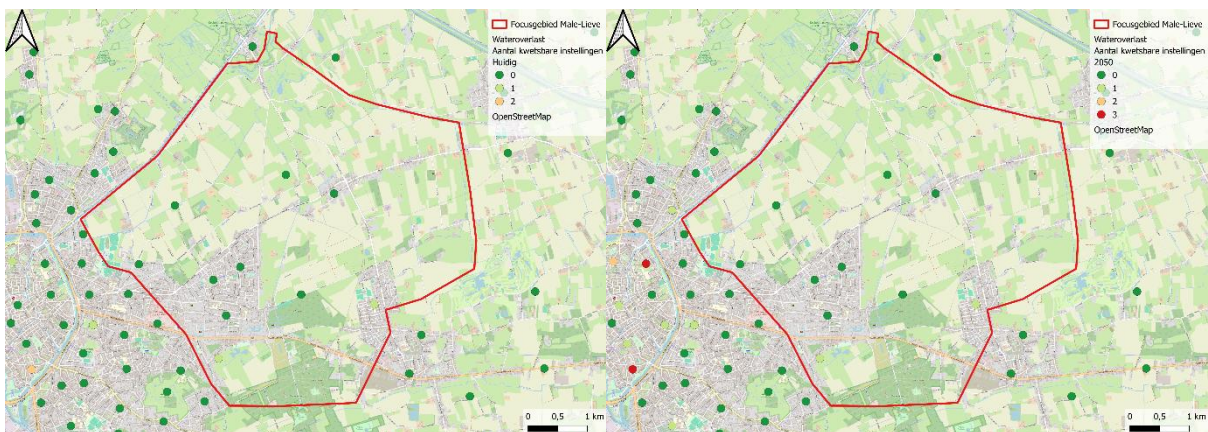


Figure 17: Vulnerable institutions and pluvial flooding in the focus area Male-Lieve: current climate (left) & future climate (2050) (right)

Biodiversity and Ecosystem Services

Biodiversity

Biodiversity is assessed based on the **biological value map** included in the Nature Value Explorer⁵ (Figure 18). 80% of the area is currently biologically less valuable, 16% biologically valuable and 4% biologically very valuable. Higher biological value areas are located surrounding the historical centre of Damme and in the south of the focus area near Maleveld and Ryckeveld.

Additionally, the biological value, rareness, quality, vulnerability and replaceability were evaluated by the Nature Value Explorer (Figure 19). The majority of the area (94%) is common in terms of **rareness**, with 6% quite rare and a negligible fraction of rare or very to extremely rare species. 61% of the focus area has a low **biological quality**, 29% a high quality and 10% a very high quality. The largest part of the focus area Male-Lieve is **biologically less vulnerable** (87%) and **replaceable** to some extent (91%).



Figure 18: Biological value map for focus area Male-Lieve (INBO, 2019).

⁵ Nature Value Explorer - <https://www.natuurwaardeverkenner.be/>



Figure 19: Biological rareness, quality, vulnerability and replaceability for focus area Male-Lieve.

Ecosystem services

Ecosystem services were assessed using two tools: the European INCA tool⁶, and the online Belgian tool Nature Value Explorer. We focus here on regulatory services related to climate change within the NBRACER framework.

- **INCA**

Within the INCA tool, the following ES are accounted for: **cultural** (nature-based tourism); **provisioning** (crop pollination, crop provisioning, wood provisioning); **regulating and maintenance** (air filtration, flood control, global climate regulation, local climate regulation, soil

⁶ Integrated Natural Capital Accounting (INCA) - <https://ecosystem-accounts.jrc.ec.europa.eu/>

retention). Here, we assess the regulating services of **flood control**, and **global and local climate regulation** for the focus area. This first analysis provides output based on EU wide available data. These can be further refined at a later stage based on more detailed local data. There are no local climate regulation outputs for Belgium based on the EU-wide results. Local climate regulation should therefore be assessed based on local data.

For **flood control**, the **potential** of a given area (Service Providing Areas, SPA) is based on the land cover data (CORINE) and a curve-number based estimate of runoff retention in which information on land use, imperviousness, slope, semi-natural land cover and riparian zones are combined. The **demand** (Service Benefiting Areas, SBA) for flood control is estimated based on economic sectors and population affected by a T500 flood. The **use** (flow) of the flood control service is given by the demand in the SBA which is covered by the upstream SPA. The potential, demand and use are calculated per catchment using Hybas level 5 catchments for the EU data. Given the coarse resolution of the data, the results are shown for the entire province of West-Flanders with indication of the three NBRACER focus areas (Figure 20 and Figure 21).

The highest flood control **potential** (SPA) is situated within the north-eastern part of West-Flanders containing the focus areas Male-Lieve and Oudlandpolder. Also in the southern areas bordering the IJzer river in the focus area Boven-IJzer, there are some catchments with slightly higher flood control potential. The **demand** (SBA) shows a different spatial pattern, with highest demand in the downstream areas, where coastal cities like Ostend and Nieuwpoort are located, and upstream in the area surrounding Kortrijk, with high economic activity and larger rivers. The same pattern is observed for the **use** (flow), indicating that in the areas where the demand is the highest, there is also the highest use of flood controlling services.

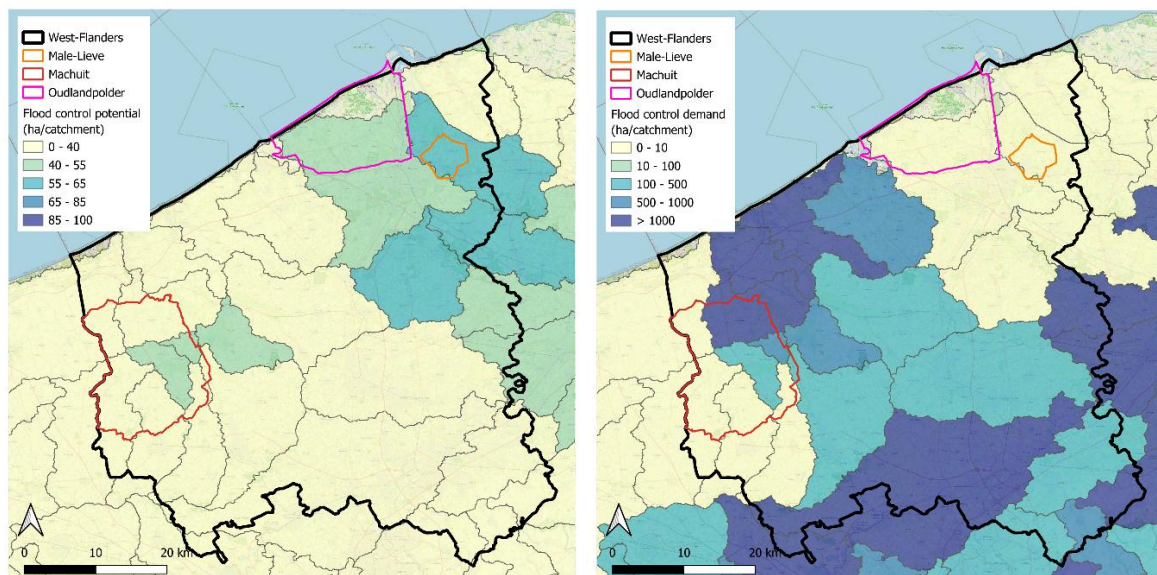


Figure 20: Flood control potential (left) and demand (right) for West-Flanders.

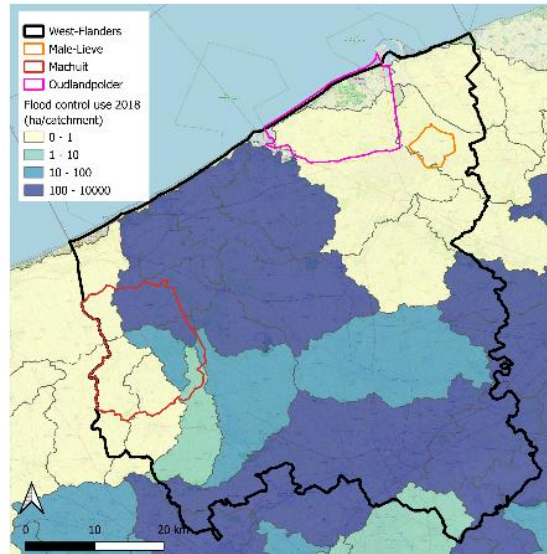


Figure 21: Flood control use for West-Flanders.

The service of **global climate regulation** considers the effect of **net carbon sequestration** (removal from the atmosphere) and **carbon retention** (storage in soil). These services are evaluated based on CORINE land use maps and LUCAS Soil Organic Carbon (SOC) maps (Figure 22). For the Male-Lieve area, the forested areas around Maleveld and Ryckvelde clearly stand out, with the highest carbon retention and sequestration values for the area. Carbon retention is also clearly higher for the agricultural areas when compared to more urban regions. Note that these maps do not take into account innovative farming techniques, as demonstrated in the “Sustainable farming practices – West-Flanders” demonstrator.

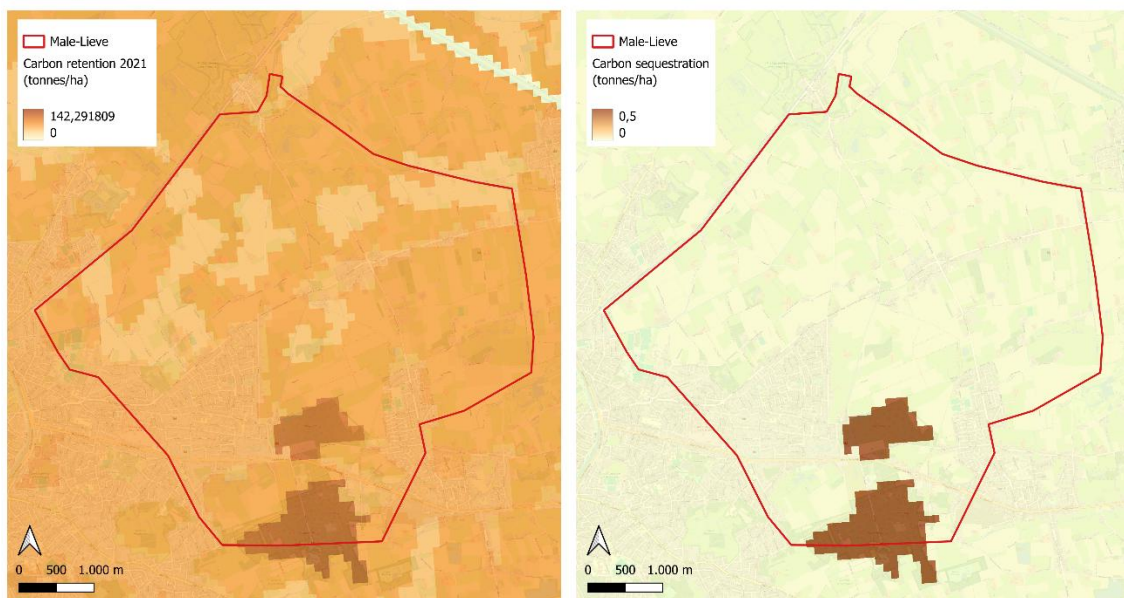


Figure 22: Global climate regulation services retention (left) and sequestration (right) for focus area Male-Lieve.

- **Nature Value Explorer**

The Nature Value Explorer tool assesses a variety of ecosystem services for a given study area using qualitative scores, quantitative values and monetary values for the current situation and after implementation of different measures. Here, the values for the current situation are presented. The main disadvantage is that these numbers are calculated for the entire study area, with no maps of how the ES vary spatially within the study area.

The following ES can be calculated using the Nature Value Explorer, alongside with the biological evaluation which was discussed earlier: **provisioning** (food, material – wood, energy from biomass); **regulating and maintenance** (air quality, water quality – denitrification, water infiltration, soil retention (erosion), global climate regulation - carbon sequestration soil, global climate regulation – carbon sequestration biomass). Here, we focus on the services of **water quality (denitrification)**, **water infiltration**, **soil retention (erosion)**, and **global climate regulation (soil and biomass)**.

The relative scores for Male-Lieve (Figure 23) indicate an overall **relatively low availability of regulating ES**. **Infiltration** has the highest score (6), which is likely related to the relatively flat topography of the area and sandy soils, also reflected in a score of 4 for **erosion control**. Carbon sequestration in both soils and biomass is low given the limited forested areas and as shown by the INCA results. Also for denitrification, a low score of 1 is obtained. These ecosystem services were also quantitatively assessed (Table 1).

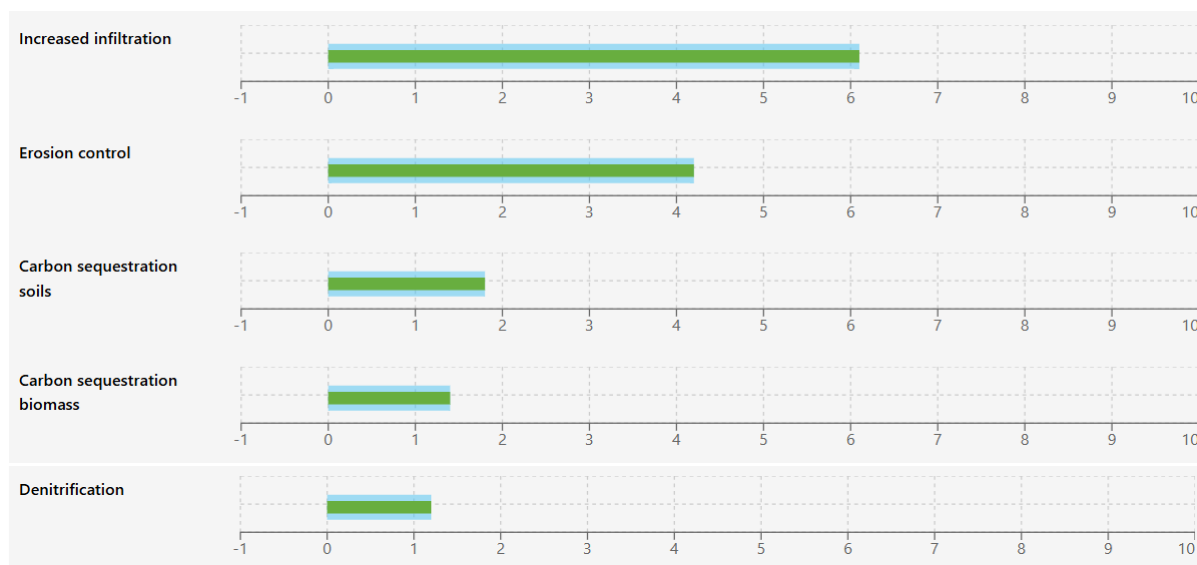


Figure 23: Qualitative scores for selected ecosystem services from Nature Value Explorer for Male-Lieve.

Table 1: Quantitative ecosystem service evaluation for focus area Male-Lieve.

Ecosystem Service	Total Male-Lieve
Infiltration (m ³ /year)	6,475,341.6
Erosion control (tonnes/year)	32,129.9 – 64,259.8
Carbon sequestration soils (tonnes C/year)	5,772.8
Carbon sequestration biomass (tonnes C/year)	92.1
Denitrification	2,155.4

1.1.2 Boven-IJzer

Landscape archetypes

Land use

Figure 24 shows the land use at 10-meter resolution within the Flemish region for the reference year 2022⁷. Within the Boven-IJzer focus area, the most prevalent land uses are **arable land**, followed by **grassland under agricultural use**, and subsequently **residential areas** including houses and gardens.

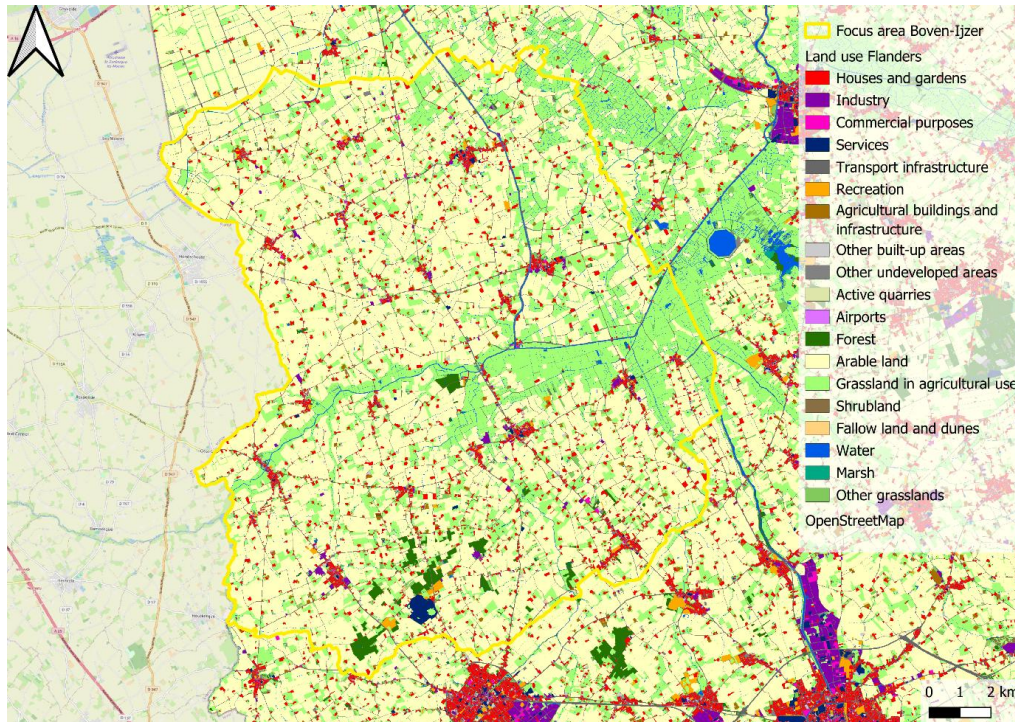


Figure 24: Land use in the focus area Boven-IJzer.

Ecoregion

An ecoregion is an area that is relatively homogeneous in terms of its physical-geographical (soil characteristics, topography) and ecological (nature and environment) conditions⁸. Within the Boven-IJzer focus area, two ecoregions are present: (i) the **polders and the tidal Scheldt**, and (ii) the **western interfluves** (Figure 25). The ecoregion of the *polders and the tidal Scheldt* is a low-lying, flat area with a subsurface composed of quaternary geological formations, deposited during repeated marine inundations caused by post-glacial sea level rises. It is further characterized by a history of artificial land reclamation and clay soils lacking distinct profiles. The ecoregion of the *western interfluves* lies between the river courses of the IJzer, Leie, and Scheldt. It is characterized by a frequently pronounced relief due to an erosion-resistant substrate

⁷ [Landgebruik - Vlaanderen - toestand 2022 | Vlaanderen.be](https://landgebruik.vlaanderen.be/toestand/2022)

⁸ [Ecodistricten en ecoregio's als instrument voor natuurstudie en milieubeleid](#)

and features a permanent groundwater table at shallow depth almost everywhere. In some areas, soils influenced by seepage and slope water are present.

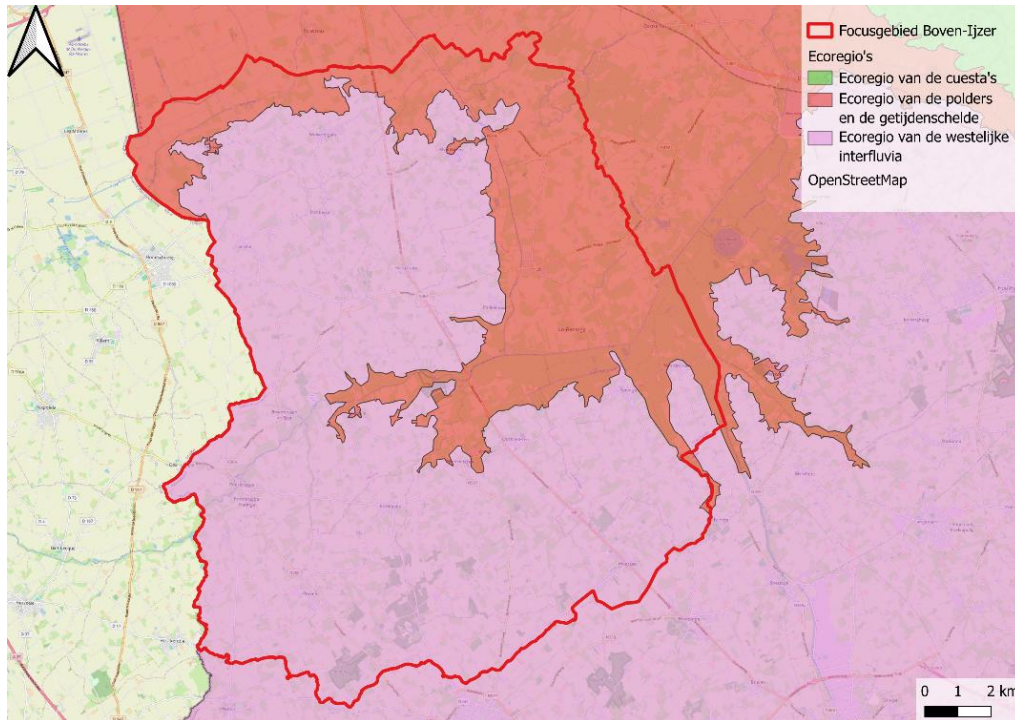


Figure 25: Ecoregions in the focus area Boven-IJzer. Eco-regions include the polders (red), the Western interfluvial (pink) and the cuesta's (green, outside focus area).

Watercourses

The Vlaamse Hydrografische Atlas (VHA), or Flemish Hydrographic Atlas provides detailed data on surface water systems in the Flanders region of Belgium (Vlaamse Milieumaatschappij, 2025)⁹. Within the Boven-IJzer focus area, a **total of 1022 watercourses** have been identified, comprising 668 public ditches, 206 non-classified watercourses, 138 second-category classified watercourses, 6 navigable watercourses, and 4 first-category classified watercourses (Figure 26). The focus area contains the Flemish upstream areas of the IJzer river, which originates in France.

⁹ [Vlaamse Hydrografische Atlas - Waterlopen, toestand 10/01/2025 | Vlaanderen.be](https://vlaanderen.be/vlaamse-hydrografische-atlas-waterlopen-toestand-10-01-2025)

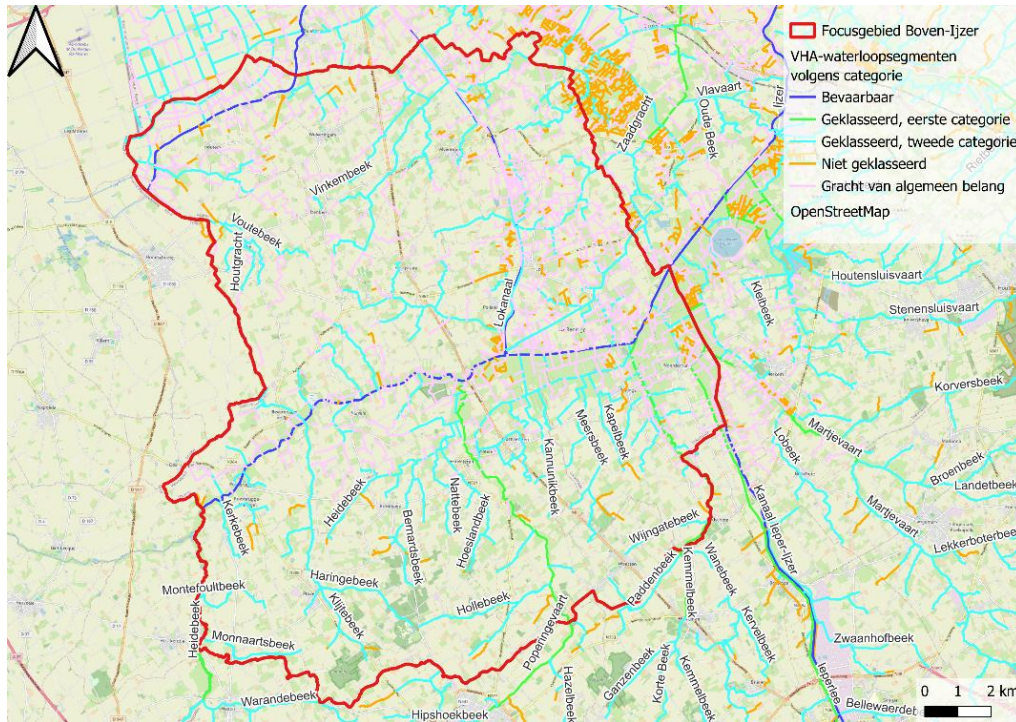


Figure 26: Watercourses in the focus area Boven-IJzer with their official classification: navigable (blue), first category (green), second category (turquoise), not classified (orange) and ditches (pink).

Climate hazards

Climate hazards and their impacts on KCS, including vulnerable people, buildings and health infrastructure are investigated based on information publicly available at [KlimaatPortaal](#)¹⁰. For more detailed explanations on indicators used, we refer to the Male-Lieve text above, which follows the same order.

Heat stress

A heat event with a return period of 20 years (T20) was used for all presented maps and figures. Spatial patterns in heat are visualized by means of the multi-year average of the **number of tropical days per year** (Figure 27). There are little to no spatial differences within the focus area, but a clear increase in the number of tropical days over time: mean of 3.4 tropical days/year (current climate) vs. 11.3 tropical days/year (future climate 2050). The **number of vulnerable residents exposed to heat stress** (Figure 28) increases from 0 (current climate) to 1424 (future climate 2050). The **number of vulnerable institutions exposed to heat stress** (Figure 29) increases from 0 (current climate) to 40 vulnerable institutions exposed, mostly childcare and education institutions and 3 hospitals/nursing homes (future climate 2050).

¹⁰ [Welkom — Klimaatportaal](#)

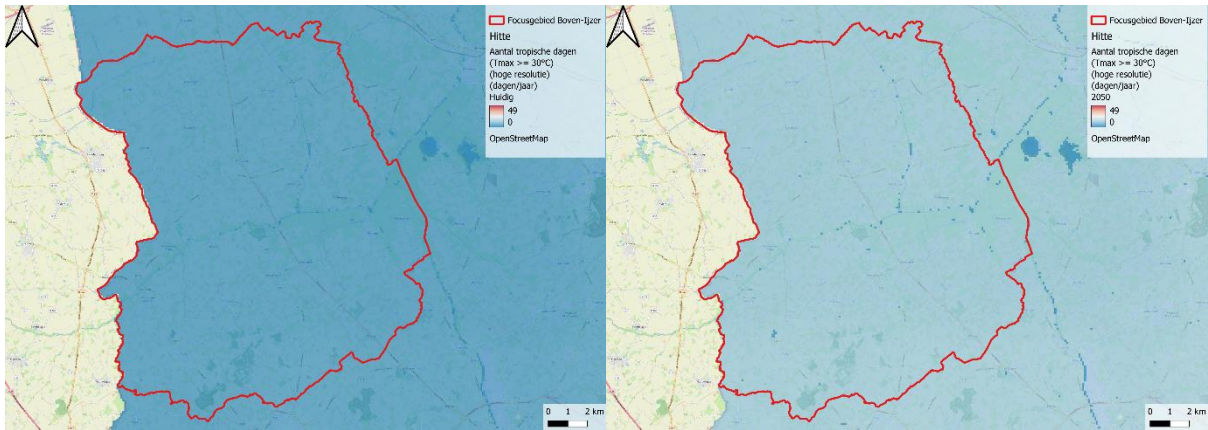


Figure 27: Number of tropical days ($T_{max} \geq 30^{\circ}\text{C}$) in the focus area Boven-IJzer (high resolution: 100 m): current climate (left) & future climate (2050) (right).

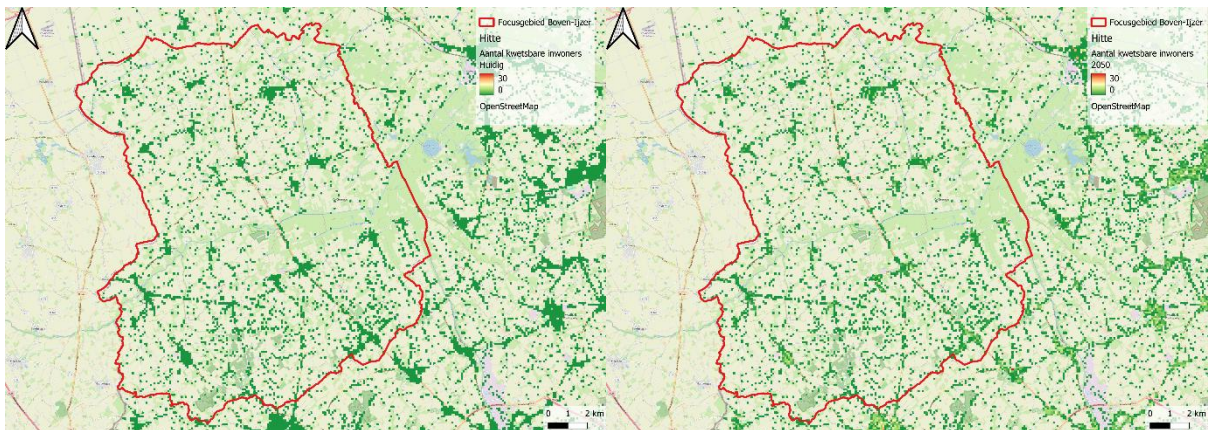


Figure 28: Number of vulnerable residents exposed to heat stress in the focus area Boven-IJzer: current climate (left) & future climate (2050) (right).

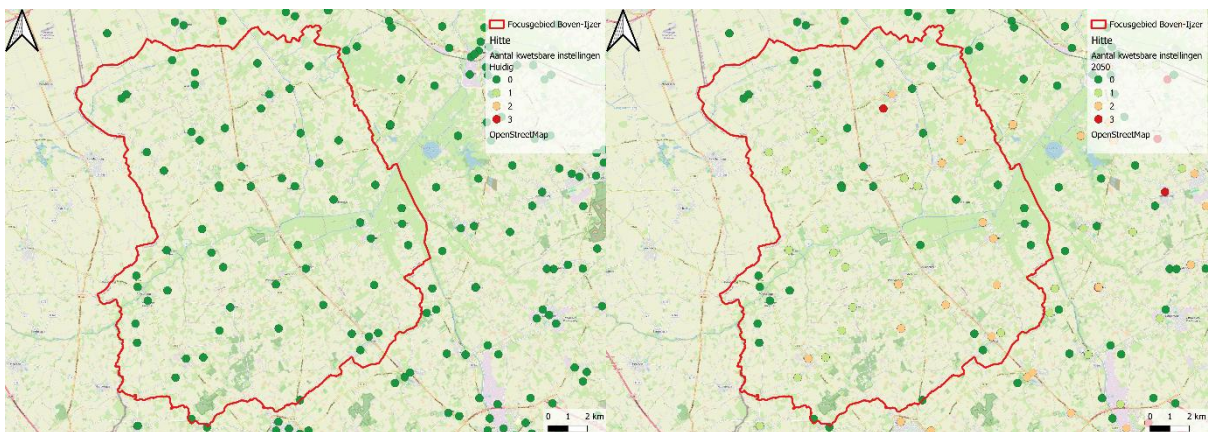


Figure 29: Vulnerable institutions with heat stress in the focus area Boven-IJzer: current climate (left) & future climate (2050) (right).

Drought

Drought-related climate risks and impacts on KCS were considered with a return period of one year (T1). For **drought duration (meteorological)** (Figure 30), the number of days per year with little or no precipitation (less than 0.1 mm/day) increases: mean of 174.7 days/year (current climate) vs. 210.4 days/year (future climate 2050). There is little to no spatial variation within the focus area.

Regarding **agricultural parcels with significant drought stress** (Figure 31): for the current climate, 10 parcels (0.08% of the agricultural parcels in the region) and 22.2 ha (0.09% of the total area of the region) are identified; whereas for the future climate (2050), 891 parcels (7.4%) and 1828.9 ha (7.3%) (assuming current crops). Agricultural drought stress is evaluated based on current crops and environmental factors like soil texture. The spatial patterns therefore reflect the effects of both factors, with a slightly higher number of parcels affected by drought in the southern part of the focus area, which is characterized by sandy soil (Figure 4). Especially crop vulnerability to drought impacts the pattern.

Vulnerable ecotopes with significant drought stress (Figure 32) for the current climate, 1 parcel and 0.90 ha (0.003% of the total area in the region) is identified; whereas for the future climate (2050), 63 parcels and 96.9 ha (0.39%).

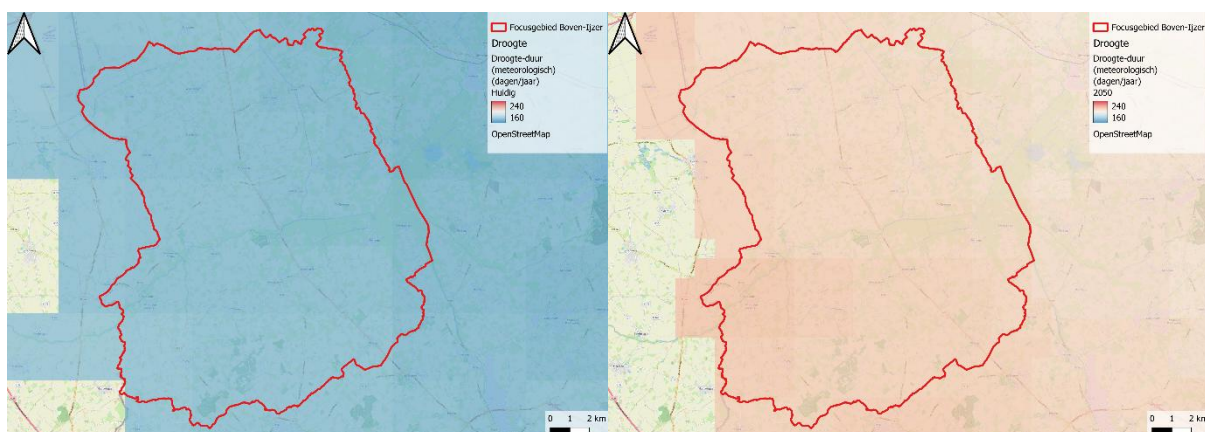


Figure 30: Drought duration (days/year) (meteorological) in the focus area Boven-IJzer: current climate (left) & future climate (2050) (right).

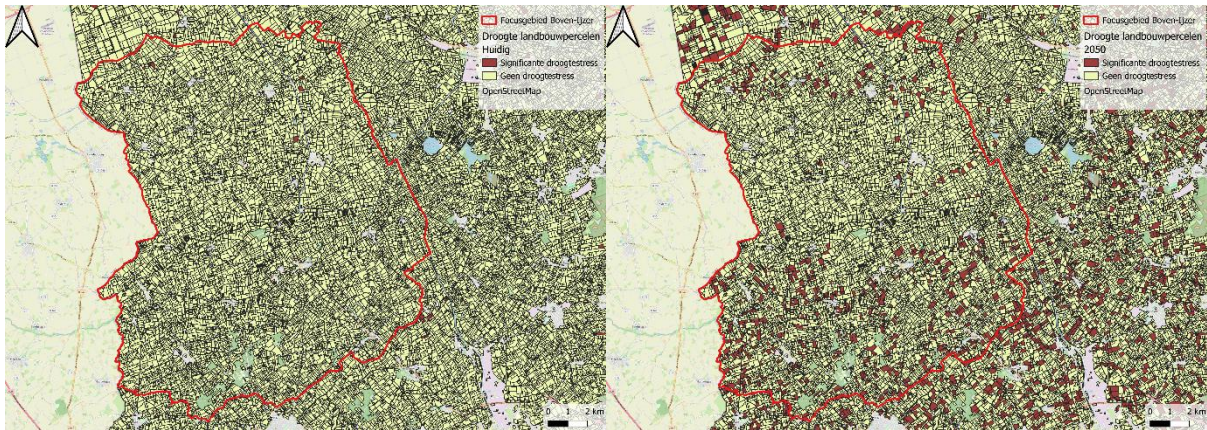


Figure 31: Agricultural parcels with significant drought stress in the focus area Boven-IJzer: current climate (left) & future climate (2050) (right). Red parcels have significant drought stress.

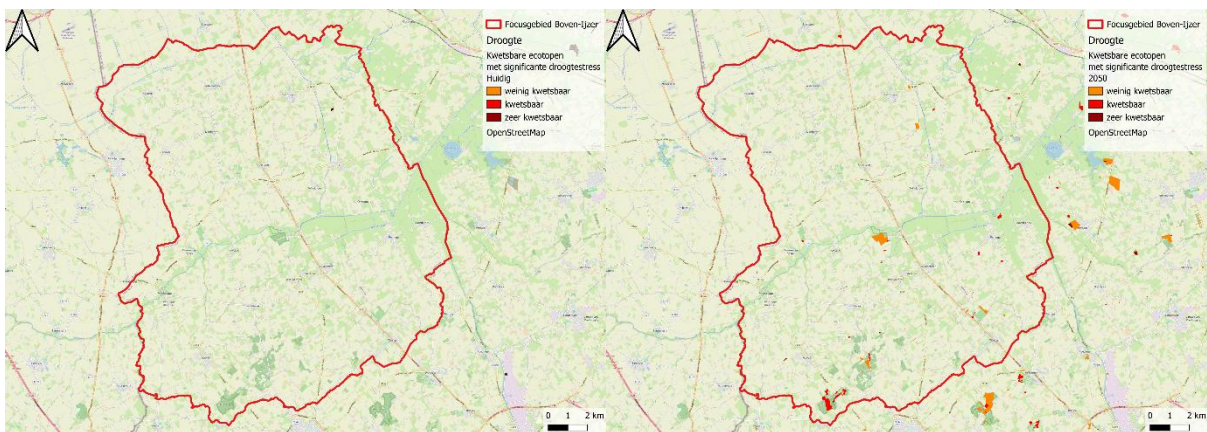


Figure 32: Vulnerable ecotopes with significant drought stress in the focus area Boven-IJzer: current climate (left) & future climate (2050) (right). The legend indicates limited vulnerable (orange), vulnerable (red) and very vulnerable (dark red) ecotopes.

Fluvial flooding

Water depth during a flood with a probability of once every 1000 years (T1000) (Figure 33) was identified especially in the middle part of the region, along the IJzer river itself and the downstream areas of the southern tributaries (Poperingevaart and Heidebeek, Kemmelbeek, Bollaertbeek). Under current climate, water up to 474 cm deep and mean water depth of 132.31 cm; whereas for future climate (2050), water up to 492 cm deep and mean water depth of 143.17 cm.

The **number of buildings by statistical sector with a probability of flooding** once every 1000 years (T1000) (Figure 34) was identified especially in the middle part of the region bordering the IJzer river. Considering only statistical sectors fully contained within the perimeter, at least 44 buildings were exposed under current climate; whereas at least 127 buildings were exposed under future climate (2050), showing the same spatial pattern but intensified.

Vulnerable institutions at risk of flooding (Figure 35) (including childcare facilities, pre-primary, primary and special education, hospitals and nursing homes) for T1000 included 2 vulnerable institutions exposed under current climate (an education institution in Stavele and a

hospital/nursing home in Reninge) vs. 3 vulnerable institutions exposed under future climate (2050) (childcare and education institution in Stavele and hospital/nursing home in Reninge)

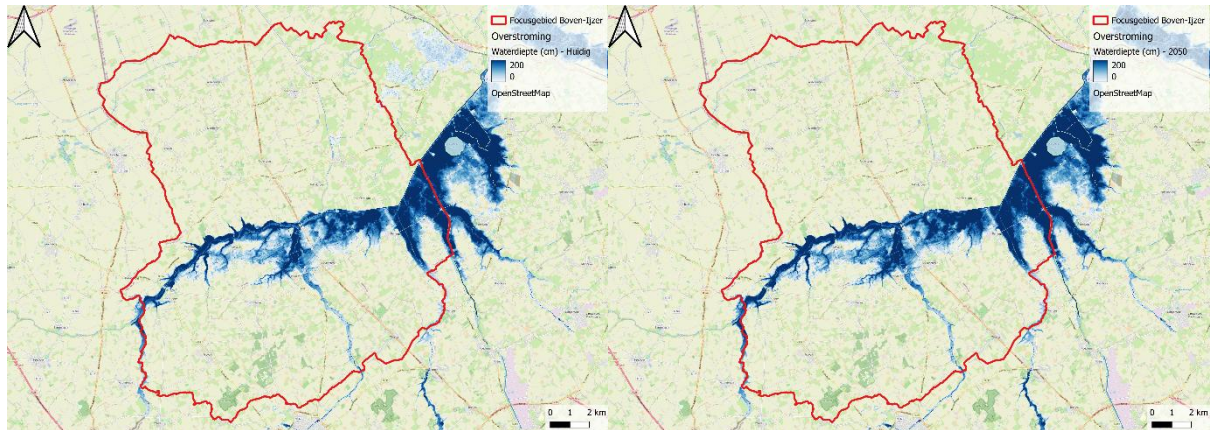


Figure 33: Water depth due to fluvial flooding (T1000) in the focus area Boven-IJzer: current climate (left) and future climate (2050) (right).

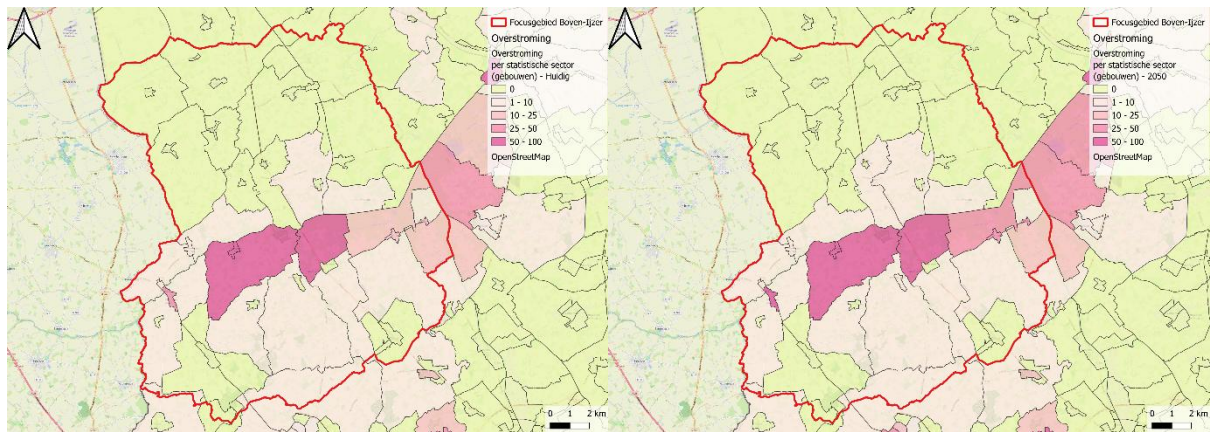


Figure 34: Fluvial flooding by statistical sector (number of buildings) in the focus area Boven-IJzer: current climate (left) and future climate (2050) (right).

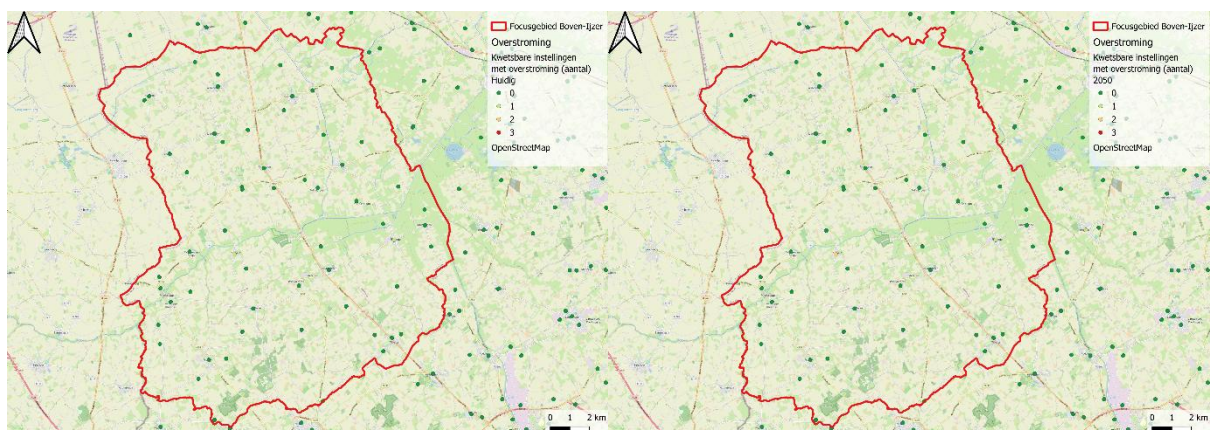


Figure 35: Vulnerable institutions at risk of fluvial flooding (number) in the focus area Boven-IJzer: current climate (left) and future climate (2050) (right).

Pluvial flooding

The **maximum water depth resulting from pluvial flooding** due to intense precipitation associated with a T1000 event (Figure 36) was identified especially in the eastern part of the region (Noordschote), the valley of IJzer, and the valley of Poperingevaart. Under current climate, water depths reached up to 378 cm, with a mean water depth of 43 cm; whereas under future climate (2050), water depths reached up to 404 cm, with a mean water depth of 47 cm, affecting the same regions but over a more extended area.

The **number of buildings by statistical sector with a probability of pluvial flooding** for a T1000 intense precipitation event (Figure 37) were analysed considering only statistical sectors fully contained within the perimeter. Under current climate, at least 3812 buildings were exposed, (especially risks at urban centers: Alveringem, Lo, Oostvleteren, Proven, Roesbrugge-Haringe); whereas under future climate (2050), at least 5887 buildings were exposed, for which climate projections indicate an expansion in the number of statistical sectors exposed to water nuisance risks and a worsening of the impact in currently affected areas.

Vulnerable institutions at risk of pluvial flooding (Figure 38) (including childcare facilities, pre-primary, primary and special education, hospitals and nursing homes) due to intense precipitation (T1000) showed no difference. In both climate scenarios, 1 vulnerable institution was exposed (childcare in Alveringem).

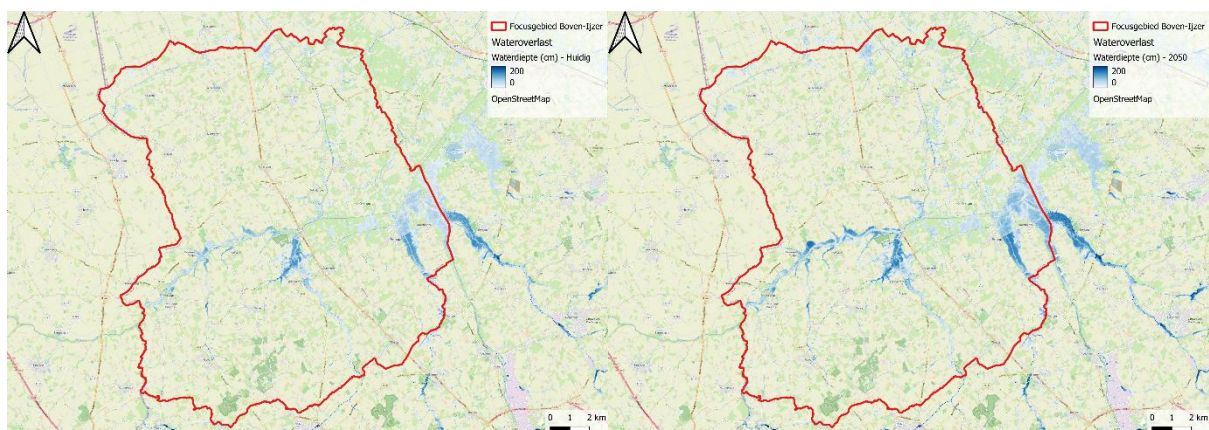


Figure 36: Water depth (cm) by pluvial flooding in the focus area Boven-IJzer: current climate (left) & future climate (2050) (right).

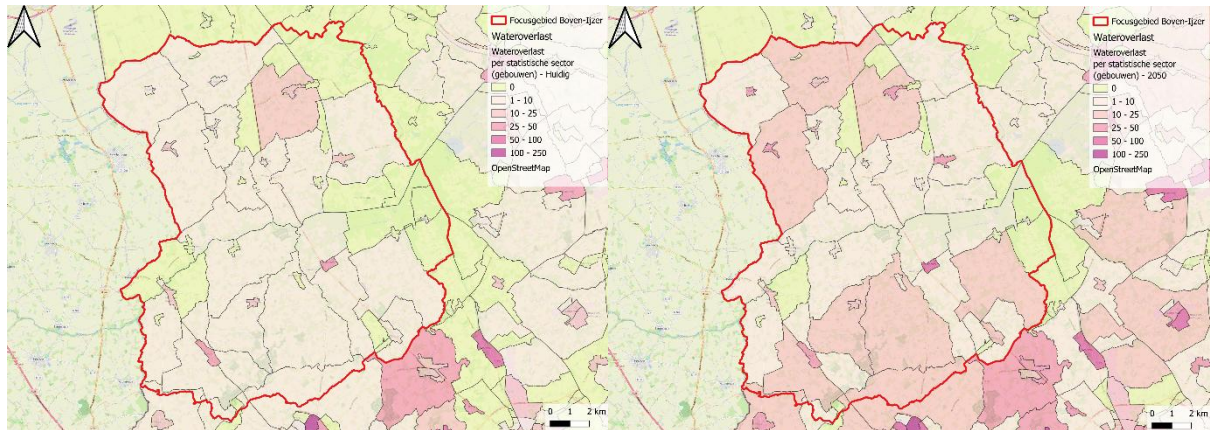


Figure 37: Pluvial flooding by statistical sector (buildings) (number) in the focus area Boven-IJzer: current climate (left) & future climate (2050) (right).

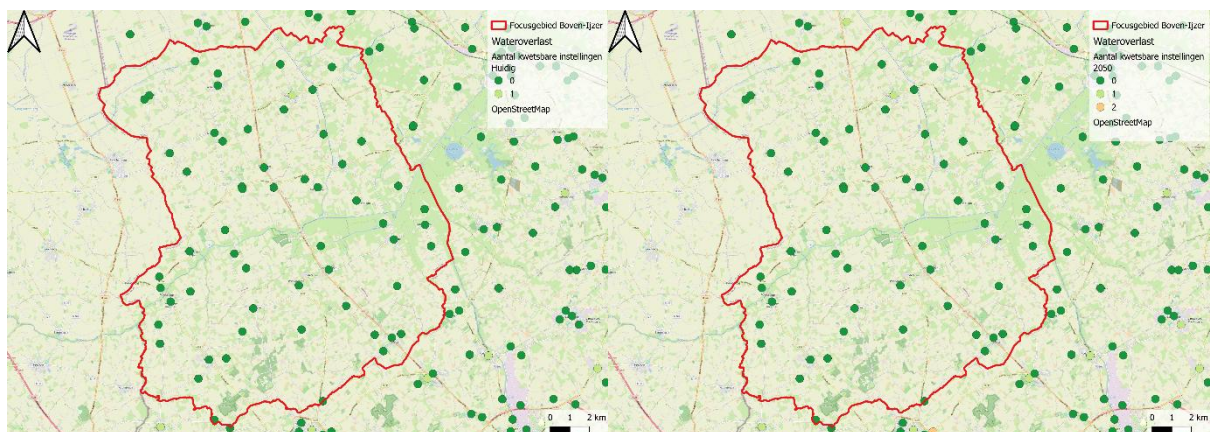


Figure 38: Vulnerable institutions by pluvial flooding in the focus area Boven-IJzer: current climate (left) & future climate (2050) (right).

Biodiversity and Ecosystem Services

Biodiversity

Biodiversity is assessed based on the **biological value map** included in the Nature Value Explorer¹¹ (Figure 39). The majority of the area is biologically less valuable. The area surrounding the IJzer river and more scattered areas in the eastern side of the study area are classified as biologically valuable. Biologically very valuable areas are present in the southern part of the study area near the Couthofbos, Canadabos, the area surrounding castle De Lovie, Dozinghembos and Bardelenbos. The biological value, rareness, quality, vulnerability and replaceability were not evaluated for the focus area Boven-IJzer, as it is out of scope for the current work of NBRACER in this focus area.

¹¹ Nature Value Explorer - <https://www.natuurwaardeverkenner.be/>

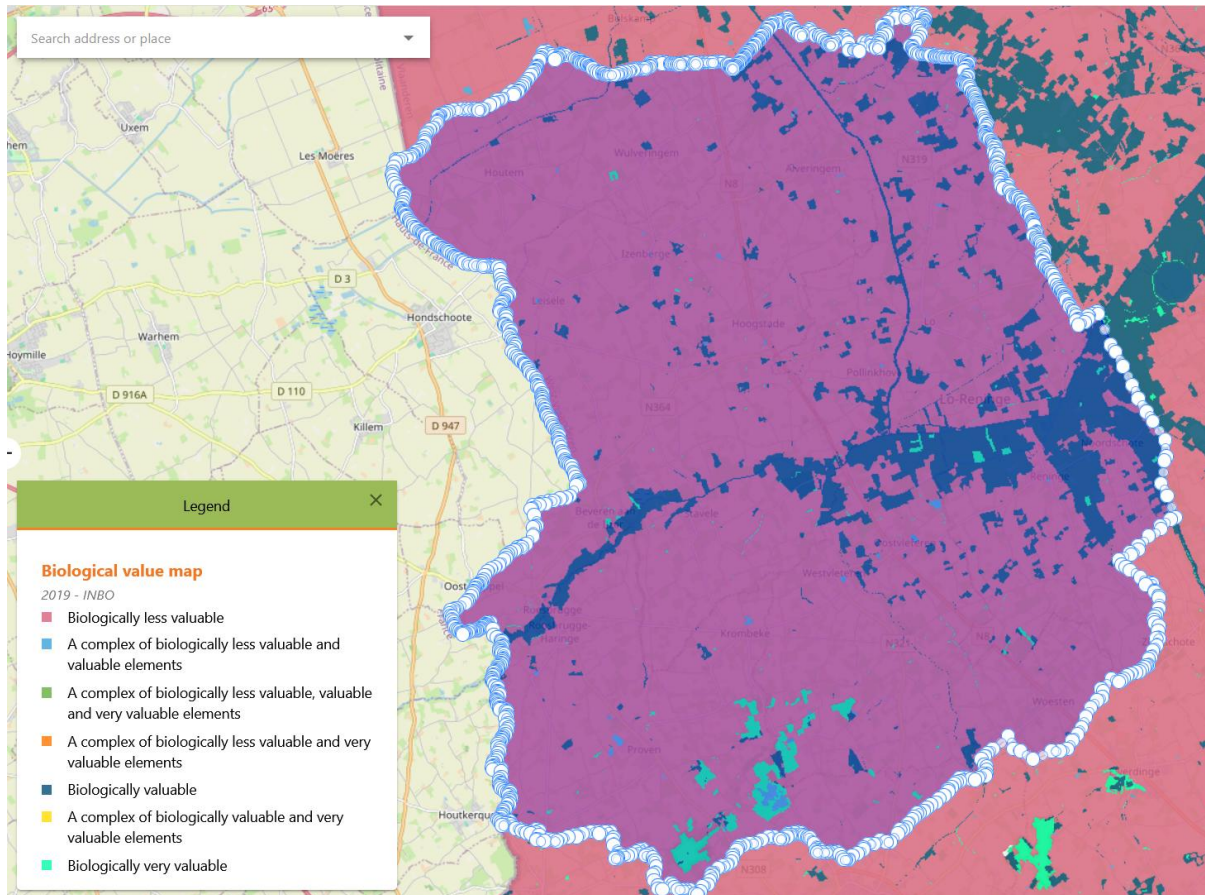


Figure 39: Biological value map for focus area Boven-IJzer (INBO, 2019).

Ecosystem services

Ecosystem services were assessed using two tools: the European INCA tool¹², and the online Belgian tool Nature Value Explorer. We focus here on regulatory services related to climate change within the NBRACER framework.

- **INCA**

Similarly to the analysis performed for the focus area Male-Lieve, here we assess the regulating services of **flood control, global and local climate regulation** based on EU wide available data. As such, there are no local climate regulation outputs, and an overview for flood control is already provided for the whole region of West-Flanders under the dedicated section of the focus area Male-Lieve.

For the service of **global climate regulation** in the Boven-IJzer (Figure 40), the forested areas in the southern part of the focus area have the highest carbon retention and sequestration values. The grassland areas surrounding the IJzer river and more scattered throughout the area also have elevated carbon retention compared to the agricultural and urban areas.

¹² Integrated Natural Capital Accounting (INCA) - <https://ecosystem-accounts.jrc.ec.europa.eu/>

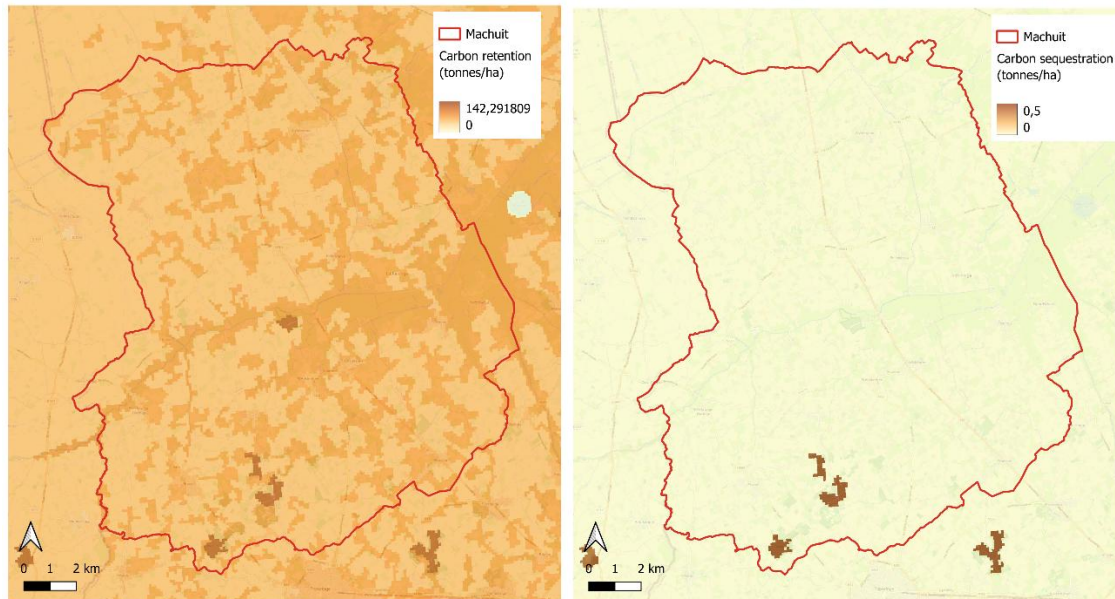


Figure 40: Global climate regulation services retention (left) and sequestration (right) for focus area Boven-IJzer.

- **Nature Value Explorer**

The Nature Value Explorer has a study area limit of 50.000.000 m², which is exceeded by the focus area Boven-IJzer. Ecosystem scores are therefore calculated for a subarea, consisting of the upstream area of the IJzer river as indicated on Figure 41. This sub-area was selected as it is the upper part of the catchment. The relative scores for the subarea of Boven-IJzer are comparable to those of Male-Lieve, with an overall **relatively low availability of regulating ecosystem services** (Figure 42). **Infiltration** capacity has the highest score of 6, followed by **erosion control** (4). Carbon sequestration in both soils and biomass is low given the limited forested areas and as shown by the INCA results. Also for denitrification a low score of 1 is obtained. These ecosystem services were also quantitatively assessed (Table 2).

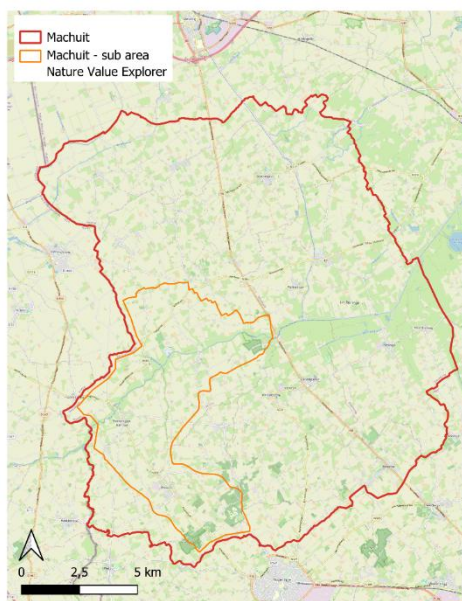


Figure 41: Sub-area for which ecosystem services were calculated using the Nature Value Explorer, corresponding to VHA catchment of the upstream Ilzer.

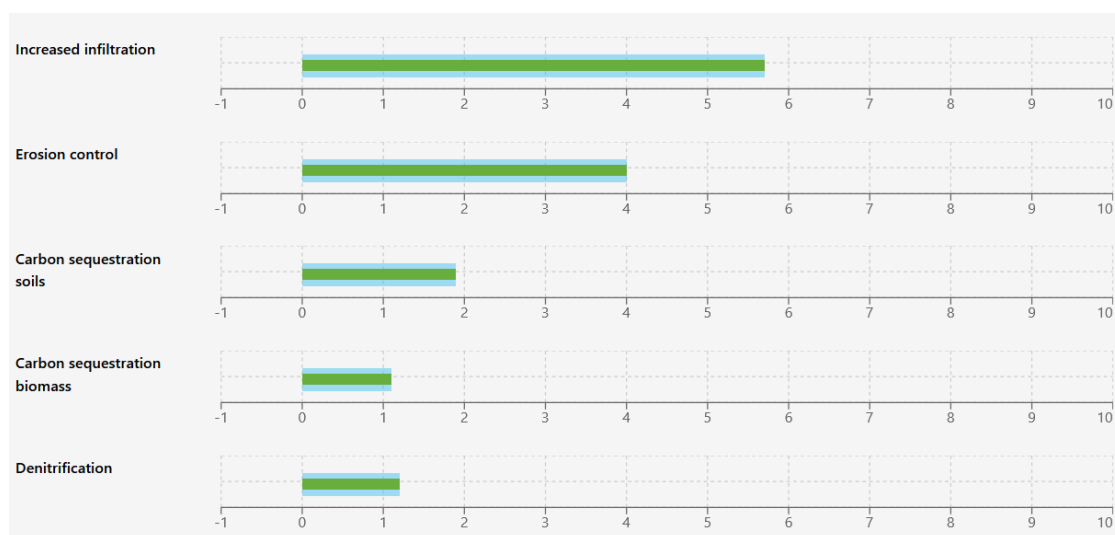


Figure 42: Qualitative scores for selected ecosystem services from Nature Value Explorer for sub area of Boven-Ilzer.

Table 2: Quantitative ecosystem service evaluation for sub area Boven-Ilzer.

Ecosystem Service	Total Boven-Ilzer – sub area
Infiltration (m ³ /year)	10,928,047.3
Erosion control (tonnes/year)	283,515.1 – 425,299.3
Carbon sequestration soils (tonnes C/year)	10,899.2
Carbon sequestration biomass (tonnes C/year)	47.5
Denitrification	6,413.8

5.2 Nouvelle-Aquitaine

For the region of Nouvelle-Aquitaine, we have mapped land use and main climate hazards related to the specific demonstrators and its two focus areas: **Marais Poitevin** and **Ramage**. The maps have been prepared based on the [Géoportail ARB Nouvelle-Aquitaine](#) and the [observatoires cartographiques et statistiques](#) for Nouvelle-Aquitaine.

Location of demonstration sites

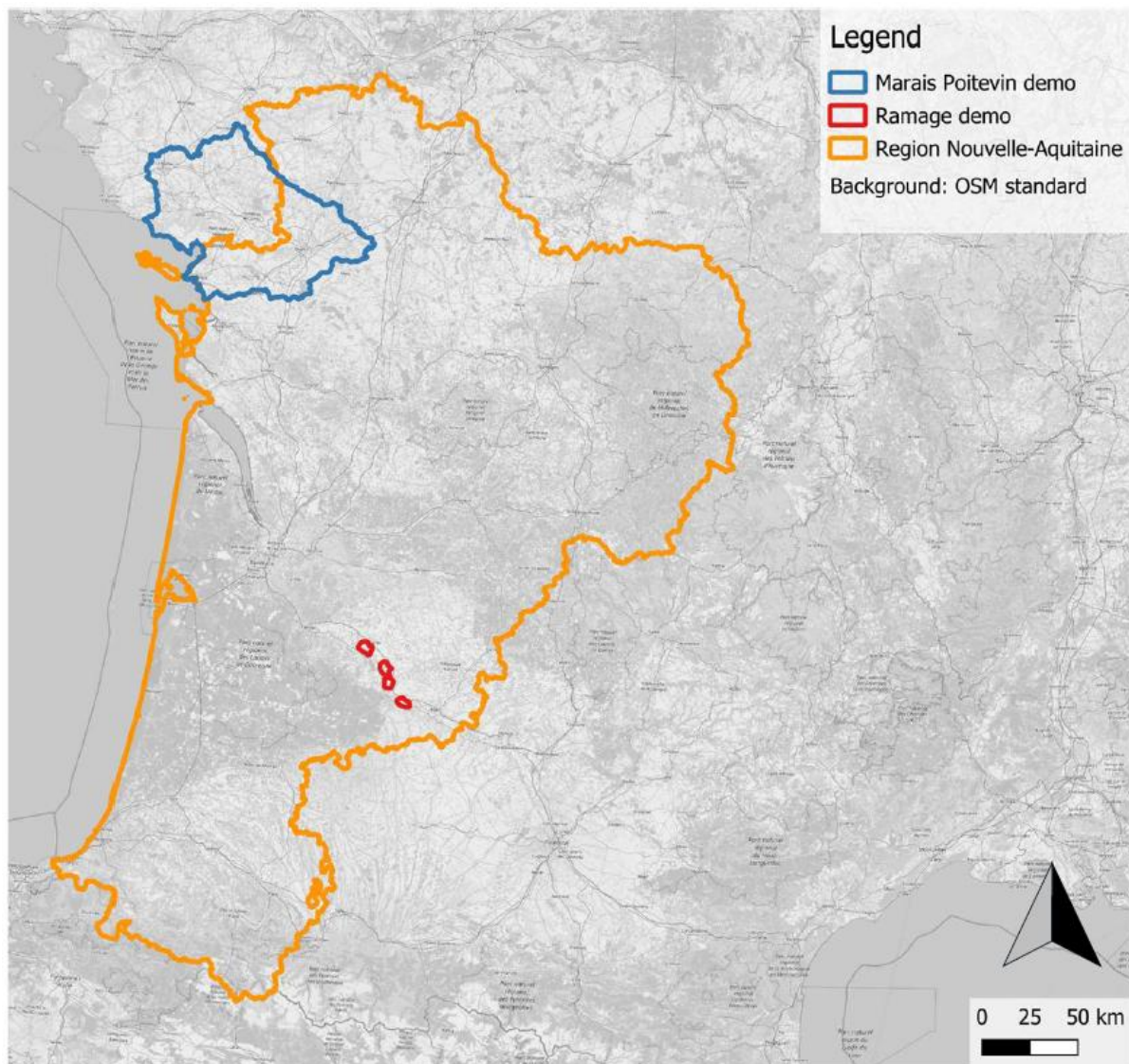


Figure 43: Location of the Rural Demonstrators in Nouvelle-Aquitaine. Note: the physical demonstrator of the Marais Poitevin is located beyond the territory of Nouvelle-Aquitaine.

Land Use

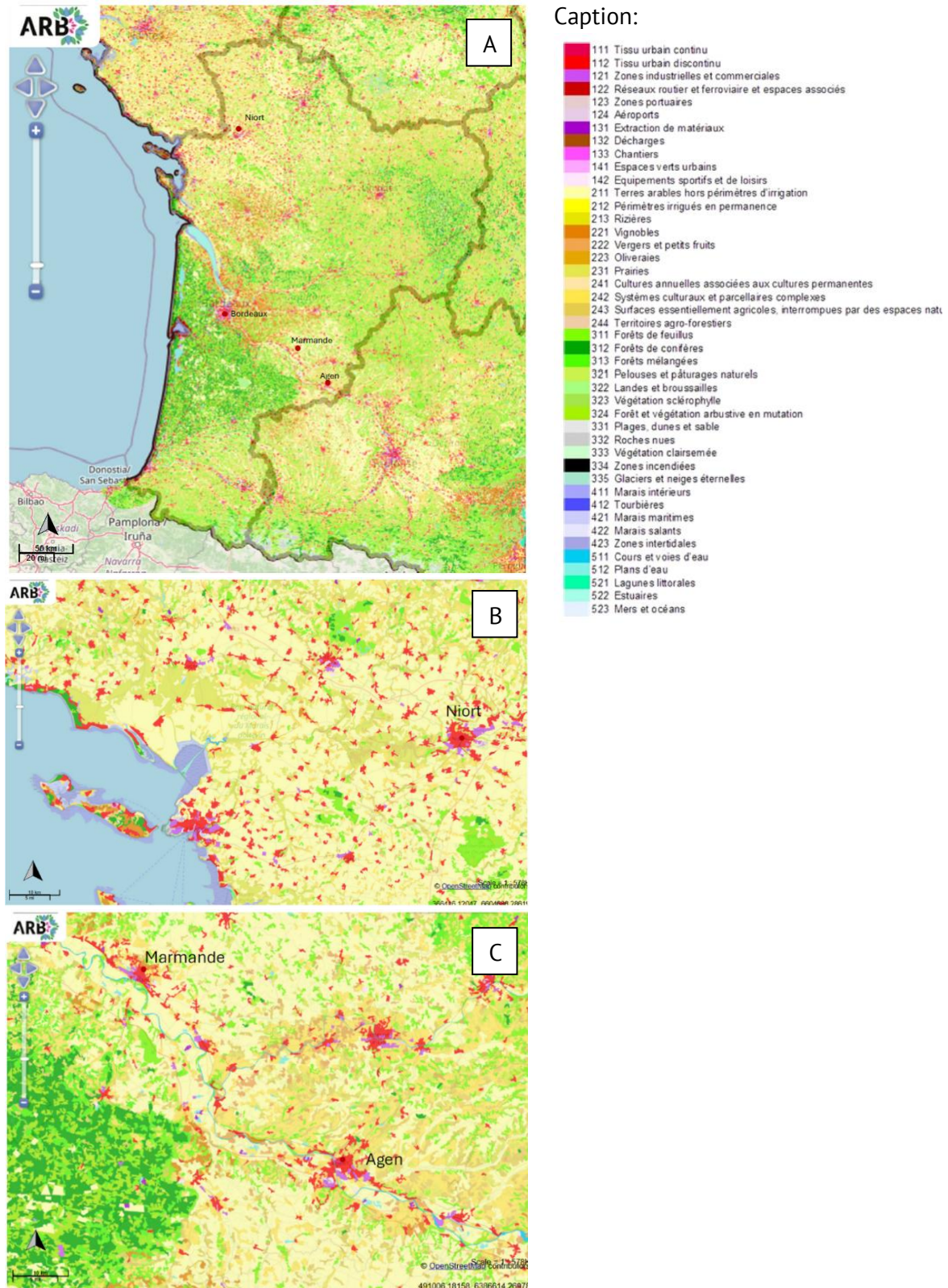


Figure 44: Land use for the Nouvelle-Aquitaine region (A), and in the proximity of the Rural Demonstration sites Marais Poitevin (B) and Ramage (C).

Climate hazards

For Nouvelle-Aquitaine, data are available for **fire risks**, **flooding risks**, and **specific humidity** (related to **drought**). For this Demonstration Region, no future projections of risks/hazards are available. The fire risk map (represented through average annual surface of burnt natural areas) shows a clear spatial pattern with highest risks along the southern coast and lower Garonne valley, though also many inland regions have a relatively high fire risk. The Marais Poitevin region has a low risk (Figure 45).

The fluvial flooding risk is shown on a map (Figure 46) with municipalities with current fluvial flooding. A spatial pattern clearly emerges, dominated by the topography and location of big rivers.

No drought maps are available, but we have plotted maps of relative humidity (Figure 47, Figure 48 and Figure 49). These maps were downloaded from DRIAS¹³, a projection model based on 3 temperature scenarios (RCP 2.6, 4.5, 8.5) for 2021-2050. Again, the southern and coastal parts of Nouvelle-Aquitaine stand out as areas with drought risk.

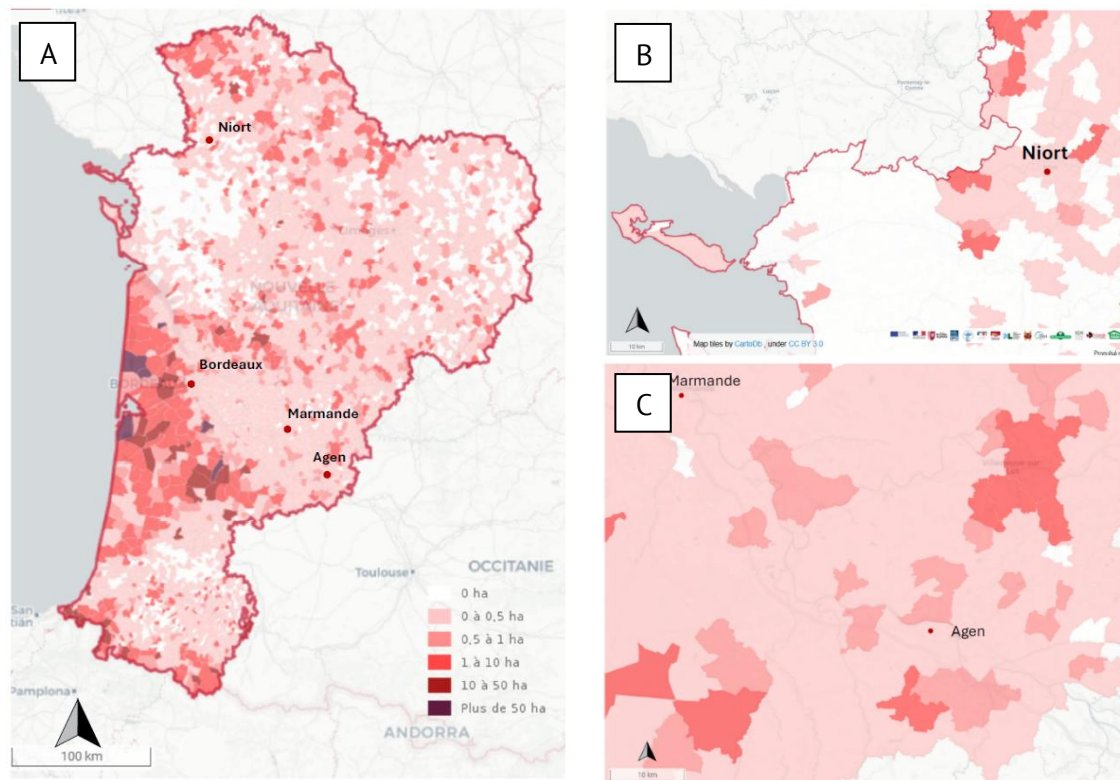


Figure 45: Average annual surface of burnt natural areas (2006-2022) for the Nouvelle-Aquitaine region (A), and in the and in the proximity of the Rural Demonstration sites Marais Poitevin (B) and Ramage (C).

¹³ Service DRIAS les futurs du climat : <https://www.drias-climat.fr/>

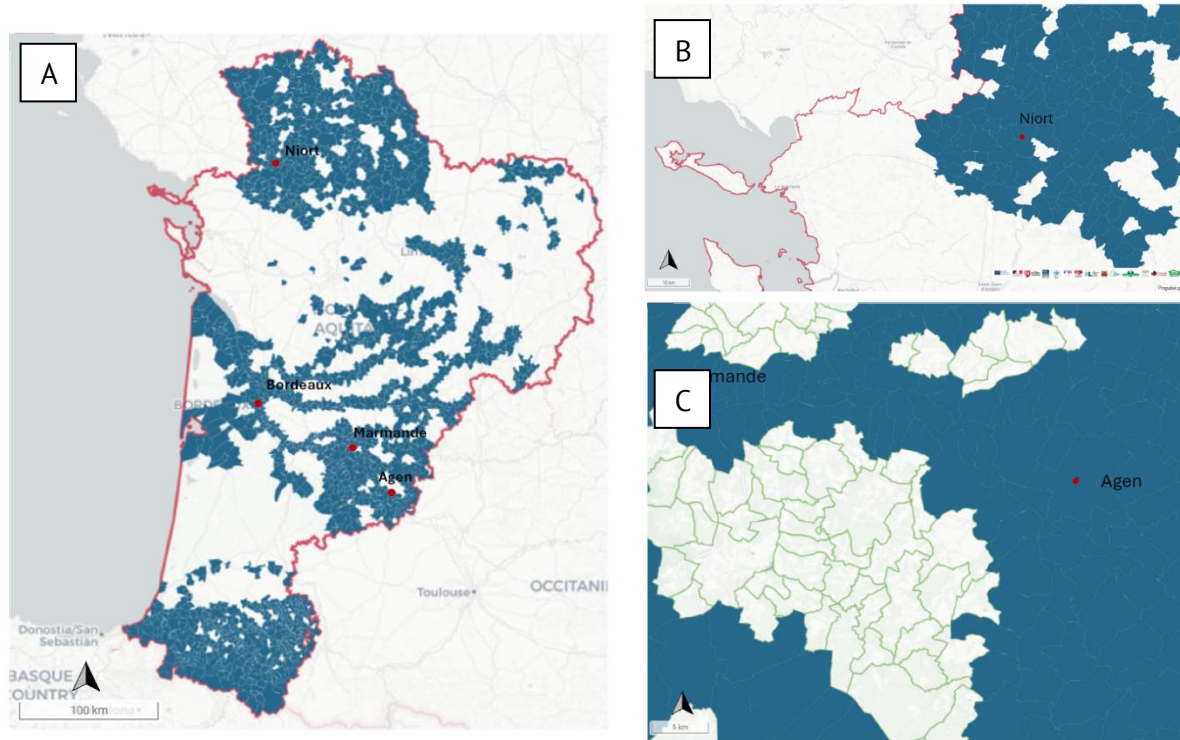


Figure 46: Fluvial flooding risk for the Nouvelle-Aquitaine region (A), and in the proximity of the Rural Demonstration sites Marais Poitevin (B) and Ramage (C), representing municipalities with such risk.

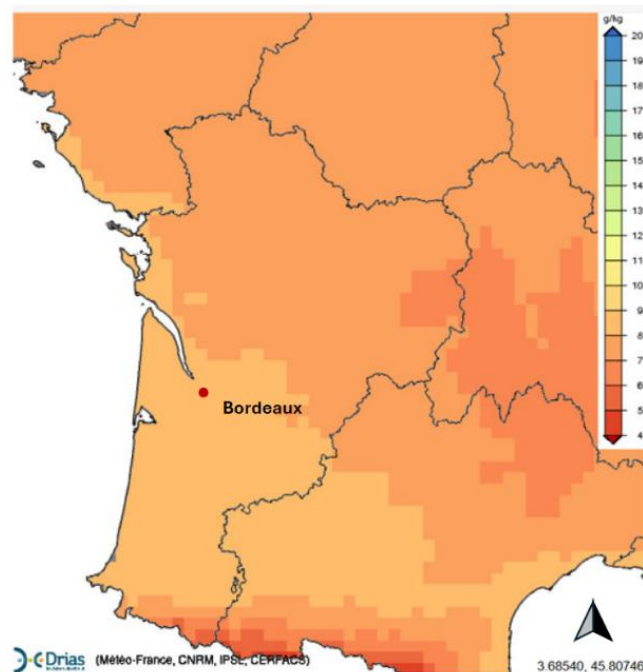


Figure 47: Specific humidity [g/kg] RCP2.6: scenario with a climate policy aimed at reducing CO₂ concentrations near horizon (2021-2050) - annual average DRIAS-2020 multi-model product: median.

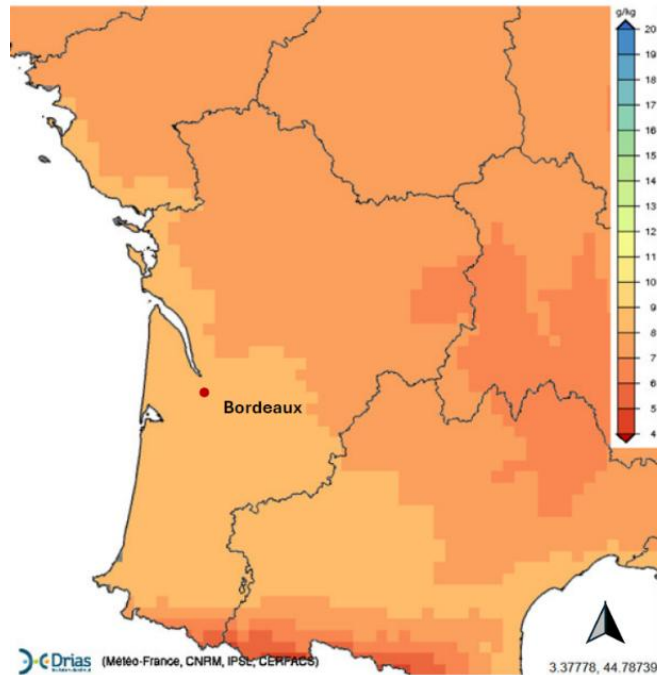


Figure 48: Specific humidity [g/kg] RCP4.5: scenario with a climate policy aimed at stabilizing CO₂ concentrations near horizon (2021-2050) - annual average DRIAS-2020 multi-model product: median.

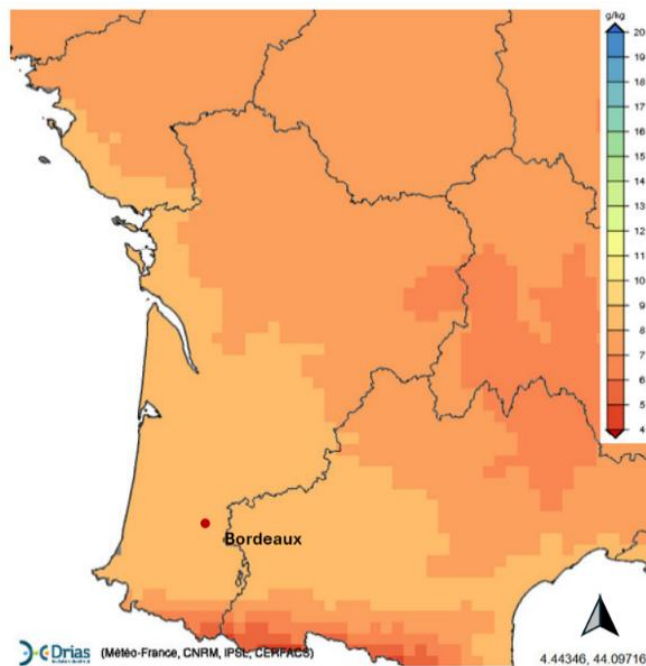


Figure 49: Specific Humidity [g/kg] RCP8.5: no climate policy scenario near horizon (2021-2050) - annual average DRIAS-2020 multi-model product: median.

Water courses

Because both Rural Demonstrators focus on water-related risks, we also plot some data on water courses. A first map shows the status of the water courses. **Few courses reach a good or very good status** in Nouvelle-Aquitaine, except for near the Pyrenees and some coastal courses (Figure 50, Figure 51 and Figure 52). An aspect of the water quality relevant for the Ramage Demonstrator is the (maximal) water temperature, which is shown in the next set of maps. Data confirm the high water temperatures around the Ramage Demonstration site for the Garonne River (Figure 53).

Water quality

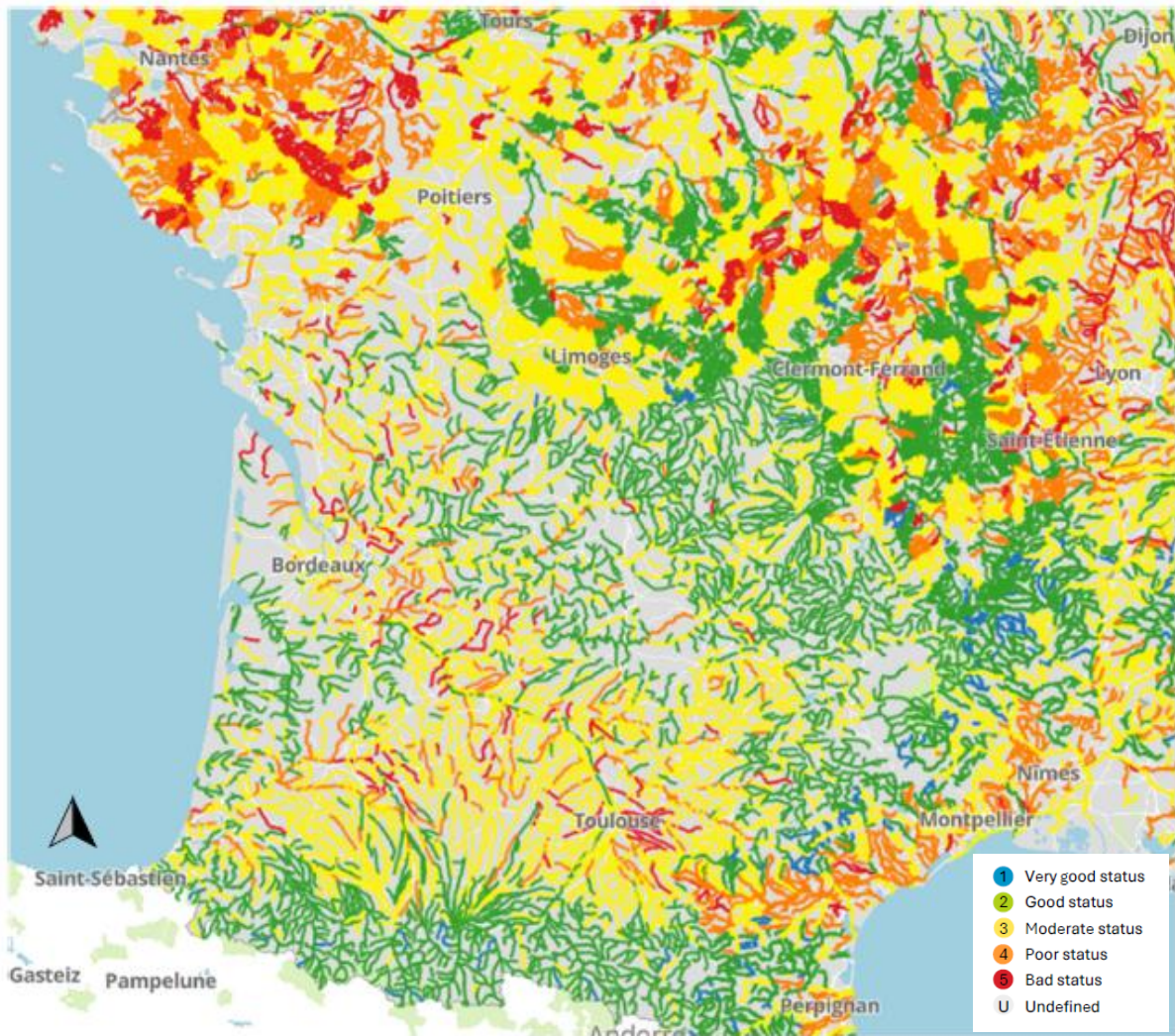


Figure 50: Ecological state of the watercourses in the region of Nouvelle-Aquitaine.

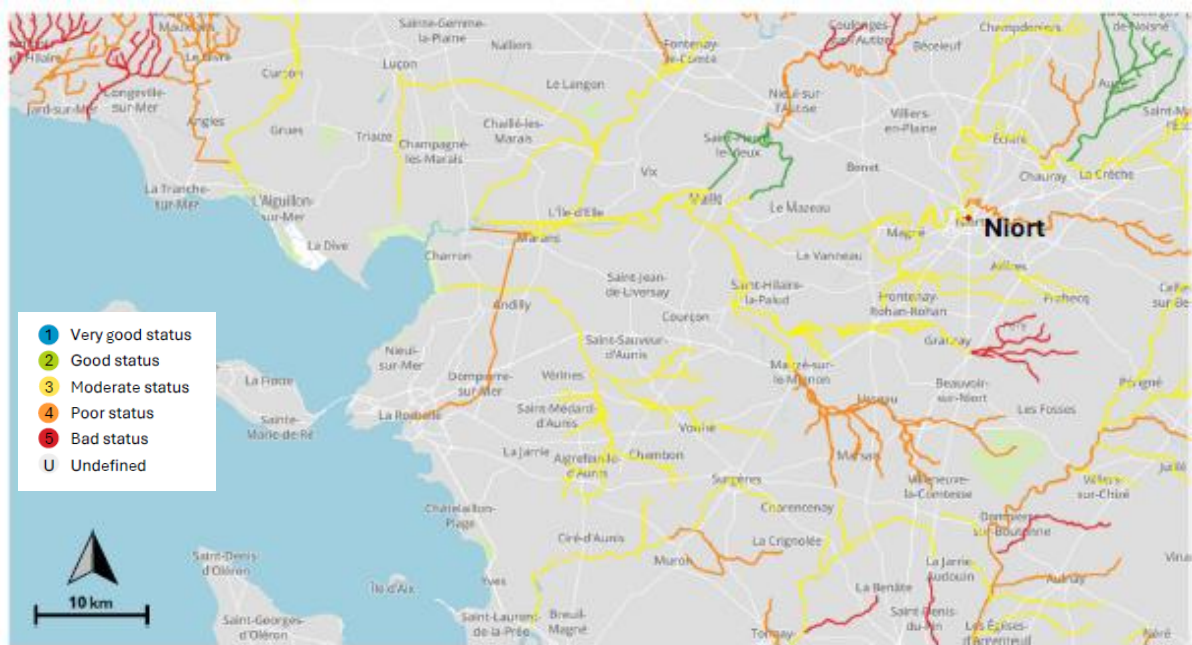


Figure 51: Ecological state of the watercourses in the proximity of the Rural Demonstration site Marais Poitevin.

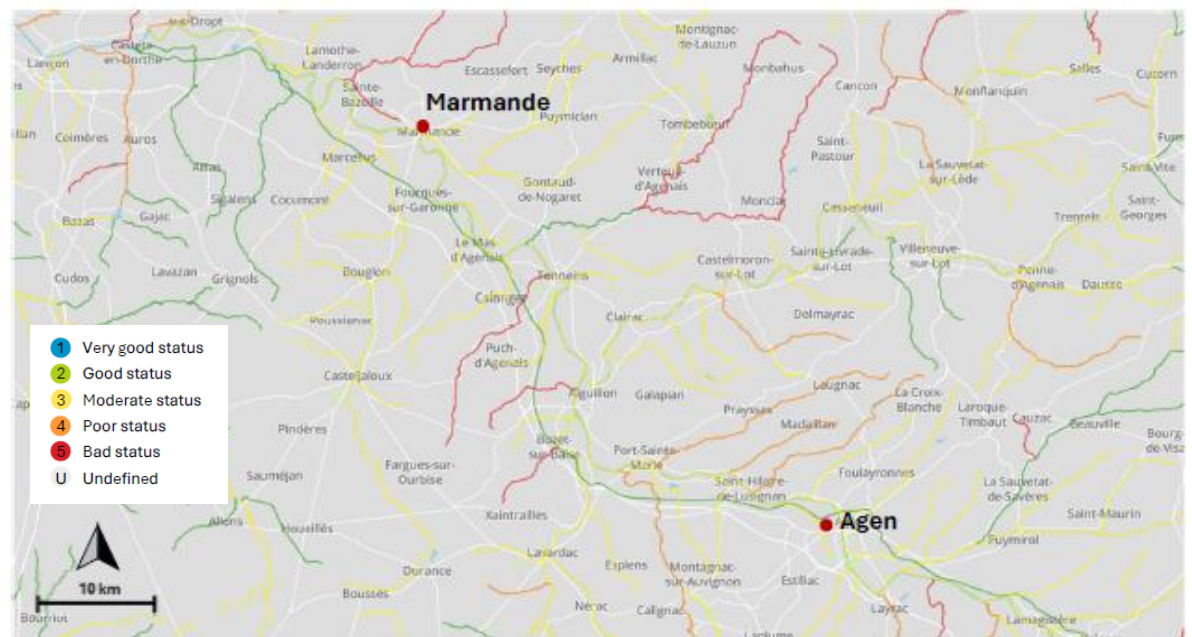


Figure 52: Ecological state of the watercourses in the proximity of the Rural Demonstration site Ramage.

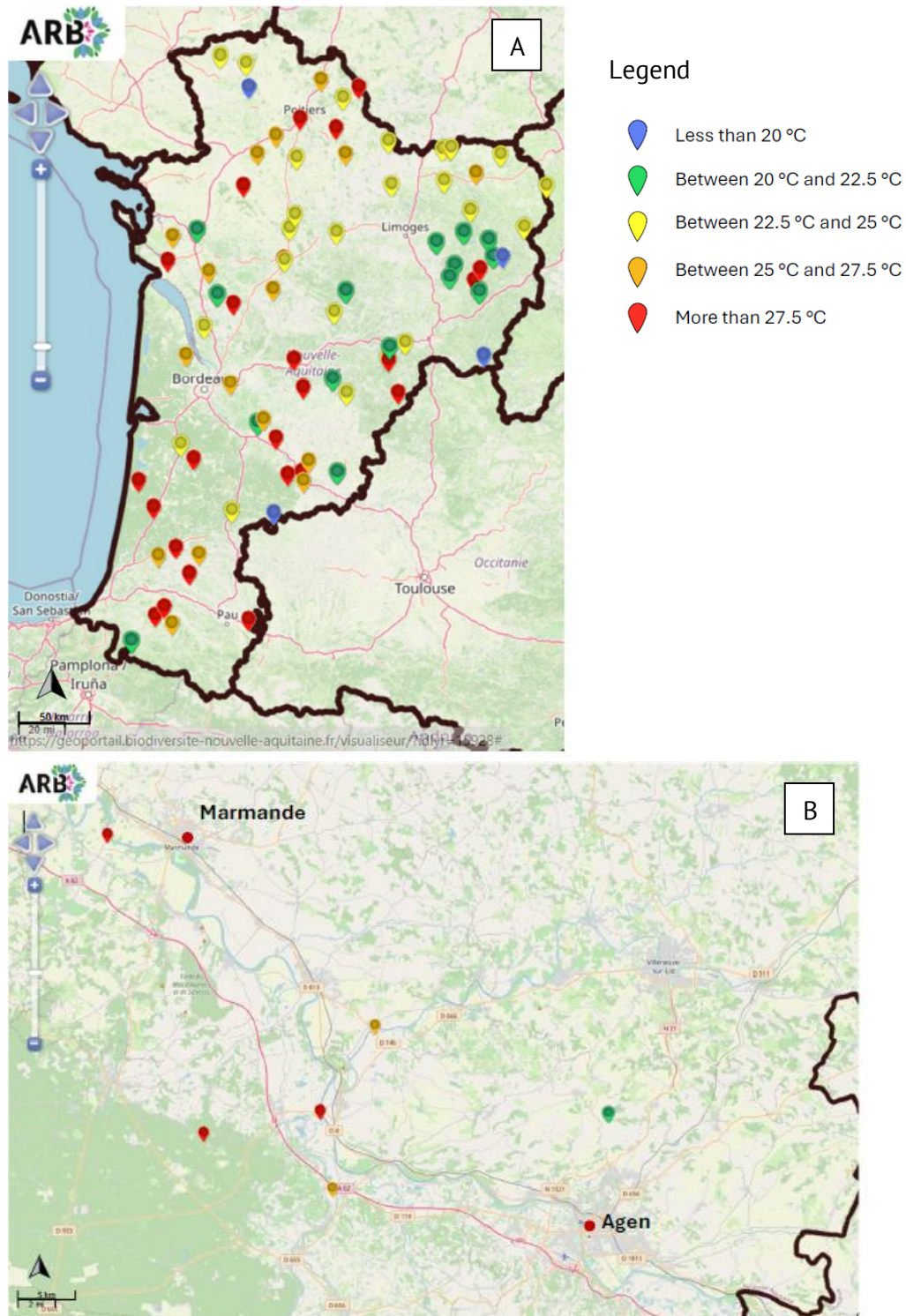


Figure 53: Maximum temperature¹⁴ of the water courses in the Nouvelle-Aquitaine region (A), and in the proximity of the Rural Demonstration site Ramage (B). These data are not available for the Marais Poitevin.

¹⁴ Office Française de la Biodiversité (Réseau National de suivi des Températures (RNT), NAIADES), API Hub'Eau – last actualisation 05/2022.

5.3 Cantabria

The Cantabrian Rural Demonstrators are mapped in Figure 54. Based on the thematics of our rural demonstrators, maps have been provided for the main climate hazards: fluvial flooding (Figure 55), potential soil erosion (Figure 56) and wildfires (Figure 57). These maps clearly show the spatial distribution of each hazard in the region. They can be combined with the land use and land cover map (Figure 58) to get an idea about the location of main KCSs and their exposure. Our Rural Demonstrators also include some regulatory ecosystem services that are relevant for the solutions, and some of these have been mapped in Figure 59 to Figure 61.

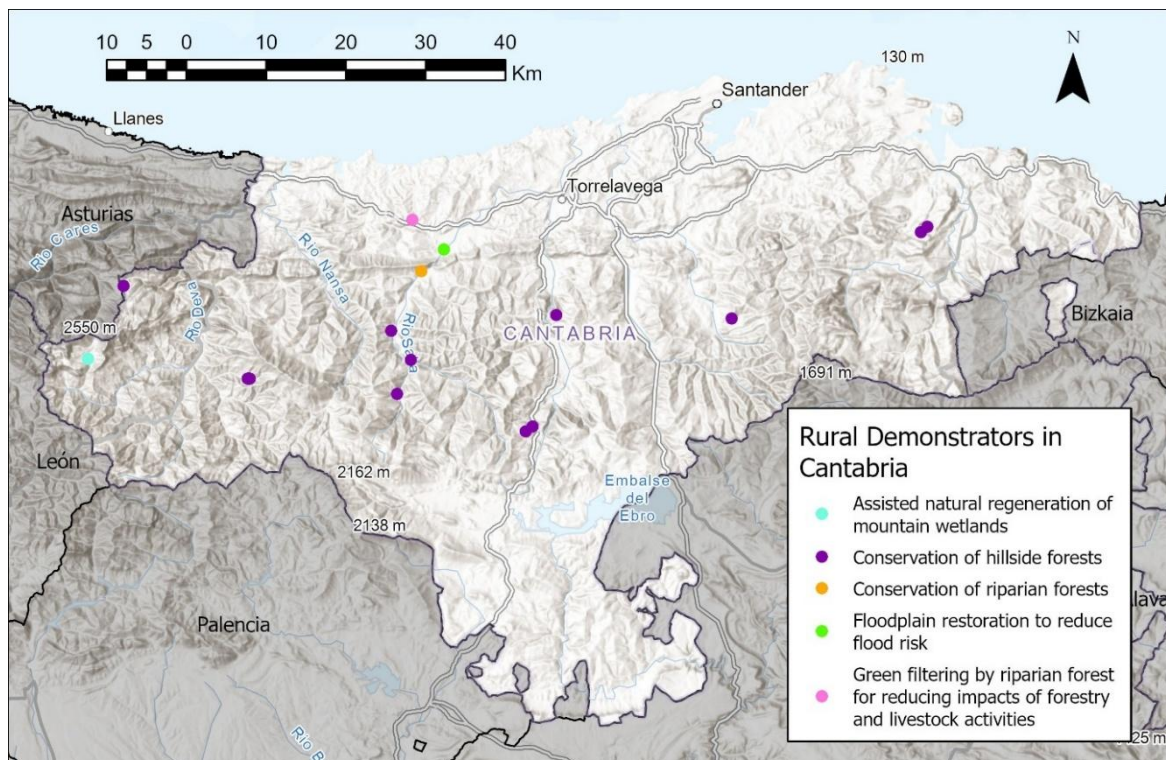


Figure 54: Map of the demonstration sites in Cantabria.

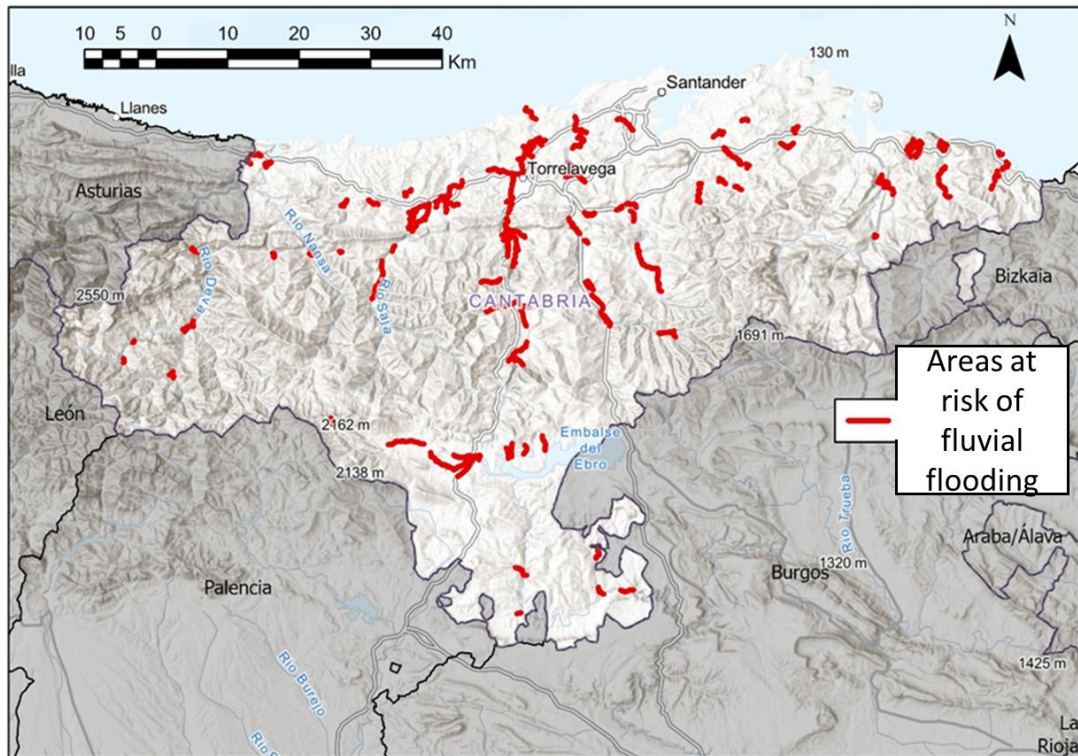


Figure 55: Distribution of areas of significant potential risk of river flooding (ARPSI), defined according to the technical criteria of the Preliminary Flood Risk Assessment of the Spanish Ministry for Ecological Transition and Demographic Challenge.

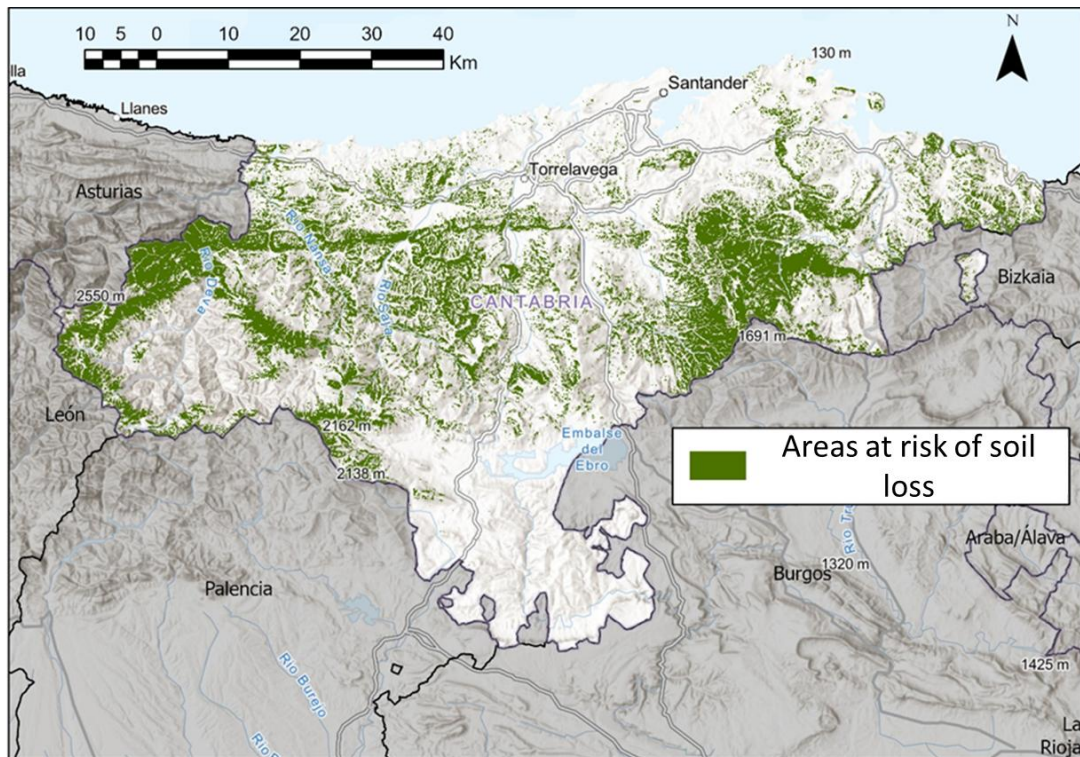


Figure 56: Distribution of areas of significant potential erosion and soil loss risk, defined according to a geomorphological approach (Benda et al., 2011).

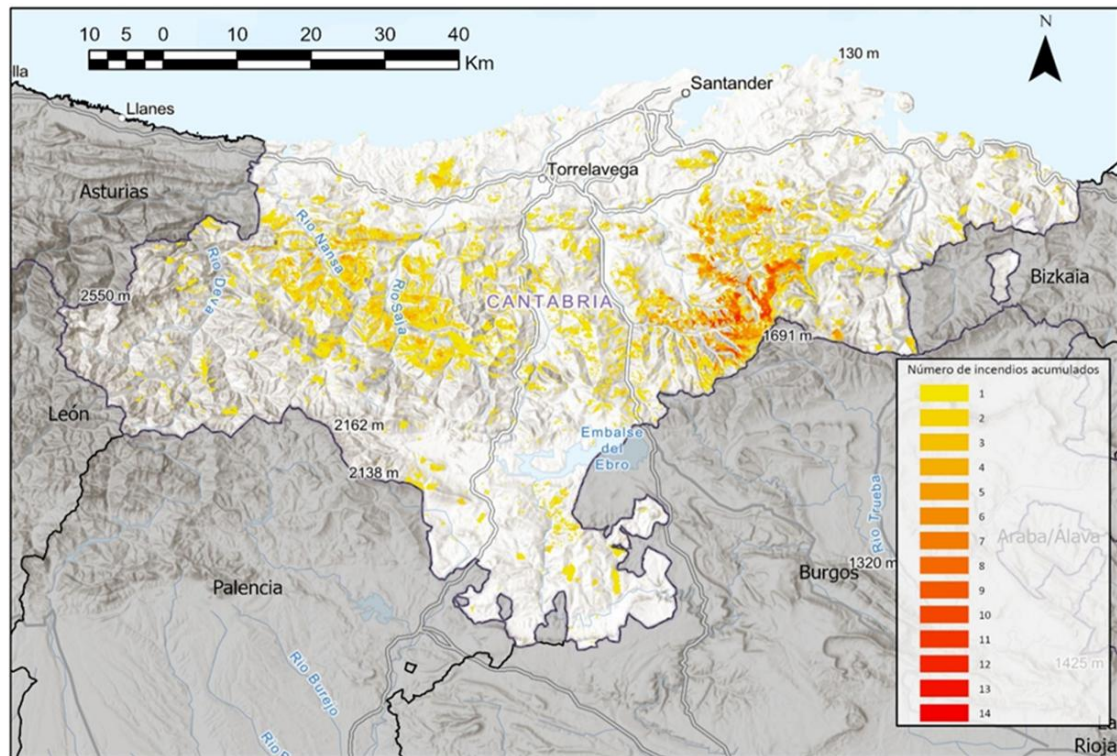


Figure 57: Characterization of the statistical hazard for the fire regime in Cantabria. This indicator presents a recurrence analysis based on historical fire data (2009-2022) provided by the Regional Ministry of Rural Development, Livestock, Fisheries and Food of the Government of Cantabria.

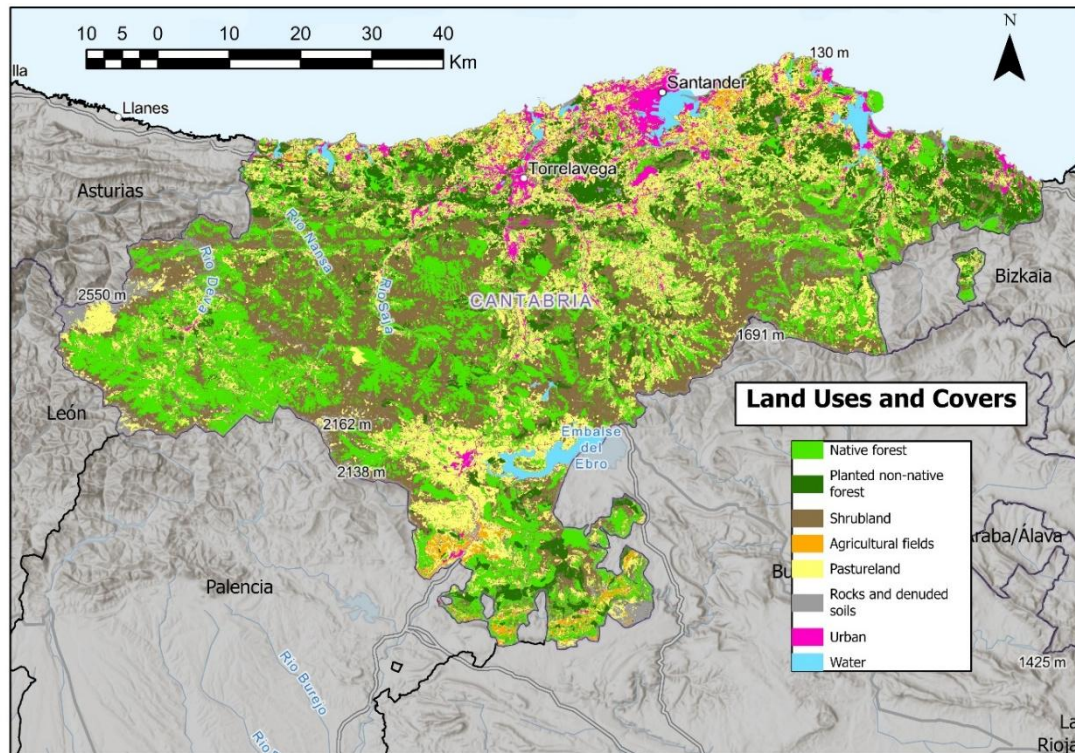


Figure 58: Land use and land cover map. This map comes from a 5-metre rasterisation, followed by a reclassification into 8 classes of land cover and land use from the official regional map of Cantabria (<https://mapas.cantabria.es/>).

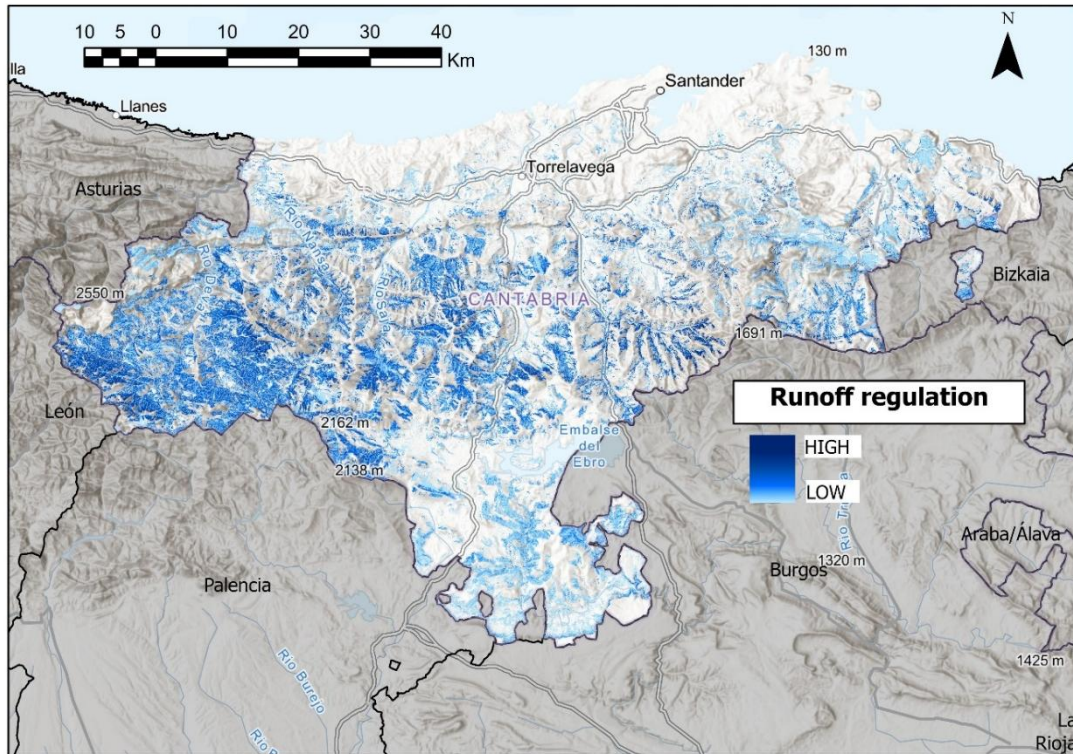


Figure 59: Map of hydrological regulation performed by native forest on slopes through runoff reduction. The higher the index, the greater the forest's contribution to reducing rapid flow into the river, which can lead to peak flows.

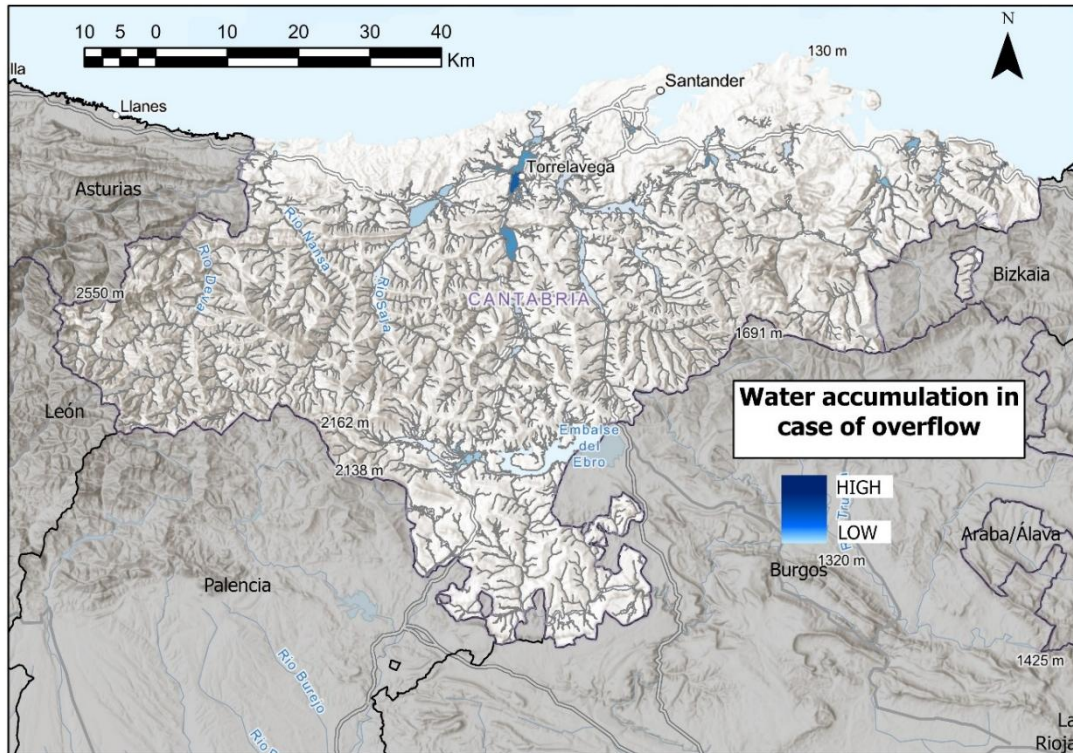


Figure 60: Map showing the potential water storage capacity that floodplains could temporarily hold in the event of overflow. The higher the index value, the greater the storage capacity and, therefore, the greater the contribution to reducing the frequency and peak of flooding downstream.

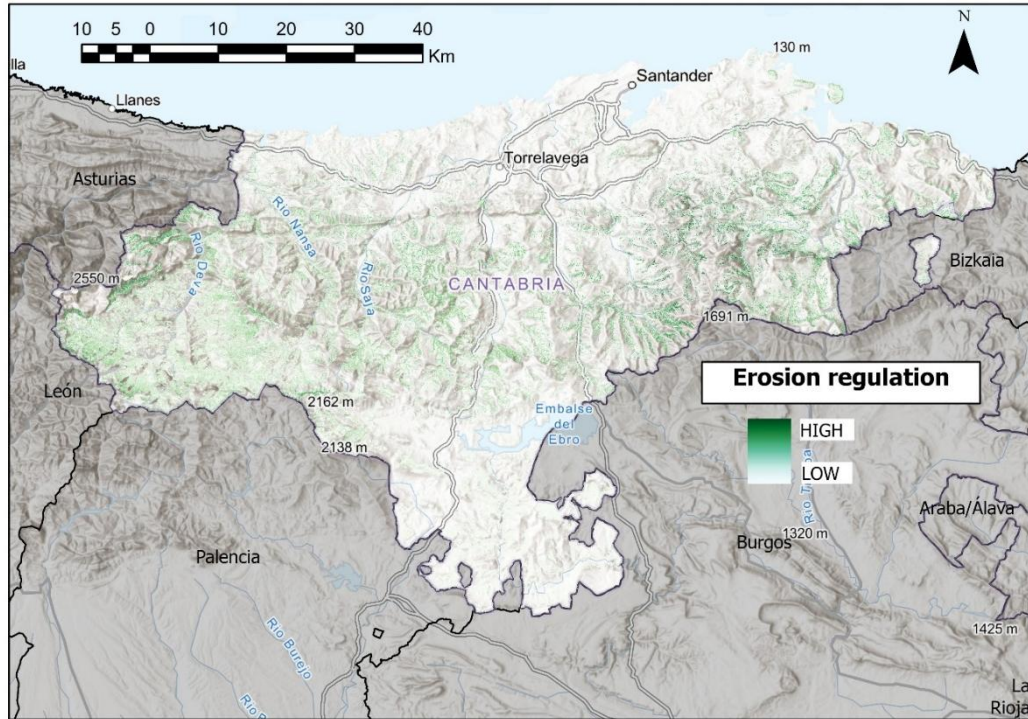


Figure 61: Map of erosion regulation performed by native forest on slopes. The higher the index, the greater the forest's contribution to reducing erosion and soil losses.

6 Discussion of results

6.1 Co-design steps

There are different definitions of **co-design**, also in relation to the design of NbS for climate adaptation. In its core, co-design is based on **a collaborative approach to design and implement a solution** (Basnou et al., 2020; Lupp et al., 2021). All regions are applying the Mission driven innovation approach and the concept of the **Regional Resilience Journey** (WP1). This entails the application of concepts on quadruple helix interplay, multi-actor and multi-level governance, and inter- and transdisciplinary approaches, that will be applied in all the regions. The different NBRACER regions will vary in applying these approaches, as this will require the introduction of new ways of working. Further, the regions are all at different stages of the Regional Resilience Journey, but also their demonstrated solutions are diverse and at different readiness levels. As such, the **co-design processes should be tailor-made for the specific solutions, within the different contexts**.

Key principles for the co-design process include:

- **Integrative** – Co-design of solutions that lead to benefits across sectors, regions, and governance levels. It ensures solutions that are aligned with multi-level policies and priorities, while balancing different interests.
- **Inclusive** – Co-design invites diverse voices, especially those often left out, like marginalized communities. It creates space for open dialogue, helping to address power imbalances and differing values.
- **Adaptive (iterative)** – Co-design is an ongoing process of learning and improving over time. It supports climate resilience by including feedback, adjusting plans, and working with a wide network of stakeholders.
- **Pluralist** – Co-design values different kinds of knowledge – scientific, local, traditional, ... It brings together various perspectives on nature and climate, encouraging new ways of thinking and working together.

NBRACER has defined the following 5 steps for the co-design process:

- (1) **Issue framing** – Involvement of stakeholders to debate and raise awareness on the regional climate risks and the role of NbS for climate adaptation. Stakeholder consultations are often focused on the identification of the problem and building a trust basis for further collaboration.
- (2) **Knowledge gathering and diagnosis** – Establishing a knowledge basis and evidence support is crucial to enable stakeholders to make informed decisions. This stage can involve capacity building, monitoring and gathering of data to assess the baseline and allow to debate potential solutions to address the identified issues.
- (3) **Co-design of options** – Stakeholders are involved in and actively contribute to the design of different solutions, including NbS. The design stage is once again informed with the gathered data and knowledge and builds further capacity.

- (4) **Stakeholder validation** – The co-designed NbS are implemented and validated with and by stakeholders. Stakeholders are actively involved in the monitoring of the solutions and perceive directly the benefits brought by its implementation.
- (5) **Decision-making and agreement** – The gathered knowledge allows to compare and validate different solutions, upon which an agreement or consensus can be reached among stakeholders pending their different opinions and perspectives.

Table 3: Overview of the co-design steps in the NBRACER Rural Demonstrators (caption: X – applied; (X) – partially applied).

NBRACER Rural Demonstrators	Co-design steps				
	1. Issue framing	2. Knowledge gathering and diagnosis	3. Co-design of options	4. Stakeholder validation	5. Decision making and agreement
1 DK - Nr Nisum	X	X	(X)	X	
2 WFL - Differentiated mowing	X	X	X	(X)	
3 WFL - Raising water level on cropland	X	X	(X)	X	(X)
4 WFL - Renaturalization of streams			X	X	(X)
5 WFL - Riparian zones Machuit	X	X	(X)	X	
6 WFL - Soil improvement practices Ilzer	X	X	(X)	X	
7 WFL - Sustainable farming practices		X		X	
8 NA - Marais Poitevin	X	X	X	X	
9 NA - Artificial water recharge	X	X	X	X	
10 CA - Green filtering by riparian forest	X	X		X	
11 CA - Conservation of riparian forests	X	X		X	
12 CA - Conservation of hillside forests	X	X		X	
13 CA - Regeneration of mountain wetlands	X		X	X	
14 CA - Floodplain restoration	X	X			

Table 3 summarizes which phases of co-design are applied in the NBRACER Rural Demonstrators, as interpreted by WP4 knowledge partners. **Most rural demonstrators are at early stages of issue framing and knowledge gathering**, aimed at raising stakeholder awareness of regional climate risks and their impact on the KCSs, as well as providing evidence-based support for the implementation of NbS to enhance regional climate resilience. . For instance, all the demonstrators in Cantabria are working on gathering data, monitoring and modelling of ecosystem services and benefits to communicate to local governments about the importance of NbS for regional adaptation (co-design steps 1 & 2).

Few demonstrators have already moved towards co-design of options together with stakeholders, and even fewer have currently reached the stages of stakeholder validation and decision-making. For example, for the renaturalization of streams, West-Flanders has regular workshops and consultations to reach a consensus including the concerns and needs of local stakeholders regarding the re-meandering projects implemented in the area (co-design steps 3, 4 and 5). Also, for sustainable farming practices in West-Flanders, the NbS are now being applied by the farmers and directly validated by them as the key interest stakeholder group (co-design step 4). Further support of the NBRACER Approach will be targeted at implementation and mainstreaming of NbS, pushing towards the last steps of the co-design process.

The reason why, in many cases, NBRACER partners focus more on early stages of co-design is because **NBRACER aims at increasing the readiness level of a solution**, resulting in less advanced NbS being the centre of the demonstrators. For instance, in West-Flanders, different provincial or regional rural climate adaptation projects have been funded and supported during the last 10 years. Those have already cycled through most, if not all, of the co-design steps and have resulted in implementation plans with support and agreement of relevant stakeholders. Although a comprehensive overview of the co-design process is lacking, these projects in West-Flanders have resulted in sets of validated solutions (portfolios). The NBRACER demonstrators are an addition to these portfolios, with a focus on solutions that required more co-design and increase of readiness level at the beginning of the NBRACER project.

6.2 Types of stakeholders involved

Success in co-design is achieved by aligning with the key principles and **engaging the right stakeholders at the right time**. Table 4 provides a theoretical definition for the different types of stakeholders and their recommended degree of involvement throughout the co-design process.

Table 4: Different types of involved stakeholders and their level of engagement in the co-design process.

Stakeholder type	Description	Level of engagement in the co-design process
Type 1: Observers	Least affected or involved; can include academia, media, international organizations.	Low – Provide insights, but are not decision-makers or implementers
Type 2: Moderately concerned officials	Authorities or political representatives; moderately affected by the hazards and/or solutions.	Medium – May support or block implementation
Type 3: Affected silent stakeholders	Civil society or private sector groups; most affected by the hazards and/or solutions but rarely involved.	Medium to high – Key for implementation buy-in
Type 4: Wise and active stakeholders	Knowledge holders, often from civil society or NGOs; affected by NbS and involved across stages.	High – Ideal co-design partners
Type 5: Stakeholders in charge	Decision-makers and funders; influence hazard and solution design directly.	Very high – Key actors for co-design ownership and implementation

This theoretical definition has been translated into different stakeholder groups, according to the involved partners in each of the NBRACER Rural Demonstrators. The proposed categories are:

- **Farmers**, as a key stakeholder group with special relevance in the rural landscape;
- **Water managers**, since water management is often identified as a relevant KCS in the rural landscape;
- **Local or regional governments**, as stakeholders in charge as decision-makers with ownership over the co-design process and implementation of the NbS;
- **Citizens**, often as stakeholders affected by the implementation of the NbS;
- **Nature**, often through NGOs, as representation of the natural environment;
- **Landowners**, often as stakeholders affected by the implementation of the NbS due to land use changes in the rural landscape;
- **Researchers**, as knowledge partners by providing science evidence to inform decision-making for the implementation of NbS.

Table 5 describes the stakeholder groups involved in each one of the NBRACER Rural Demonstrators. A first interesting conclusion is that two sub-groups of stakeholders can be identified from within the five stakeholder types: (i) the **‘designers’**, with focus on technical knowledge and the local context, and (ii) the **‘reviewers’**, with focus on the end-user experience and perception of the solution.

Table 5: Overview of the stakeholder groups involved in the NBRACER Rural Demonstrators (caption: X – involved; (X) – partially involved).

NBRACER Rural Demonstrators	Stakeholder groups involved						
	Farmers	Water managers	Local or regional governments	Citizens	Nature	Landowners	Researchers
1 DK - Nr Nissum		X	X	X			X
2 WFL - Differentiated mowing	X	X	X	X	X	X	X
3 WFL - Raising water level on cropland	X	X	X			X	X
4 WFL – Renaturalization of streams	X	X	X	X	X	X	X
5 WFL - Riparian zones Machuit	X	X	X	X	X	X	X
6 WFL - Soil improvement practices IJzer	X	X	X	X	X	X	X
7 WFL - Sustainable farming practices	X		X				X
8 NA - Marais Poitevin	X	X	X	X	X	X	X
9 NA - Artificial water recharge	X	X	X	X		X	X
10 CA - Green filtering by riparian forest	(X)	X	X			X	X
11 CA - Conservation of riparian forests	X	X	X	X		X	X
12 CA - Conservation of hillside forests	X		X	X		X	X
13 CA - Regeneration of mountain wetlands	X		X	X	X	X	X
14 CA - Floodplain restoration	X	X	X	X	(X)	X	X

Researchers and local or regional governments are involved in all NbS demonstrators. It is interesting to note that, according to the theoretical definition of Table 4, researchers are included in the Stakeholder Type 1 (Observers), which states a low level of engagement in the co-design process. However, in the NBRACER Rural Demonstrators, researchers play a very active role in providing technical knowledge to decision-makers and even take ownership of the co-design process. For instance, in Cantabria, FIHAC and UC as knowledge partners oversee the co-design process by bringing the stakeholders together and focusing on issue framing and monitoring for knowledge gathering.

Farmers and water managers are also common among the involved stakeholder groups for the NBRACER Rural Demonstrators. Particularly, for the agricultural NbS in West-Flanders, these three stakeholder groups are closely interlinked. For instance, raising of the water level in cropland agriculture is done from the perspective of the water managers, with the goal of increasing the water retention capacity of the soil for preventing flooding, but also for allowing water availability in case of drought. However, this will impact farming practices, therefore raising the need to closely involve farmers in the co-design of NbS to promote acceptance of the new practice and highlight their benefits for the affected stakeholders.

Landowners are also commonly involved in the Rural Demonstrators, whereas **citizens and nature are in general the least involved** stakeholder groups. Although nature is often not mentioned as a specific stakeholder, many demonstrators have (co-)benefits for biodiversity, often represented

through the involvement of government bodies. For instance, in Marais Poitevin in Nouvelle-Aquitaine, the nearby residents and landowners of the plots selected for river restoration are closely involved in the project to provide their legal authorization for the execution of the works and ensure implementation buy-in from the start of the process. In this demonstrator, nature representation is also involved through, e.g. the National Office for Biodiversity, which participates in the co-design of the solution aiming at enhanced local biodiversity and contributes to the ecological monitoring of the NbS.

6.3 Key Community Systems

The EU Mission on Adaptation to Climate Change refers to Key Community Systems (KCSs) as the underlying systems within the regions (**Appendix A: Glossary – Enabling conditions & Key Community Systems**). Table 6 synthesizes the most relevant KCSs that are impacted by climate risks in each one of the NBRACER Rural Demonstrators.

Table 6: Overview of the most relevant Key Community Systems (KCSs) in the NBRACER Rural Demonstrators (caption: X – impacted; (X) – partially impacted).

NBRACER Rural Demonstrators	Key Community Systems					
	Critical Infrastructure	Water Management	Land use & Food systems	Health & Wellbeing	Ecosystems & NbS	Local Economic Systems
1 DK - Nr Nissum	X	X		(X)	X	
2 WFL - Differentiated mowing	(X)	X	X	(X)	X	
3 WFL - Raising water level on cropland		X	X		X	
4 WFL - Renaturalization of streams	(X)	X	(X)	(X)	X	(X)
5 WFL - Riparian zones Machuit	X	X	X	X	X	
6 WFL - Soil improvement practices Ilzer	X	X	X	X	X	
7 WFL - Sustainable farming practices		X	X		X	
8 NA - Marais Poitevin	X	X	X		X	
9 NA - Artificial water recharge		X	X		X	X
10 CA - Green filtering by riparian forest		X	X		X	
11 CA - Conservation of riparian forests		X	X		X	

12 CA - Conservation of hillside forests			X		X	
13 CA - Regeneration of mountain wetlands		X	X		X	
14 CA - Floodplain restoration	X	X	(X)	X	X	

The main conclusion is that **Water Management** and **Ecosystems & NbS** are identified as relevant KCSs for (almost) **all NBRACER Rural Demonstrators**. Ecosystems & NbS as a KCS itself is directly related to the implementation of NbS, whereas water management is often associated with the identified climate risks (e.g., flooding and drought). For instance, the artificial aquifer recharge in Nouvelle-Aquitaine is an NbS directly implemented to improve the ecosystem health of the Garonne River, which is also the main water source of the region, impacted by pluvial flooding and drought.

Land use & Food systems is a relevant KCS for the **agriculture-related NbS**, which is often also associated to **Local Economic Systems** with farming as a mean of subsistence for the local stakeholders. For example, in the soil improvement practices on arable land in the Ilzer catchment in West-Flanders, the NbS such as non-tillage agriculture and carbon farming can have a direct impact on crop yield and affect the direct revenues for the farmer. Nonetheless, these measures contribute to higher soil biodiversity and more climate robust agriculture, shifting the food production system and land use as currently known.

Critical Infrastructure and **Health & Wellbeing** are the **least relevant KCSs** for the NBRACER Rural Demonstrators. Health & Wellbeing are often associated with NbS demonstrators contributing to an improved user experience of the landscape (e.g., mental wellbeing, recreational value of the landscape, etc), whereas Critical Infrastructure might be relevant in the cases where NbS implementation requires land use changes involving, e.g., roads or houses.

6.4 Climate risks

There are several frameworks available for the categorization of climate risks (Appendix A: Glossary – Climate risks; consult more information in Deliverables 5.1 and 5.2). However, for the purpose of simplifying, the following climate hazards are listed for this deliverable: **flooding** (pluvial and fluvial), **drought**, **water quality**, **soil erosion**, and **wildfires**. Table 7 describes the identified climate hazards that impact the KCSs in each one of the NBRACER Rural Demonstrators.

Table 7: Overview of the identified climate risks for the NBRACER Rural Demonstrators (caption: X – relevant; (X) – partially relevant).

NBRACER Rural Demonstrators	Climate risks					
	Pluvial flooding	Fluvial flooding	Drought	Water quality	Soil erosion	Wildfires
1 DK - Nr Nisum	X			X		
2 WFL - Differentiated mowing		X	(X)	X		
3 WFL - Raising water level on cropland	(X)	(X)	X	(X)		
4 WFL - Renaturalization of streams		X	X	X		
5 WFL - Riparian zones Machuit	X	X	X	X		
6 WFL - Soil improvement practices IJzer	X	X	X	X	X	
7 WFL - Sustainable farming practices	(X)	(X)	X	X	X	
8 NA - Marais Poitevin		X	X			
9 NA - Artificial water recharge			X	X		
10 CA - Green filtering by riparian forest					X	X
11 CA - Conservation of riparian forests		X		X	X	
12 CA - Conservation of hillside forests	X	X	X	X	X	
13 CA - Regeneration of mountain wetlands		(X)	X	X	X	
14 CA - Floodplain restoration		X		X		

It is interesting to note that the identified climate risks vary more depending on the regional context rather than on the NbS demonstrator itself; in other words, regions put NbS in place because of their (anticipated) capacity to offer a solution to the identified regional climate risks:

- The region of **Central Denmark** faces a great risk related to **flooding** due to increased precipitation, as such their NbS demonstrator aims to tackle precisely that by providing extra capacity for treatment of rainwater and avoid combined sewer overflows.
- **West-Flanders** has identified **flooding** and **drought** as the main climate risks for their rural landscape. Therefore, the region works on NbS that can not only allow effective management of exceedance of water in case of heavy rainfall events but also store this water locally for it to be available during the dry season (e.g., renaturalization of streams). **Water quality** is also a main concern, especially in the case of agricultural land use, reason why there are three agriculture-related NbS demonstrators in West-Flanders (e.g., soil improvement practices in the IJzer catchment, sustainable farming practices). This also links to the urban demonstrators in this region, which focus on water quality.
- **Nouvelle-Aquitaine** also identifies **flooding** and **drought** as main climate hazards for the region. For instance, the Marais Poitevin demonstrator is focused on restoration of the river floodplain in order to accommodate for higher river flows in the case of heavy rainfall, and the artificial water recharge demonstrator investigates optimized underground storage of rainwater to maintain the ecological flow of the river during the dry summer periods.
- **Cantabria** NbS demonstrators are all dealing with **water quality** and, in all cases except for the floodplain restoration demonstrator, **drought** is a key issue that is being addressed. The demonstrators on conservation of riparian and hillside forests are addressing **flooding**. The latter is also addressing **soil erosion**, which is also being addressed by the

floodplain restoration demonstrator. **Wildfires** is a climate risk specifically identified for this region.

6.5 Readiness level of solutions

The readiness level of a solution refers to its maturity for full-scale implementation: in the context of NBRACER, the maturity level of an NbS demonstrator and its potential for mainstreaming. It can cover both **Technology Readiness Level (TRL)**, to estimate the technical maturity of NbS, and **Societal Readiness Level (SRL)**, to assess the level of societal adaptation of the demonstrator, including ethical, legal, social, and economic factors (**Appendix A: Glossary – Readiness level**). Table 8 summarizes the TRL of the NBRACER Rural Demonstrators, including potential improvements by co-design in the project that go also beyond technological aspects.

Table 8: Overview of the readiness level of the NBRACER Rural Demonstrators and its expected increase in the project, including the improvements by co-design.

NBRACER Rural Demonstrators	Expected increased of the solution's readiness level	Improvements by co-design
1 DK - Nr Nisum	TRL 5 to 7-8: demonstration of a pilot treatment wetland.	Technological demonstration and gaining experience; gathering knowledge to inform decision makers. Governance aspects and social acceptance of a NbS.
2 WFL - Differentiated mowing	TRL 3 to 6: initiated research on the concept focused on issue framing and analysing best practices on the field.	Governance aspects: development of process and value chains with stakeholders.
3 WFL - Raising water level on cropland	TRL 3 to 7: preparation of plans for the installation of weirs in selected field sites.	Social acceptance: synergies/trade-offs for the affected stakeholders (farmers), and their involvement on NbS monitoring.
4 WFL - Renaturalization of streams	TRL 3 to 7: initiated research on the concept focused on issue framing and analysing best practices on the field.	Governance aspects: development of a process design flow diagram and recommendation sheet for improving implementation.
5 WFL - Riparian zones Machuit	TRL 6 to 7-8: demonstration of riparian zones in the Machuit valley.	Finances and resources & Governance and engagement: map additional implementation sites, create a technical sheet, assess regulatory frameworks.
6 WFL - Soil improvement practices IJzer	TRL 5 to 7-8: demonstration of sustainable farming techniques in the IJzer catchment.	Behavioural change & Data and knowledge: support transition practices with farmers, collect evidence on benefits and ecosystem services provided by NbS.
7 WFL - Sustainable farming practices	TRL 5 to 7-8: demonstration of carbon farming and non-tillage practices in dedicated plots.	Social acceptance: support transition practices with farmers by collecting evidence on the benefits of NbS.

8 NA - Marais Poitevin	TRL 5 to 7-8: demonstration of river restoration in the Marais Poitevin.	Governance aspects: stakeholder engagement for monitoring and participatory sciences, assess replication potential.
9 NA - Artificial water recharge	TRL 4 to 7-8: demonstration of groundwater recharge in the selected plots of the Garonne River catchment.	Governance aspects: raise stakeholder awareness through monitoring and data evidence, including citizen science; assess regulatory frameworks and replication potential.
10 CA - Green filtering by riparian forest	TRL 5 to 6-7: validation and demonstration of water quality improvement by riparian forests.	Gathering knowledge to inform decision-makers: monitoring campaigns to raise stakeholders' awareness on the benefits of the NbS.
11 CA - Conservation of riparian forests	TRL 5 to 6-7: validation of riparian forest functions for thermal regulation and erosion control.	Gathering knowledge to inform decision-makers: monitoring campaigns to raise stakeholders' awareness on the benefits of NbS.
12 CA - Conservation of hillside forests	TRL 5 to 6-7: validation of hillside forest functions for thermal regulation.	Gathering knowledge to inform decision-makers: monitoring campaigns to raise stakeholders' awareness on the benefits of NbS.
13 CA - Regeneration of mountain wetlands	TRL 6 to 7-8: validation of the functions of mountain wetlands for erosion, water retention and thermal regulation.	Governance aspects: stakeholder involvement for stimulating behavioural changes related to prescribed burnings of the area and livestock grazing.
14 CA - Floodplain restoration	TRL 5 to 6-7: validation of floodplain restoration for enhanced water retention and drought resilience.	Gathering knowledge to inform decision-makers: monitoring campaigns to raise stakeholders' awareness on the benefits of NbS.

6.6 Scale of demonstrators

Each demonstrator and region have a different approach related to the increase of readiness level aimed at for the demonstrators, as the overview provided in Table 9. Most demonstrators are **place-based physical pilots** that focus on a real-life demonstration, capturing technical and (in most cases) non-technical aspects. However, there are particular demonstrators which are focused at a more **holistic level** and on **identifying enabling non-technical conditions**. These demonstrators do not have one specific field site and, as such, do not have a specific technical focus, although a literature study on technical aspects is part of the issue framing and knowledge gathering steps of co-design. This implies that monitoring (Task 4.2 / Deliverable 4.2) will also not focus on physical parameters at site level. Specific references on the demonstrator case descriptions are added (through a sticky note) if the scale is not place-based or site specific (see Section 4: Rural Demonstrators).



Table 9: Overview of the scale of the NBRACER Rural Demonstrators.

NBRACER Rural Demonstrators	Scale of demonstrator
1 DK - Nr Nisum	Local place-based
2 WFL - Differentiated mowing	Holistic for the entire demo region
3 WFL - Raising water level on cropland	Local place-based
4 WFL - Renaturalization of streams	Holistic for the entire demo region
5 WFL - Riparian zones Machuit	Local place-based
6 WFL - Soil improvement practices IJzer	Holistic for a specific sub-region
7 WFL - Sustainable farming practices	Local place-based
8 NA - Marais Poitevin	Local place-based
9 NA - Artificial water recharge	Local place-based
10 CA - Green filtering by riparian forest	Local place-based
11 CA - Conservation of riparian forests	Local place-based
12 CA - Conservation of hillside forests	Spread over the entire demo region
13 CA - Regeneration of mountain wetlands	Local place-based
14 CA - Floodplain restoration	Local place-based

7 Conclusions and recommendations

The co-design processes documented in Deliverable D4.1 have demonstrated the value of participatory approaches in shaping NbS tailored to rural climate resilience. There are 14 Rural Demonstrators in NBRACER, showing the importance of this landscape type for the NBRACER partners. The Rural Demonstrators are spread over 4 Atlantic regions: Cantabria, Nouvelle-Aquitaine, West-Flanders and Central Denmark. For each demonstrator, we describe into detail the co-design process, including aspects such as governance and enabling conditions, monitoring planned in NBRACER, climate risks, KCS and ES. The most common impacted KCSs are **Land Use & Food systems** and **Water Management**. This is logical from the setup of the demos in a rural landscape. Because we focus only on NbS, also Ecosystems & NbS are always impacted, even if they are not always represented as stakeholders.

Each demonstrator is tailored towards its specific settings, with a focus on specific climate hazards and involving relevant stakeholders. Across the 14 Rural Demonstrators, the integration of stakeholders has been instrumental in aligning technical feasibility with local needs and values. The diversity of regional contexts and solution types underscores the importance of flexible and context-sensitive co-design frameworks.

The key learnings from the discussion include:

- **Early-stage engagement is critical** – Because NBRACER demonstration aims at increasing the readiness level, the selected demonstrators are mainly involved in the **early stages of co-design**. Most demonstrators are still in the initial phases of issue framing and knowledge gathering. These stages are essential for building trust, raising awareness of climate risks, and establishing a shared understanding of the challenges and opportunities.
- **Stakeholder diversity enhances solution robustness** – Because of the setting of a Horizon Europe project, **researchers are a key stakeholder group** for each demo. As expected for a rural setting, **farmers, water managers, landowners**, but also **local governments** are involved in most demos. Nature and citizens are less frequently involved, although their involvement might be indirect through one of the other groups. Demonstrators that actively involve a broader range of stakeholders tend to show stronger alignment with community priorities and greater potential for long-term adoption.
- **Readiness levels vary widely** – While some demonstrators are close to full-scale implementation, others require further technical validation, governance support, and societal buy-in. Co-design has allowed to identify barriers and enabling conditions that influence readiness.
- **Climate risks are region-specific** – The demonstrators reflect a strong alignment between local climate hazards and the design of NbS. It will not come as a surprise that in the Atlantic Region **drought** and **flooding** play a major role. **Water quality** and **soil erosion** are also often identified as climate risks. The nature, likelihood, potential impact and co-occurrence of these risks varies across the regions. This reinforces the importance of place-based approaches in adaptation planning.

To enhance the effectiveness and scalability of co-design processes in future phases of NBRACER and similar initiatives, the following recommendations are proposed by the knowledge partners:

1. **Strengthen inclusive engagement** – Expand stakeholder involvement to include underrepresented groups such as citizens, youth, and nature advocacy organizations. This will foster broader ownership and ensure that NbS reflect diverse perspectives and values.
2. **Enhance capacity building and knowledge exchange** – Provide targeted training and resources to stakeholders, especially those unfamiliar with NbS. Facilitate peer learning across regions to share best practices and lessons learned.
3. **Integrate monitoring and feedback loops early** – Embed monitoring frameworks and Key Performance Indicators (KPIs) into the co-design process from the outset. This will support adaptive management and evidence-based decision-making.
4. **Improve governance coordination** – Address fragmentation by establishing clear roles, responsibilities, and decision-making pathways among stakeholders. Promote multi-level governance structures that align local actions with regional and national strategies. Long term commitment and funding arrangements help to ensure reliability and continuity.
5. **Leverage digital tools and visual platforms** – Continue using collaborative platforms like MIRO to visualize co-design progress, facilitate remote participation, and document stakeholder inputs in a transparent and accessible manner.
6. **Support long-term stakeholder engagement** – Develop strategies for maintaining stakeholder involvement beyond the project lifecycle, including community stewardship models, local champions, and integration into existing planning processes. Coming to co-design of solutions is not always easy, finding agreement is a step post NBRACER.
7. **Tailor co-design to readiness levels** – Adapt the depth and intensity of co-design activities based on the maturity of each demonstrator. Early-stage solutions may benefit more from exploratory workshops, while advanced demonstrators require validation and mainstreaming support.

Overall, the co-design exercise has laid a solid foundation for mainstreaming of rural NbS and has highlighted the importance of adaptive, inclusive, and integrative approaches. The lessons learned will inform the next phases of NBRACER, particularly in **developing robust regional portfolios** and **upscaling successful solutions across biogeographical contexts**. By implementing these recommendations, NBRACER can further strengthen its role as a catalyst for systemic climate adaptation through NbS, ensuring that solutions are not only technically sound but also socially accepted and institutionally supported.

8 References

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9 Appendix A: Glossary

Please find here below a glossary with a collection of definitions, abbreviations, and descriptions of important elements to take into consideration when filling in the template.

9.1 Climate risks

The European Climate Risk Assessment (EUCRA) enables a comprehensive assessment of the major climate risks Europe is facing today and in the future. It identifies 36 climate risks that threaten energy and food security, ecosystems, infrastructure, water resources, financial systems, and people's health (Table 10).

Table 10: Extensive list of 36 major climate risks identified in the comprehensive assessment of the European Climate Risk Assessment (EUCRA, European Environment Agency). Source: European Climate Risk Assessment (adapted).

Ecosystems	1. Coastal erosion and inundation in coastal ecosystems 2. Anthropogenic pressure in marine ecosystems 3. Risks to biodiversity and carbon sinks from increased frequency and intensity of wildfires 4. Risks to biodiversity and carbon sinks from more frequent and severe drought and related insect pest outbreaks 5. Species distribution shifts in food web dynamics and associated ecosystems 6. Climate-induced species invasion 7. Reduction of low flow in aquatic and wetland ecosystems 8. Decreasing soil health 9. Cascading impacts from forest disturbances
Food	10. Adverse weather conditions for crop production 11. Risks to food security, agricultural production, and supply chains 12. Risks to food and nutrition security from increasing prices 13. Changed environmental conditions for fisheries and aquaculture 14. Increased spread of pests and diseases for livestock production
Health	15. Heat stress in human health 16. Risks to population and built environment from wildfire, heat and drought 17. Risk to wellbeing due to non-adapted buildings 18. Health stress for outdoor workers from increased heat 19. Emergence of harmful pathogens in waters 20. Stress to health systems and health infrastructure 21. Geographic expansion and spread of infectious diseases
Infrastructure	22. Risks to population, infrastructure, and economic activities from pluvial, and fluvial flooding 23. Risks to population, infrastructure, and economic activities from coastal flooding 24. Damage to infrastructure and buildings 25. Energy disruption due to heat and drought 26. Energy disruption due to flooding 27. Widespread disruption of marine transport 28. Widespread disruption of land-based transport

Economy	29. Compromise of European solidarity mechanisms
	30. Public finances leading to a financial crisis
	31. Stability of European property and insurance markets
	32. Risks to population and economic sectors due to water scarcity
	33. Interruption of pharmaceutical supply chains
	34. Disruption in key industrial sectors of supply chains for raw materials and components
	35. Disruption of financial markets
	36. Inviabilization of winter tourism in regions that highly depend on it

9.2 Enabling conditions & Key Community Systems

The **Enabling Conditions** refer to means for enabling innovation that are intrinsic to the regions. The EU Mission on Adaptation to Climate Change mentions 4 Enabling Conditions on the edges of the chart (Figure 62): (1) **knowledge and data** to reveal what is happening and the how the solutions help; (2) **governance** and political structure, as well as **engagement** from citizens and stakeholders; (3) **finance and resources** of the local economic systems; (4) **behavioural change**.

The **Key Community Systems (KCSs)** correspond to the key areas and underlying systems where innovation can happen within the regions. The EU Mission on Adaptation to Climate Change refers to 6 KCSs in the middle of the chart (Figure 62): (1) **critical infrastructure**; (2) **health and well-being**; (3) **land use and food systems**; (4) **water management**; these are all linked to (5) **ecosystems and nature-based solutions**, together with the (6) **local economic systems**.

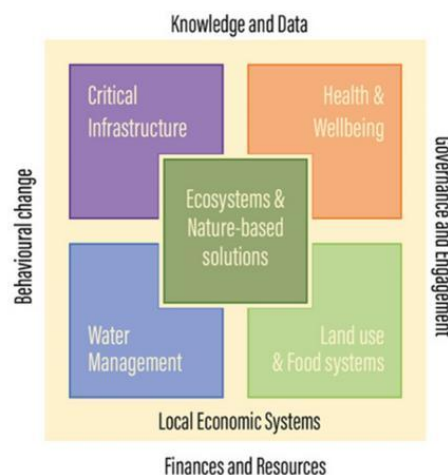


Figure 62: Key innovations areas mentioned in the EU Mission for adaptation to climate change. Source: [A solutions-focused approach to adapting Europe to the climate crisis | Research and Innovation](#).

9.3 Ecosystem Services

The World Bank has provided a framework to support the identification of suitable investments on NbS based on the processes taking place, which functions can be extracted from those (i.e., Ecosystem Services), and which benefits they give for people (i.e., co-benefits) (Figure 63).

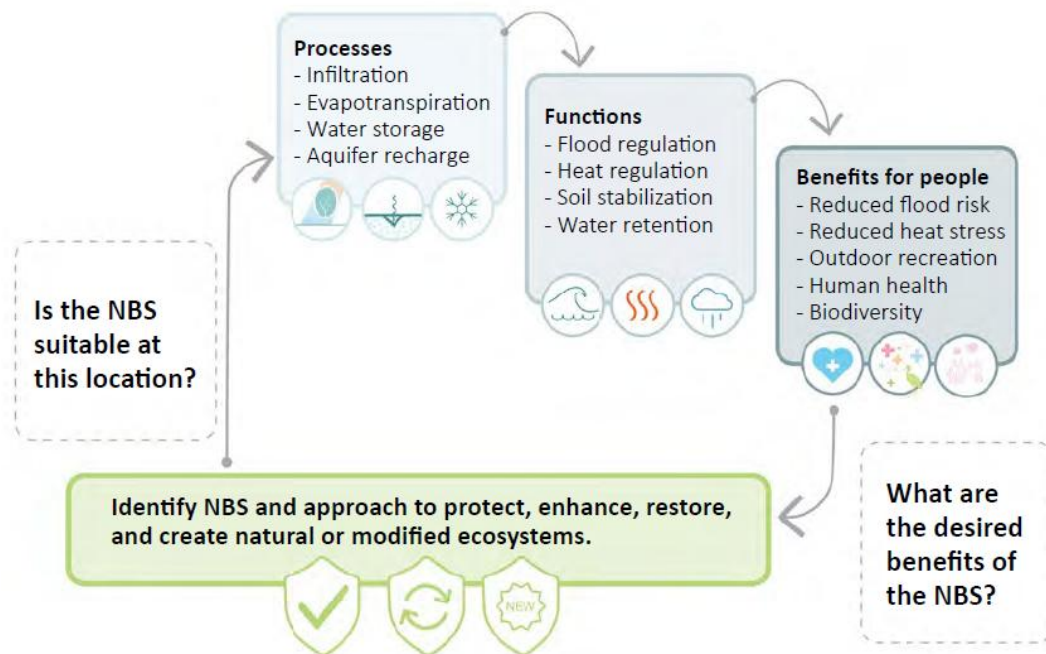


Figure 63: Framework to support the identification of suitable implementation of NbS at a given location based on the processes taking place, provided functions and benefits for people. Source: World Bank, 2021 (adapted).

Ecosystem Services (ES) are the services that an ecosystem supplies and from which humans can take benefit. The European Environment Agency (EEA) proposes the following thematic, class and group structure for a Common International Classification of Ecosystem Services (CICES) (Figure 64):

- **Provisioning services:** which covers material or energetic outputs from ecosystems, including food, water and other resources;
- **Regulation and maintenance services:** which covers factors that affect the ambient biotic and abiotic environment, such as flood and disease control, nutrient cycling and primary productivity, that maintain the conditions for life on Earth;
- **Cultural services:** which covers non-material (intellectual, cognitive, symbolic) uses, such as spiritual and recreational benefits.

Theme	Class	Group
Provisioning	Nutrition	Terrestrial plant and animal foodstuffs
		Freshwater plant and animal foodstuffs
		Marine plant and animal foodstuffs
		Potable water
	Materials	Biotic materials
		Abiotic materials
	Energy	Renewable biofuels
Regulation and Maintenance	Regulation of wastes	Renewable abiotic energy sources
		Bioremediation
	Flow regulation	Dilution and sequestration
		Air flow regulation
		Water flow regulation
	Regulation of physical environment	Mass flow regulation
		Atmospheric regulation
		Water quality regulation
	Regulation of biotic environment	Pedogenesis and soil quality regulation
		Lifecycle maintenance & habitat protection
		Pest and disease control
Cultural	Symbolic	Gene pool protection
		Aesthetic, Heritage
	Intellectual and Experiential	Religious and spiritual
		Recreation and community activities
		Information & knowledge

Figure 64: Classification of Ecosystem Services: thematic, class and group structure proposed by Common International Classification of Ecosystem Services (CICES, European Environment Agency). Source: [Classification of ecosystem services \(EEA\) \(UNCEE/5/7\) Introduction to the CICES proposal](#).

A detailed list of ES, as defined within NBRACER, can also be found in D5.1 Annex (Ecosystem Services). The **Ecosystem Services provided by NbS** can be subdivided into **main regulatory function and co-benefits**. The main regulatory function corresponds to the main purpose of their design, referring to the specific (climate) challenge to which the solutions aim to respond to. Nonetheless, NbS often provide other ES beyond their design purpose – these are referred to as **co-benefits**. See the example below (Figure 65) for a better understanding of the two concepts (in this case, the main regulatory function is urban flood management, and several direct and indirect co-benefits have been identified).

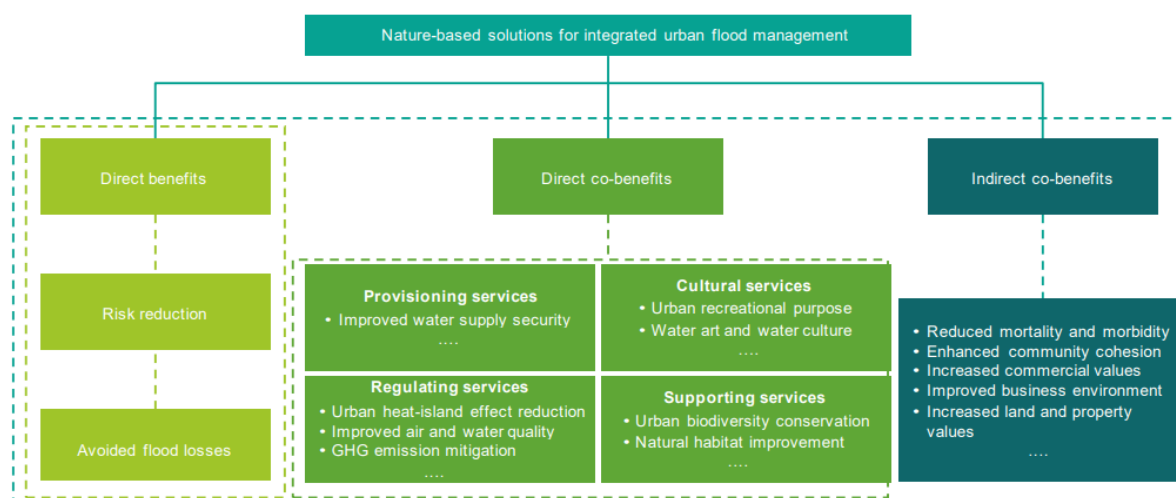


Figure 65: Example of benefits and Ecosystem Services provided by NbS for integrated urban flood management. Source: Wishart et al., 2021.

9.4 Readiness level

The schemes below illustrate what each readiness level corresponds to in terms of **Technology Readiness Level (TRL)** (Figure 66) and **Societal Readiness Level (SRL)** (Figure 67).

TRL	Description	Example
1	Basic principles observed	Scientific observations made and reported. Examples could include paper-based studies of a technology's basic properties.
2	Technology concept formulated	Envisioned applications are speculative at this stage. Examples are often limited to analytical studies.
3	Experimental proof of concept	Effective research and development initiated. Examples include studies and laboratory measurements to validate analytical predictions.
4	Technology validated in lab	Technology validated through designed investigation. Examples might include analysis of the technology parameter operating range. The results provide evidence that envisioned application performance requirements might be attainable.
5	Technology validated in relevant environment	Reliability of technology significantly increases. Examples could involve validation of a semi-integrated system/model of technological and supporting elements in a simulated environment.
6	Technology demonstrated in relevant environment	Prototype system verified. Examples might include a prototype system/model being produced and demonstrated in a simulated environment.
7	System model or prototype demonstration in operational environment	A major step increase in technological maturity. Examples could include a prototype model/system being verified in an operational environment.
8	System complete and qualified	System/model produced and qualified. An example might include the knowledge generated from TRL 7 being used to manufacture an actual system/model, which is subsequently qualified in an operational environment. In most cases, this TRL represents the end of development.
9	Actual system proven in operational environment	System/model proven and ready for full commercial deployment. An example includes the actual system/model being successfully deployed for multiple missions by end users.

Figure 66: Technology Readiness Level (TRL) scale diagram. Source: [What are Technology Readiness Levels \(TRL\)? - TWI](#) (adapted).

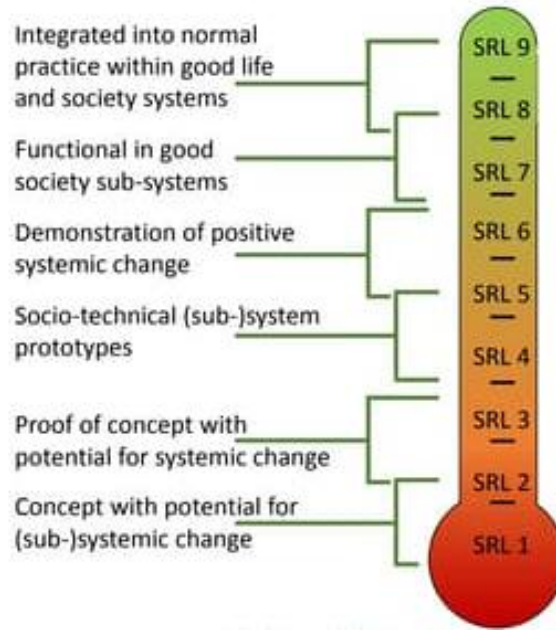


Figure 67: Societal Readiness Level (SRL) scale diagram. Source: [Cut Carbon Symposium: Societal Readiness Levels | PPT](#) (adapted).

9.5 Landscape (sub)archetypes

NBRACER considers 3 landscape types: **marine & coastal**, **urban**, and **rural**. Nonetheless, it is relevant to further characterize landscape (sub)archetypes in order to better define each region and draw conclusions based on replicability and suitability of solutions across contexts. The framework for the landscape (sub)archetypes refers to three different types of datasets: (i) the **European CORINE Land Cover classes** (as initially addressed in the NbS questionnaire) in combination with others, such as Copernicus Urban Atlas and Coastal Zones (Table 11); (ii) the landscape archetypes are translatable and relate to all the **functional units of the conceptual model formulated in Task 5.1** (Table 12); and, (iii) whenever data is available, **base layers are also considered** for specific landscape characterization relating to **geomorphology, soil type, groundwater levels, elevation**, etc.

Table 11: European CORINE Land Cover classification.

Artificial surfaces	Agricultural areas	Forest and semi-natural areas	Wetlands	Water bodies
• Continuous urban areas • Discontinuous urban areas • Industrial or commercial units • Road and rail networks and associated land • Port areas • Airports • Mineral extraction sites • Dump sites • Construction sites • Green urban areas • Sport and leisure facilities	• Non-irrigated arable land • Irrigated land arable land • Rice fields • Vineyards • Fruit trees and berry plantations • Olive groves • Pastures • Annual crops associated with permanent crops • Complex cultivation patterns • Land principally occupied by agriculture, with significant areas of natural vegetation • Agroforestry areas	• Broad-leaved forest • Coniferous forest • Mixed forest • Natural grasslands • Moors and heathland • Sclerophyllous vegetation • Transitional woodland-shrub • Beaches, dunes, sands	• Inland marshes • Peat bogs • Salt marshes • Salines • Intertidal flats	• Water courses • Water bodies • Coastal lagoons • Estuaries • Sea and ocean

Table 12: Detailed list of functional units identified in NBRACER Deliverable 5.1 *Technical framework supporting the design and implementation of NbS: development and application* (Table 7, Appendix 2). For each functional unit, the geomorphic processes that dominate the unit and therefore characterise it are listed. The functional units are defined according to two geomorphic classification systems (see last column). The element of the classification considered to be most like the functional unit and whose definition has been taken from it is shown in bold.

Functional units	Dominant geomorphic processes	Definition	Geomorphic Classification System
Interfluve	Pedogenetic processes associated with vertical subsurface soil water movement	The area between rivers; esp. the relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction. (Bates and Jackson, 1995)	(Haskins, et al. 1998) [Common landform] Interfluve
Hillslope (Montgomery, 1999)	Slope processes	A positive relief generated by an unspecified tectonic/structural process.	(Nanson, et al., 2022) Solid Earth BGU: Tectonic high BGU-T: Compressional ridge; tectonic dome
		A positive relief generated by bedrock bedding (modified after Huggett, 2017).	BGU: Bedding ridge BGU-T: Cuesta; homoclinal ridge; hogback
		A natural elevation of the land surface, rising rather prominently above the surrounding land, usually of limited extent and having a well-defined outline (rounded rather than peaked or rugged), and generally considered to be less than 300 m from base to summit; the distinction between a hill and a mountain is arbitrary and dependent on local usage. (Bates and Jackson, 1995).	(Haskins, et al. 1998) [Landscape Term] Hill
		Any part of the Earth's crust higher than a hill, sufficiently elevated above the surrounding land surface of which it forms a part to be considered worthy of a distinctive name, characterized by a restricted summit area (as distinguished from a plateau), and generally having comparatively steep sides and considerable bare rock surface; it can occur as a single, isolated eminence, or in a group forming a long chain or range, and it may form by earth movements, erosion, or volcanic action. Generally, a mountain is considered to project at least 300 m above the surrounding land.	[Landscape Term] Mountain

Table 12 (cont.): Detailed list of functional units identified in NBRACER Deliverable 5.1 *Technical framework supporting the design and implementation of NbS: development and application* (Table 7, Appendix 2). For each functional unit, the geomorphic processes that dominate the unit and therefore characterise it are listed. The functional units are defined according to two geomorphic classification systems (see last column). The element of the classification considered to be most like the functional unit and whose definition has been taken from it is shown in bold.

Functional units	Dominant geomorphic processes	Definition	Geomorphic Classification System
Hollow/Torrent (Montgomery, 1999)	Processes of water flow concentration (runoff) only after precipitation events. The rest of the time, slope processes dominate	Though diverse in form, GULLIES tend to be relatively small (though larger than RILLS), steep, narrow, deeply incised SUBAERIAL CHANNELS that are carved into unconsolidated regolith (modified from Goudie, 2006).	(Nanson, et al., 2022) Coastal or fluvial BGU: Subaerial channel BGU-T: Gully
		A very small valley, such as a small ravine in a cliff face, or a long, narrow hollow or channel worn in earth or unconsolidated material (as on a hillslope) by running water and through which water runs only after a rain or the melting of ice or snow; it is smaller than a gulch. (b) Any erosion channel so deep that it cannot be crossed by a wheeled vehicle or eliminated by ploughing, esp. one excavated in soil on a bare slope. (c) A small, steep-sided wooded hollow. (Bates and Jackson, 1995).	(Haskins, et al. 1998) [Common Landform] Gully
River channel and banks (Montgomery, 1999)	Stream processes, driven by water flow	Formed of alluvium, usually have mobile boundaries and are self-adjusting in response to changing conditions. Commonly parabolic or trapezoid in cross section with adjacent, roughly horizontal FLOODPLAINS are inundated when the channel exceeds bank full capacity (modified from Goudie, 2006).	(Nanson, et al., 2022) Coastal or fluvial BGU: Subaerial channel BGU-T: River; Creek
		The bed where a natural body of surface water flows or may flow; a natural passageway or depression of perceptible extent containing continuously or periodically flowing water, or forming a connecting link between two bodies of water; a watercourse. (Bates and Jackson, 1995).	(Haskins, et al. 1998) [Fluvial Landform and Microfeature] Stream Processes (Subprocess Modifiers: Undifferentiated, Eroding, Transporting or Depositional)
		The sloping margin of, or the ground bordering, a stream, and serving to confine the water to the natural channel during the normal course of flow. It is best marked where a distinct channel has been eroded in the valley floor, or where there is a cessation of land vegetation. A bank is designated as right or left as it would appear to an observer facing downstream. (Bates and Jackson, 1995).	• Channel • Bank

Table 12 (cont.): Detailed list of functional units identified in NBRACER Deliverable 5.1 *Technical framework supporting the design and implementation of NbS: development and application* (Table 7, Appendix 2). For each functional unit, the geomorphic processes that dominate the unit and therefore characterise it are listed. The functional units are defined according to two geomorphic classification systems (see last column). The element of the classification considered to be most like the functional unit and whose definition has been taken from it is shown in bold.

Functional units	Dominant geomorphic processes	Definition	Geomorphic Classification System
Riparian zone	Riparian processes, driven by a high lateral-vertical connectivity between the river and the terrestrial area	Transitional semiterrestrial areas regularly influenced by freshwater, normally extending from the edges of water bodies to the edges of upland communities. These are 'three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems' (Gregory et al. 1991). In this sense, flood recurrence interval may be an objective approach to delineate the outward boundary of the riparian zone. In this regard, the 50-yr flood has been indicated as an appropriate hydrological descriptor for riparian zones as it usually coincides with the first terrace or other upward sloping surface (Ilhardt et al., 2000).	
Floodplain (Montgomery, 1999)	Recurrent river flooding processes	The relatively flat area of land between the banks of the parent stream and the confining valley walls, over which water from the parent stream flows at times of high discharge. The sediment that comprises a FLOODPLAIN is mainly alluvium derived from the parent stream (modified from Goudie, 2006) and can be comprised of CONFINED / CUT-AND-FILL, BRAIDED, LATERAL MIGRATION or ANABRANCHING FLOODPLAIN deposits (Nanson and Croke, 1992).	(Nanson, et al., 2022) Coastal or fluvial BGU: Floodplain BGU-T: High-energy confined floodplain; Medium-energy unconfined floodplain; Low-energy cohesive floodplain
		A small alluvial plain bordering a river, on which alluvium is deposited during floods. (Bates and Jackson, 1995).	(Haskins, et al. 1998) [Fluvial Element Landform] Stream Processes (Subprocess Modifiers: Undifferentiated, Eroding, Transporting or Depositional) - Floodplain Alluvial flat - Meander scar - Meander scroll - Oxbow - Levee

Table 12 (cont.): Detailed list of functional units identified in NBRACER Deliverable 5.1 *Technical framework supporting the design and implementation of NbS: development and application* (Table 7, Appendix 2). For each functional unit, the geomorphic processes that dominate the unit and therefore characterise it are listed. The functional units are defined according to two geomorphic classification systems (see last column). The element of the classification considered to be most like the functional unit and whose definition has been taken from it is shown in bold.

Functional units	Dominant geomorphic processes	Definition	Geomorphic Classification System
Estuary	Marine-river mixing processes determined by the tidal cycle	A near-horizontal depositional surface formed above mean high water spring tide level. Typically located on the landward margins of saltmarshes and along estuary and lagoon shorelines.	(Nanson, et al., 2022) Coastal BGU: tidal flat BGU-T: supratidal flat
		The seaward end or the widened funnel shaped tidal mouth of a river valley where freshwater comes into contact with seawater and where tidal effects are evident; e.g., a tidal river, or a partially enclosed coastal body of water where the tide meets the current of a stream (Bates and Jackson, 1995).	(Haskins, et al. 1998) [Coastal Marine Landform] Shoreline Processes Estuary
Delta	Sedimentation processes subject to tidal, waves and currents dynamics	A discrete shoreline sedimentary protuberance formed where a river enters a body of water and supplies sediment more rapidly than it can be redistributed by basinal processes (modified from: Elliott, 1986).	(Nanson, et al., 2022) Coastal and fluvial BGU: delta BGU-T: front; pro-; upper; lower; bayhead; shelf edge; tidal delta
		The low, nearly flat, alluvial tract of land at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable area, crossed by many distributaries of the main river, perhaps extending beyond the general trend of the coast, and resulting from the accumulation of sediment supplied by the river in such quantities that it is not removed by tides, waves, and currents. Most deltas are partly subaerial and partly below water. (Bates and Jackson, 1995)	(Haskins, et al. 1998) [Landscape term] Delta [FLuvial Landform] Stream Processes (Subprocess Modifiers: terminal deposition)
		The level or nearly level surface composing the landward part of a large delta; strictly, an alluvial plain characterized by repeated channel bifurcation and divergence, multiple distributary channels, and interdistributary flood basins. (Bates and Jackson, 1995)	• Delta ○ Delta plain

Table 12 (cont.): Detailed list of functional units identified in NBRACER Deliverable 5.1 *Technical framework supporting the design and implementation of NbS: development and application* (Table 7, Appendix 2). For each functional unit, the geomorphic processes that dominate the unit and therefore characterise it are listed. The functional units are defined according to two geomorphic classification systems (see last column). The element of the classification considered to be most like the functional unit and whose definition has been taken from it is shown in bold.

Functional units	Dominant geomorphic processes	Definition	Geomorphic Classification System
Coastal cliff	Wave erosion	A steep slope, or ESCARPMENT formed in rock, ranging in height from tens to hundreds of metres.	(Nanson, et al., 2022) Coastal BGU: rocky coast BGU-T: cliff
		A cliff or slope produced by wave erosion, situated at the seaward edge of the coast or the landward side of the wave-cut platform, and marking the inner limit of beach erosion. It may vary from an inconspicuous slope to a high, steep escarpment. (Bates and Jackson, 1995)	(Haskins, et al. 1998) [Coastal Marine Landform] Shoreline Processes • Cliff
Intertidal reef	Tidal variation	A general term for an occurrence of rock, biogenic, or other stable material that lies at or near the sea surface and is elevated at least partially above the surrounding seabed (in the intertidal case: the area above water level at low tide and underwater at high tide). In-situ, positive relief, persistent build-ups of primarily skeleton-supported framework (+ internal binding), that influence the local sedimentary environment (Klement, 1967), and supports (or supported) living communities during active accretion. Definition modified from a range of sources: (Cumings, 1932; Goudie, 2006; Harris and Baker, 2020; Klement, 1967; Lo lacono et al., 2018). Cf. REEF (Marine Setting)	(Nanson, et al., 2022) Biogenic - Marine BGU: reef BGU-T:
		A bioherm of sufficient size to develop associated facies. It is erected by, and composed mostly of the remains of, sedentary or colonial and sediment-binding organisms, generally marine: chiefly corals and algae, less commonly crinoids, bryozoans, sponges, mollusks, and other forms that live their mature lives near but below the surface of the water (although they may have some exposure at low tide; in fact, in the intertidal case: the area above water level at low tide and underwater at high tide). Their exoskeletal hard parts remain in place after death, and the deposit is firm enough to resist wave erosion. An organic reef may also contain still-living organisms. (Bates and Jackson, 1995)	(Haskins, et al. 1998) [Coastal Marine Landform] Shoreline Processes • Organic reef

Table 12 (cont.): Detailed list of functional units identified in NBRACER Deliverable 5.1 *Technical framework supporting the design and implementation of NbS: development and application* (Table 7, Appendix 2). For each functional unit, the geomorphic processes that dominate the unit and therefore characterise it are listed. The functional units are defined according to two geomorphic classification systems (see last column). The element of the classification considered to be most like the functional unit and whose definition has been taken from it is shown in bold.

Functional units	Dominant geomorphic processes	Definition	Geomorphic Classification System
Subtidal coast		A low gradient surface formed below mean low tide level. Typically located at the seaward of saltmarsh and mangrove communities.	(Nanson, et al., 2022) Coastal BGU: tidal flat BGU-T: subtidal flat
		(a) A strip of land of indefinite width (may be many kilometers) that extends from the low tide line inland to the first major change in landform features (remains submerged except during particularly low tides). (Bates and Jackson, 1995)	(Haskins, et al. 1998) [Landscape term] Coast
		An extensive, nearly horizontal, marshy or barren tract of land that remains submerged except during particularly low tides and consisting of unconsolidated sediment (mostly mud and sand). It may form the top surface of a deltaic deposit. (Bates and Jackson, 1995)	[Coastal Marine Landform] Shoreline Processes • Subtidal flat
Coastal land-reclamation area or polder		Land reclamation is the process of creating new land from the sea. The simplest method of land reclamation involves simply filling the area with large amounts of heavy rock and/or cement, then filling with clay and soil until the desired height is reached. Draining of submerged wetlands is often used to reclaim land for agricultural use. (Stauber et al., 2016)	
Polder or coastal land-reclamation area		Originally meaning silted-up land or earthen wall, and generally used to designate a piece of land reclaimed from the sea or from inland water. It is used for a drained marsh, a reclaimed coastal zone, or a lake dried out by pumping. (Eisma, 2014)	

10Appendix B: Structure of the demonstrator canvas on MIRO

Demo title

Organ-
isation/
Partner

Authors: Name (Organisation); Name (Organisation)



PICTURES

Summary Brief description and objectives: Stakeholders involved and roles Climate risks Ownership and roles	Landscapes: Landscape archetype subtypes: Key Community Systems (incl. socio-econ impacts) Main regulatory function Co-benefits Enabling conditions:
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Description of Demonstrator
 Keywords:
 Description

Co-design process and improvements needed
 Involved stakeholder groups:

Governance and other enabling conditions
 Financial aspects:
 Technical aspects:
 Governance and social factors:

Monitoring and selected KPIs

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks

Key Community Systems

Ecosystem Services

 How are KCS Impacted:

CO2
Ecosystem Services

References
[1]
[2]
...

Figure 68: Structure of the MIRO canvas for co-design (illustrative blank). The nature of its content and the instructions given for the regions to fill-in each section of the canvas are described in the following subchapters.

10.1 Summary

Write a summary about your NbS case that allows readers to quickly grasp what it is about (max 5 sentences). Please include pictures (max 5) to better illustrate the system to the readers.

Brief description and objectives <i>Briefly describe your case and its research objectives. Make sure to use terms for a non-expert reader.</i>	Landscape types and (sub)archetypes <i>Select the landscape types of the project and the (sub)archetypes (see the Appendix A: Glossary section for more information). If the case addresses more than one landscape, make sure to mention it here.</i>
Stakeholders involved and roles <i>Mention which stakeholders have been involved in your demonstrator and which role they have (e.g., involved, informed, decision maker).</i>	Key Community Systems <i>Refer to the 6 Key Community Systems (KCSs) as mentioned in the EU Mission on Adaptation to Climate Change (see the Appendix A: Glossary section for more information).</i>
	Main regulatory function <i>Describe which regulatory function that your demonstrator is addressing, i.e., which is the propose of design of your NbS (see the Appendix A: Glossary section for more information on the concept of Ecosystem Services).</i>
Climate risks <i>Refer to the climate risks as mentioned in the European Climate Risk Assessment (see the Appendix A: Glossary section for more information).</i>	Co-benefits <i>NbS often provide extra Ecosystem Services besides its main regulatory function or purpose for design. Reflect which extra benefits your solution can contribute to in terms of climate mitigation, adaptation, and resilience (see the Appendix A: Glossary section for more information on the concept of Ecosystem Services).</i>
Ownership and roles <i>Describe the ownership structure of your case, i.e., who the owner is, who is responsible for maintenance and operation of the systems, and how is the setup facilitated in terms of financing.</i>	Enabling conditions <i>Refer to the 4 Enabling Conditions as mentioned in the EU Mission on Adaptation to Climate Change (see the Appendix A: Glossary section for more information).</i>

10.2 Description of the demonstrator

Link to the sections 'brief description and objectives' and 'landscape types and (sub)archetypes' in the summary. Provide a short description of the demonstrator case, including keywords (max. 4) and the following information:

- *Technical description of the demonstrator (include technical plans, if applicable);*
- *Location of the demonstrator (and contextual background, if relevant);*
- *Description of the processes involved, including which NbS have been tested and demonstrated;*
- *Why this case has been selected for the project;*
- *How the demonstrator relates to existing adaptation plans, as well as the regional adaptation journey and the vision drafted for the region;*
- *Use references to reports and literature.*
- *Max 15 lines.*

10.3 Co-design process and improvements needed

Link to the sections 'stakeholders involved and roles' and 'co-design process' in the summary. Describe the co-design process tailored according to the demonstrator, and how this co-design is contributing to improving the solution and increasing its readiness level. Consider the following key aspects:

- *Which are the involved stakeholder groups and how have they been involved?*
- *Which role does each stakeholder play in the process?*
- *How is the bridge between scientific knowledge and practice of the demonstrator?*
- *Does the region succeed in the interplay between stakeholders?*
- *Does the region succeed in involving new stakeholders and in communicating to the wider public?*
- *Which are the barriers along the co-design process and issues to be solved?*
- *What is the focus of the co-design in NBRACER project?*
- *How is NBRACER project, partnership and approach supporting the demonstrator?*
- *What are the benefits of NBRACER support?*
- *Lessons learned by co-design in other (NbS) projects*
- *Which aspects are needed to upscale the solution and can be addressed by co-design?*
- *What is the current readiness level of the demonstrator and how is the co-design process contributing to mainstreaming the solution?*
- *To what extent has the demonstrator shown progress (technological, organizational, social/societal)?*
- *How are the co-design barriers being addressed?*
- *What are the plans for long-term engagement of the stakeholders?*
- *What is the timeline foreseen for the process of the demonstrator?*
- *Use references to reports and literature.*
- *Max 40 lines.*

10.4 Governance and other enabling conditions

*Link to the sections ‘ownership and roles’ and ‘enabling conditions’ in the summary. Please describe the contribution of each enabling condition for mainstreaming NbS in the demonstrator, with particular relevance on **governance aspects**, and including the following:*

- *What are the main barriers for implementation?*
- *Are there any gaps on knowledge and data to increase the readiness level of the solution?*
- *What is the governance structure behind the demonstrator (incl. funders and decision makers)?*
- *If relevant, what is the perception of stakeholders and citizens over the solution? Is there willingness for the behavioural and systemic changes needed to mainstream this solution?*
- *Are there any needs for extra financing resources to mainstream the solution?*
- *Use references to reports and literature.*
- *Max 15 lines.*

10.5 Monitoring and selected KPIs

Please describe the monitoring framework and which Key Performance Indicators (KPIs) are under consideration for the demonstrator case. If there is no monitoring strategy already in place, please include this information in this section. A more detailed report regarding monitoring will be elaborated in the upcoming phase of the project (related to Dx.2 on lessons learnt from monitoring).

- *Use references to reports and literature.*
- *Max 10 lines.*

10.6 Climate risks, Key Community Systems, Ecosystem Services

Link to the ‘climate risks’, ‘Key Community Systems’, ‘main regulatory function’ and ‘co-benefits’ sections in the summary. Please provide additional information on (see the Appendix A: Glossary section for more information):

- *Describe further the climate risks tailored to the demonstrator*
- *Describe how the identified KCSs relate to the demonstrator*
- *How are the identified KCSs impacted by the climate risks in the context of the demonstrator?*
- *Does the demonstrator address risks for maladaptation?*
- *How does the demonstrator address the **main regulatory function and purpose for its design**?*
- *Describe the **co-benefits** provided by the demonstrator and its contribution (e.g., qualitative score, such as negative – low – medium – high).*
- *If the demonstrator has negative impacts, please refer them here as **disservices** (e.g., converting arable land into a wetland for water treatment will lower the crop production yield per area of available land).*

- *If applicable, describe which tools/methodologies are available for quantifying the Ecosystem Services delivered by the demonstrator.*
- *Use references to reports and literature.*
- *Max 20 lines.*

10.7 References

Please add any references to scientifically back up what you have described in the remaining sections of the canvas. You can number them and refer with '[x]' in the text (cfr. "engineering is described in [1]").