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 Urban Landscape systems

Deliverable D3.1

Version n° 3

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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.

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Summary

Deliverable D3.1, *Co-design of Transformative Systemic Urban 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 urban landscapes across four of the NBRACER Demonstrating Regions: Central Denmark, West-Flanders, Cantabria and Porto.

The main objective of this deliverable is to document the progress and learnings from the co-design of 5 Urban NbS Demonstrators. These demonstrators address main urban climate challenges, such as flooding and heat stress, while targeting improvements in Key Community Systems (KCSs) like Infrastructure, Water Management, Health and Wellbeing, Economic systems and Ecosystems.

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 commonalities of urban challenges and 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 contribute to the development of regional NbS portfolios and adaptation pathways for the urban landscapes in NBRACER.

This document for Deliverable 3.1 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 3.1 and this deliverable;
- Chapter 3 presents the Urban Demonstrators and reports the co-design process in a visual summary;
- Chapter 4 provides the mapping of landscapes and Ecosystem Services within the urban 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

Nature-based Solutions, NbS, Urban Landscape, Demonstration, Atlantic Biogeographical Region, Co-design

Abbreviations and acronyms

Acronym	Description
DR	Demonstrating Regions within the context of NBRACER: Central Denmark (DK), West-Flanders (BE), Nouvelle-Aquitaine (FR), Cantabria (ES), and Porto (PT).
D3.1	Deliverable of Task 3.1, corresponding to the present document: Co-design of transformative systemic solutions (due in Month 24).
D32	Deliverable of Task x.2: 'Lessons learnt from monitoring in local NbS demos', transversal to WPs 2, 3 and 4 (due in Month 36).
D3.3	Deliverable of Task x.3: 'Regional portfolios of solutions and pathways', transversal to WPs 2, 3 and 4 (due in Month 40).
D3.4	Deliverable of Task x.4: 'Lessons learnt from validating the portfolios', transversal to WPs 2, 3 and 4 (due in Month 44).
KCS	Key Community Systems
MEL	Monitoring Evaluation Learning
NbS	*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.* Source: Nature-based solutions - European Commission
RR	Replicating Regions within the context of NBRACER: Friesland (NL), East-Flanders (BE), and Cávado (PT).
SRL	Societal Readiness Level
TRL	Technology Readiness Level
T3.1	Task x.1 'Co-design of transformative systemic solutions', transversal to WPs 2, 3 and 4. Task to which the present deliverable refers to.
T3.2	Task x.2 'Monitoring and prediction of KPIs', transversal to WPs 2, 3 and 4.
T3.3	Task x.3 'Assessing the impact of solutions portfolios and pathways', transversal to WPs 2, 3 and 4.
T3.4	Task x.4 'Transposing and validating solutions', transversal to WPs 2, 3 and 4.
WP	Work Package
WP1	Work Package 1 'Integrated stocktaking, visioning and prioritising' led by Climate-KIC and mainly focused on supporting 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 the University of Cantabria.
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. Emphasising NbS and incorporating socio-ecological systems and ecosystem services dynamics, the framework supports comprehensive resilience planning, providing regions with a cohesive pathway to operationalise 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.

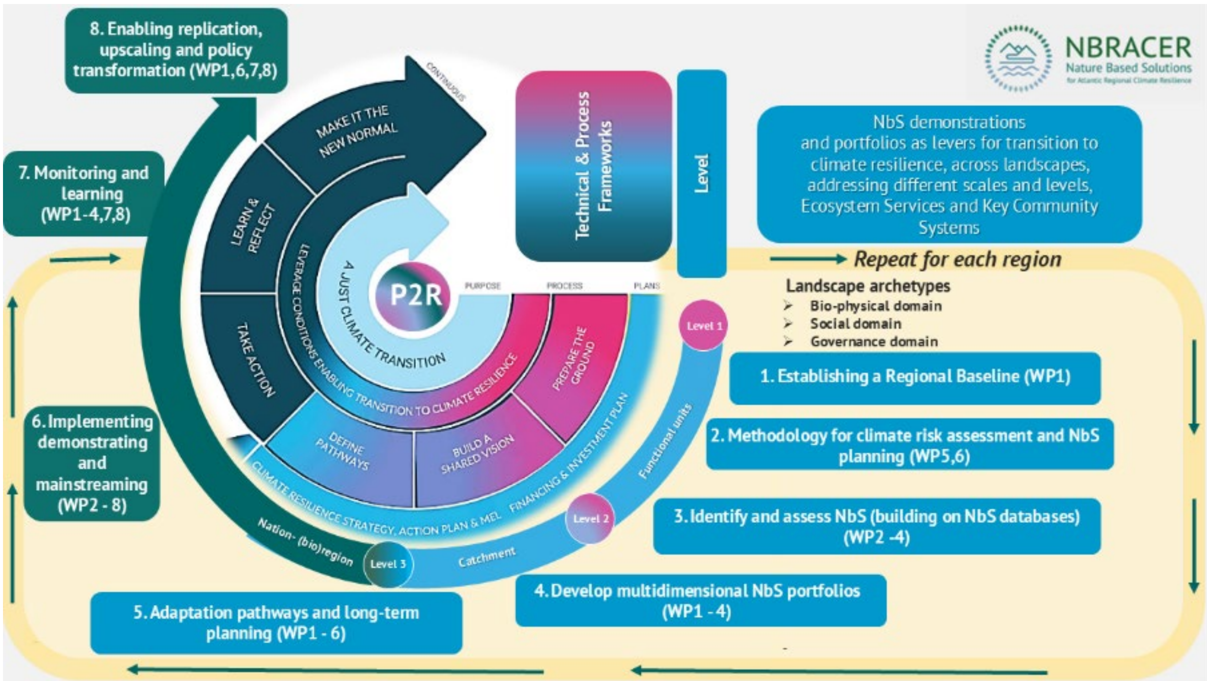

Figure 1: Overview of the NBRACER Approach with 8 steps, elaborating an iterative process for achieving a just climate transition through multi-level, multi-scale and multi-domain planning.

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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 3.1 lays the foundation for the identification of proposed NbS in consultation with stakeholders and according to the needs of the urban landscape for **Step 3: Identify and assess NbS**, serving also as a starting basis for further developing a place-based and context-specific portfolio of solutions in **Step 4: Develop multidimensional 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 the co-design of the monitoring protocols, contributing to **Step 7: Monitoring and learning**

Within Task 3.1, the WP lead, together with the Regional Coordinators and the project leads of the Demonstrators, will describe the Demonstrator within a Canvas, which includes the various aspects of the Baseline, in which the systemic approach has been applied, describing the current system, the risks, the partner networks and the environmental and socio-economic context. Together, the current state of the Demonstrator is determined, drivers and barriers are identified, and the next steps of development are defined. The Demonstrators need to be optimally aligned in the regional vision and are to be seen as exploring the defined pathways of the Transformative Adaptation Journey. In the next phase, Task 3.2, a portfolio will be built, and the upscaling and mainstreaming phases will be explored.

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2 General introduction

Characterisation of urban landscapes in the Atlantic Biogeographical Region

Urban areas in the Atlantic Biogeographical Region are characterised by a complex interplay between natural dynamics and often densely populated built environments. In the Atlantic Biogeographical Region, cities are commonly located along coastlines and in delta landscapes near major waterways, facing increasing pressure from climate change related risks. As hubs of economic activity and critical services, these urban landscapes are vulnerable, however, they can also play an important role in resilience strategies.

Climate change related challenges

Cities in this region are especially exposed to water-related risks due to their geographical settings. Cities located at the coast face sea level rise, storms and erosion of the coastline. Cities located further from the coast but close to large rivers are susceptible to riverine flooding, caused by heavy rainfall, high tides and/or meltwater. In addition, cities in general can be prone to flooding due to heavy precipitation events, as urban environments contain a high proportion of paved areas, not allowing rainwater to infiltrate into the soil. Combined with outdated sewage systems with insufficient capacity and elevation differences, this leads to a high risk of pluvial flooding. Finally, low-lying areas can also be susceptible to flooding due to high groundwater levels.

The urban heat island effect is a well-known phenomenon, describing the increase in temperature in densely built environments with a lack of open and green spaces. The increased temperatures can affect the health and well-being of citizens.

Cities also impact ecological systems, as expanding built areas often contribute to the fragmentation of habitats, disturbance of species through light, noise and chemical pollution. With a lack of space for green in urban areas, there is little room for a diversity of species to survive. This, in turn, impacts the resilience of urban areas and the well-being of citizens: green living environments can help reduce stress and increase well-being, a diversity of species can help mitigate the risk of plagues, and vegetation can reduce erosion, flooding and heat stress.

Key Community Systems

Cities are important hotspots for Key Community Systems (KCS), which are vulnerable to climate impacts.

- **Critical infrastructure** such as transportation systems, roads, energy networks and communication systems are vital to the functioning of the urban environment, but can be impacted by flooding events, heavy storms or heatwaves.
- **Health and well-being** can, amongst others, be affected by heat stress, pollution, and severe flooding events.

- **Land use and food systems**: many agrifood activities are based near cities (or even within cities, when small-scale), with processing and logistics hubs located in or at the fringes of urban areas. Logistics chains as well as agricultural activities are vulnerable to flooding and heat.
- **Water management** is increasingly challenging due to more intense precipitation events and longer periods of drought. Flood prevention, as well as long-term storage and purification of (drinking) water, are essential.
- **Ecosystems and biodiversity** can be vulnerable to climate risks, but can also play an important part in adapting and mitigating climate change related risks. Facilitating healthy green areas in cities can support biodiversity, and at the same time contribute to increasing health and wellbeing, healthy crops and lower risk of plague species, mitigate heat stress, and improve water management.
- With regard to the **local economic systems**, many cities in the Atlantic biogeographical region are port cities with industrial sites. The economic system is based on production and trade.

Nature-based Solutions in urban areas

NbS can be implemented to address the abovementioned urban challenges. For example, by creating basins or infiltration areas for rainwater to mitigate flooding and building reserves for longer periods of drought, natural purification systems such as vegetated wetlands can help purify the water while also delivering additional ecosystem services (ES). Greening urban areas helps cool the city: this is especially important in urban areas due to the urban heat island effect. NbS herewith support the ecological system, creating a more robust, climate resilient city. However, a particular challenge of implementing NbS in the urban context is the pressure on space. With many functions located in the densely built urban areas, it can be a challenge to implement them and find support in the process. Therefore, it may be necessary to integrate NbS with other functions, such as infrastructure, recreation or education, to create climate resilient cities.

Urban demonstrators

Task 3.1 improves the proposed solutions by co-design based on the multiple vulnerabilities and risks for KCSs (WP1), identifying the enabling conditions (supported by WP6) and facilitated by the mapping of landscapes and ES (developed in WP5). Local partners of each DR are closely engaged in a participatory approach, supported by the 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.

This deliverable reports on the **co-design process of testing and demonstrating NbS for climate adaptation in the various landscapes**. The main objective of this report is to report on the progress of co-design of the demonstrators, and to report on the experiences and findings, enablers, and barriers, while also registering the process of implementation.

3 Objectives

Task 3.1 focuses on the **co-design of transformative systemic solutions and further development of the NbS demos in the Urban Landscape.** This builds further on several other activities carried out within the project, such as the regional baseline reports (WP1 and WP6), the strategic regional workshops (WP1), the NbS questionnaire (WP5), and the (modelling and) mapping exercise (WP5).

This task aims to **support the regions with the co-design of their urban demonstrator cases**. To do so, WP3 provides an aligned approach to actively and closely cooperate with the Demonstrators in the NBRACER DRs by means of setting up a **knowledge base** including inspirations and examples for the regions, as well as providing **support services** proactively and on demand, to explore, identify and tackle the needs of each region and to create optimal conditions for proceeding with the Demonstrations. This task is operationalised in two main activities:

i. **Project Demonstrators' MIRO board;** a Canvas is developed to capture all relevant aspects of the Demonstrator. In meetings with the regions, all aspects have been covered and discussed, in order to determine the current state and to formulate the next steps to bring the Demonstrator further in development into full implementation. WP3 partners have organised several online meetings to discuss the Demonstrator and to fill the Miro Canvas. The Canvas is a living, working environment, which will be adapted regularly. The Canvas 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.

4 Urban Demonstrators

On the following pages, the Miro boards of the Urban Demonstrators are included:

- Central Denmark – Climate Road
- West Flanders – Constructed wetlands for decentralised water treatment
- West Flanders - Constructed wetland for treatment of industrial concentrate
- Porto – Quinta de Salgueiros
- Cantabria – Avenida Dr Madrazo Santander

Hereafter follows a discussion on the current state of the Demonstrators and conclusions. In Appendix C, higher resolution images of the Miro canvases are included. The Miro canvases of the urban demonstrators can be viewed here.

4.1 Climate Road – Central Denmark

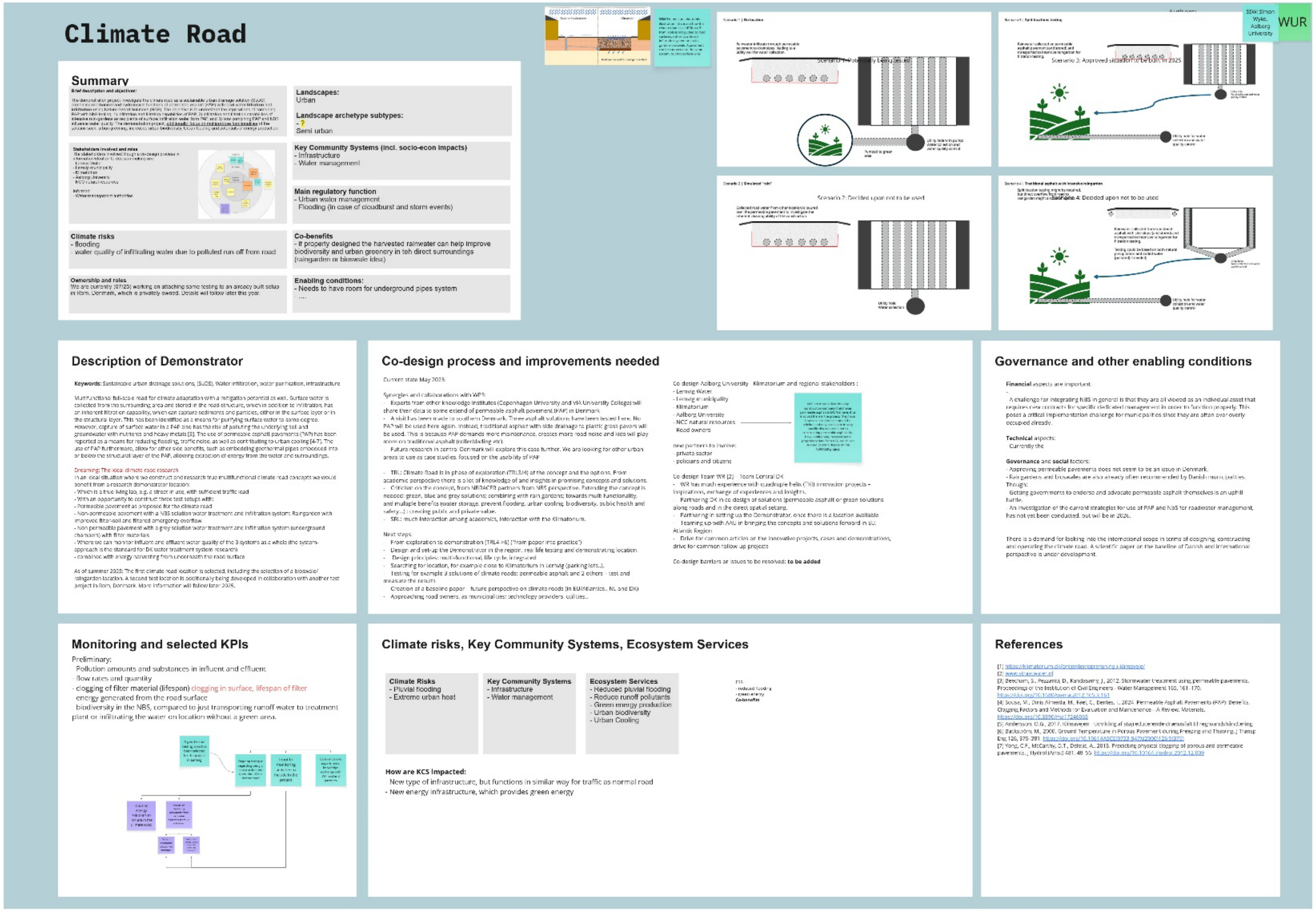

Figure 2: Snapshot of the Climate Road Demonstrator canvas.

Aalborg University is leading the 'Climate Road' Demonstrator, which has started as a research project and is currently in the phase of exploring the potential as an NbS with the regional partner network. The Canvas of the Urban Demonstrator in Central Denmark has been created in co-design among WR and Aalborg University in three online co-design sessions. WR has mobilised its experts on urban water NbS, dealing with flooding and heavy rainfall and capturing and storing water. Knowledge has been shared, and all aspects of the Canvas have been discussed and described, resulting in a basic description and clear next steps to bring the demonstrator further into readiness for demonstration.

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4.2 Constructed wetlands for decentralised water treatment – West-Flanders

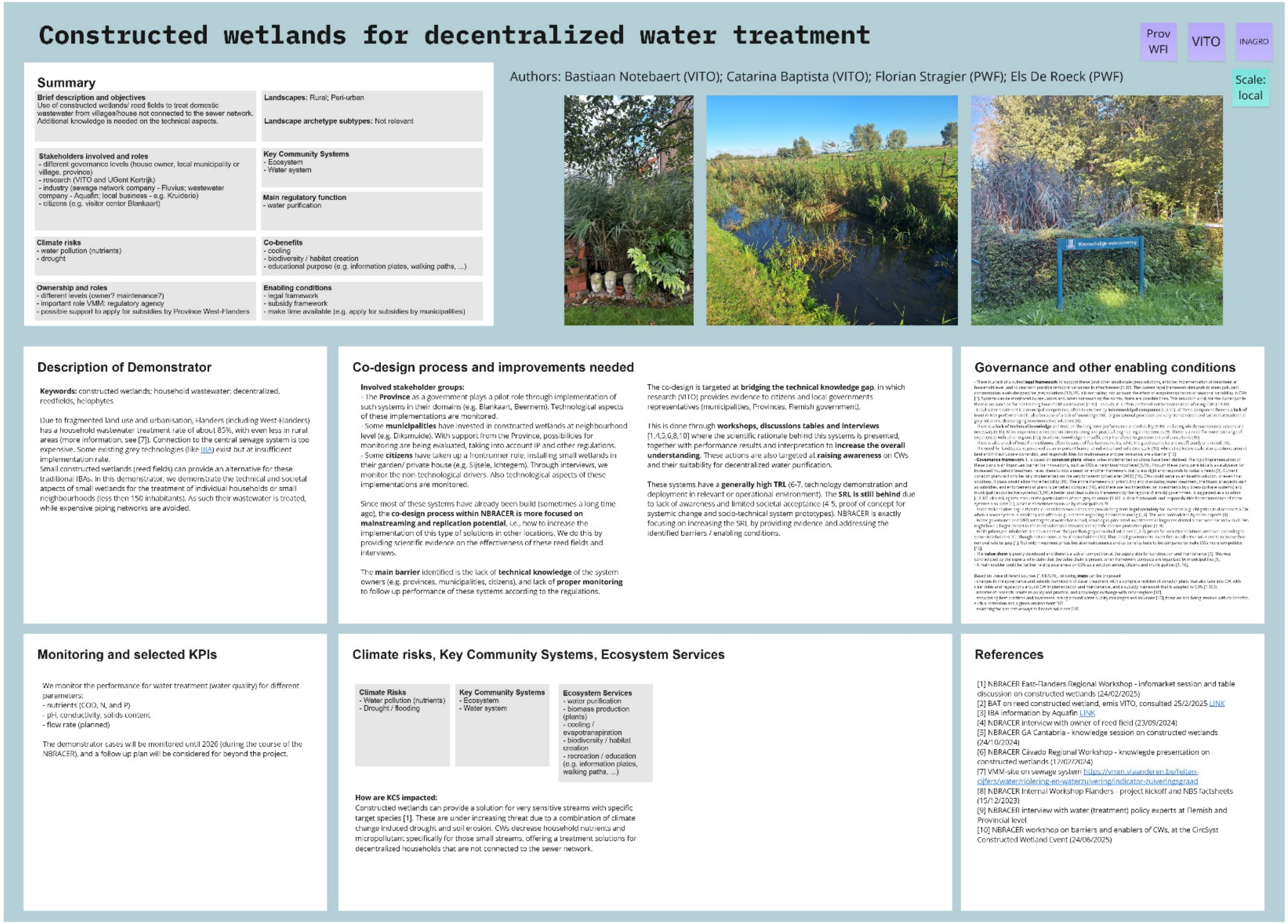

Figure 3: Snapshot of the canvas for the demonstrator: Constructed wetlands for decentralised water treatment.

The Urban Demonstrator 'Constructed Wetlands for decentralised water treatment' has been co-designed in close partnership with the province of West-Vlaanderen, the knowledge partner VITO, and the property owner, whose site is not connected to the sewage system. VITO has taken the lead in filling in the Canvas with the descriptions of the relevant aspects of the Demonstrator, with support from the Province of West-Vlaanderen. During workshops, other partners have been involved in exploring the concept and bringing the NbS towards the demonstration phase.

4.3 Constructed wetland for treatment of industrial concentrate – West-Flanders

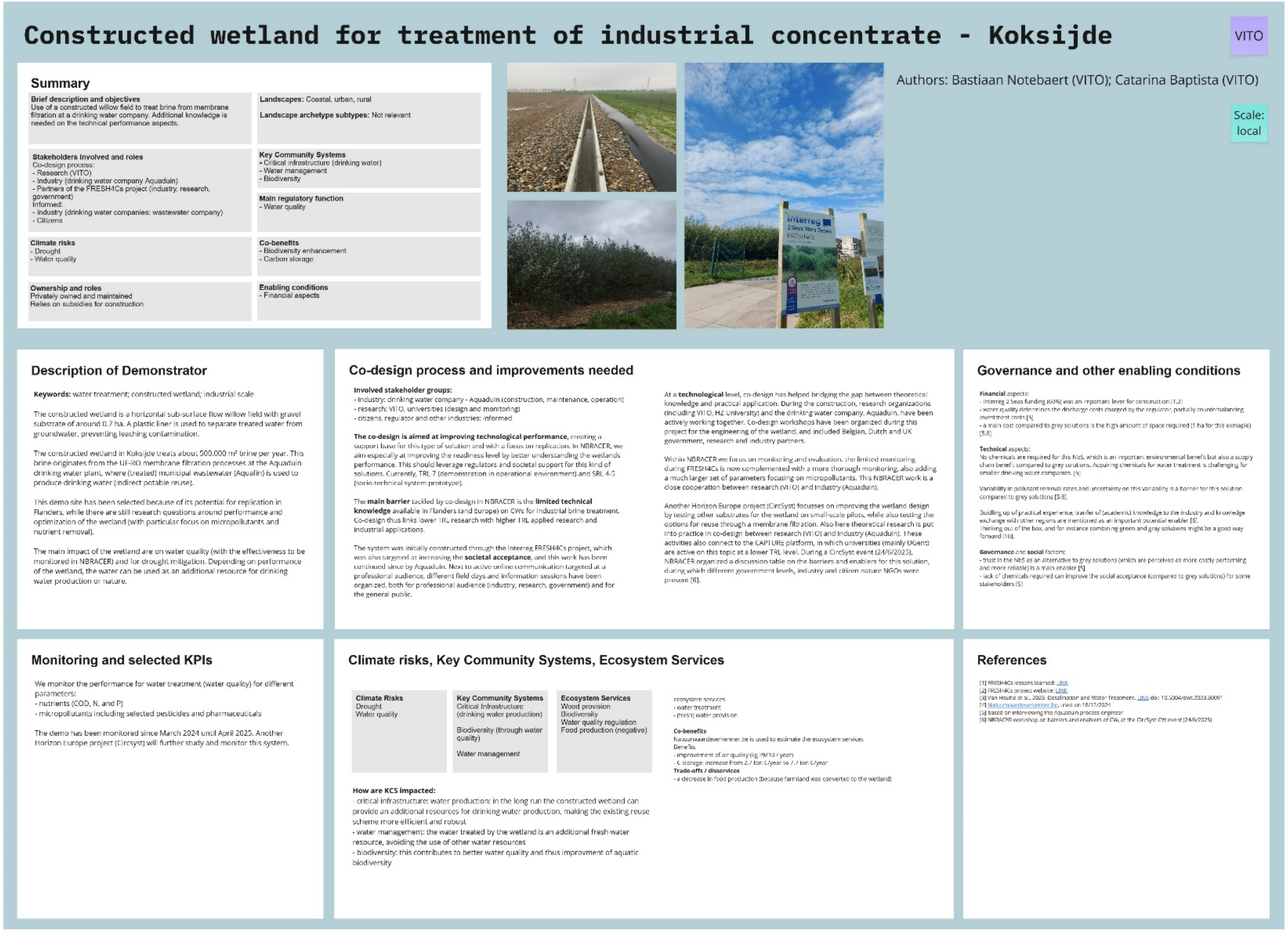

Figure 4: Snapshot of the canvas for the demonstrator: Constructed wetlands for treatment of industrial concentrate in Koksijde.

The Urban Demonstrator 'Constructed Wetlands for treatment of industrial concentrate' has been co-designed in close partnership with the industrial company and knowledge partner VITO, network partners and citizens in the direct environment of the site. VITO has taken the lead in filling in the Canvas with the descriptions of the relevant aspects of the Demonstrator. During workshops, other partners have been involved in exploring the concept and bringing the NbS towards the demonstration phase.

4.4 Quinta de Salgueiros – Porto

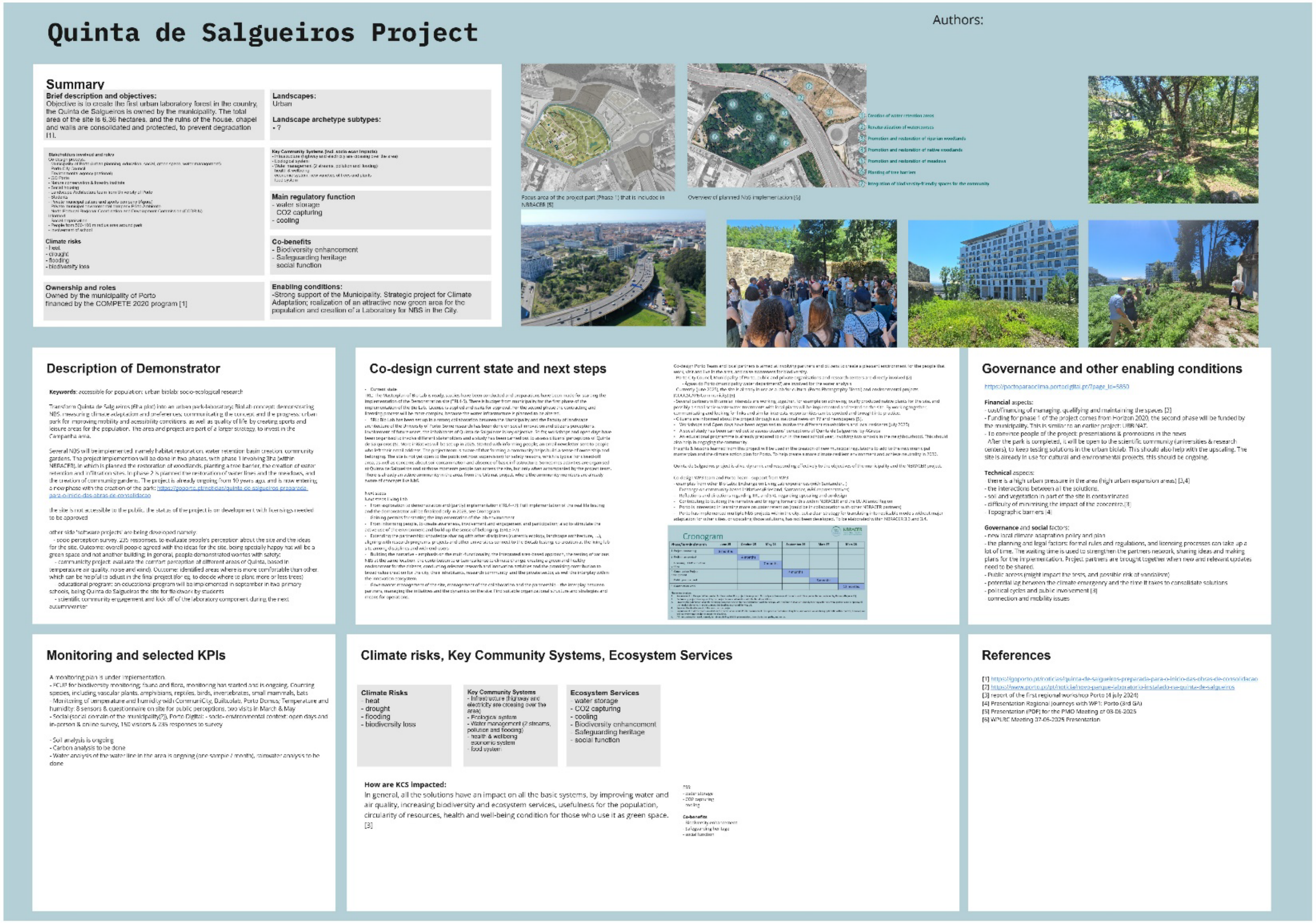

Figure 5: Snapshot of the canvas for the demonstrator of Quinta de Salgueiros, Porto.

The Porto Demonstrator is designed as a BioLab for various NbS in a local park environment. It was initiated by the Landscape Architecture Faculty of the University of Porto in close co-design with representatives of the Municipality of Porto. The descriptions of all relevant aspects of Demonstration in the NBRACER canvas have been co-designed by the Municipality of Porto, with support from the Porto University and with WR.

4.5 Avenida Dr Madrazo Santander – Cantabria

Figure 6: Snapshot of the canvas for the demonstrator, Renaturalisation of Dr. Diego Madrazo Avenue.

The Santander Urban Demonstrator was initiated by the Municipality of Santander, co-designed with landscape architects, and discussed with local and neighbourhood partners. The canvas has been developed in co-design by the project lead of the Municipality of Santander, the regional NBRACER coordinator of the Cantabria region, the regional NBRACER knowledge partner and WR.

5 Mapping of Urban Landscapes

This deliverable also addresses the mapping of Urban landscapes, which will support the co-design process and further development of demos towards portfolio development at the regional level and across landscapes. At this stage, it was decided to focus on giving an overview of already available maps and data sources, as capacity in the regions was limited. Moreover, the operationalisation of the technical and process framework in the regions still has to be further discussed and developed, which will be implemented in the following T3.3 on building an integrated balanced portfolio and adaptation pathways, supported by WP5 and WP6.

The first sections of this chapter address the locations of the demonstrators and landscape characteristics such as land use and soil type. The following paragraphs provide a short recap and additions to the landscape characteristics described in the baseline document of each Urban demonstrator region. This is followed by a description of climate change-related risks such as flooding, drought and heat stress, and how these risks can be connected to the spatial characteristics of the regions or, where possible, to the specific Demonstrator locations.

5.1 Landscape characteristics

5.1.1 Denmark

The landscape of Denmark has been strongly influenced by glacial processes, which are still visible in the elevation differences and soil types found in the landscape: flat landscapes with open plains, low valleys, and sandy, nutrient-poor soils in the southwest, where glaciers retreated and meltwater formed valleys; and ice pushed ridges and nutrient-rich clayey soils towards the north and east (Figure 7 and Figure 8).

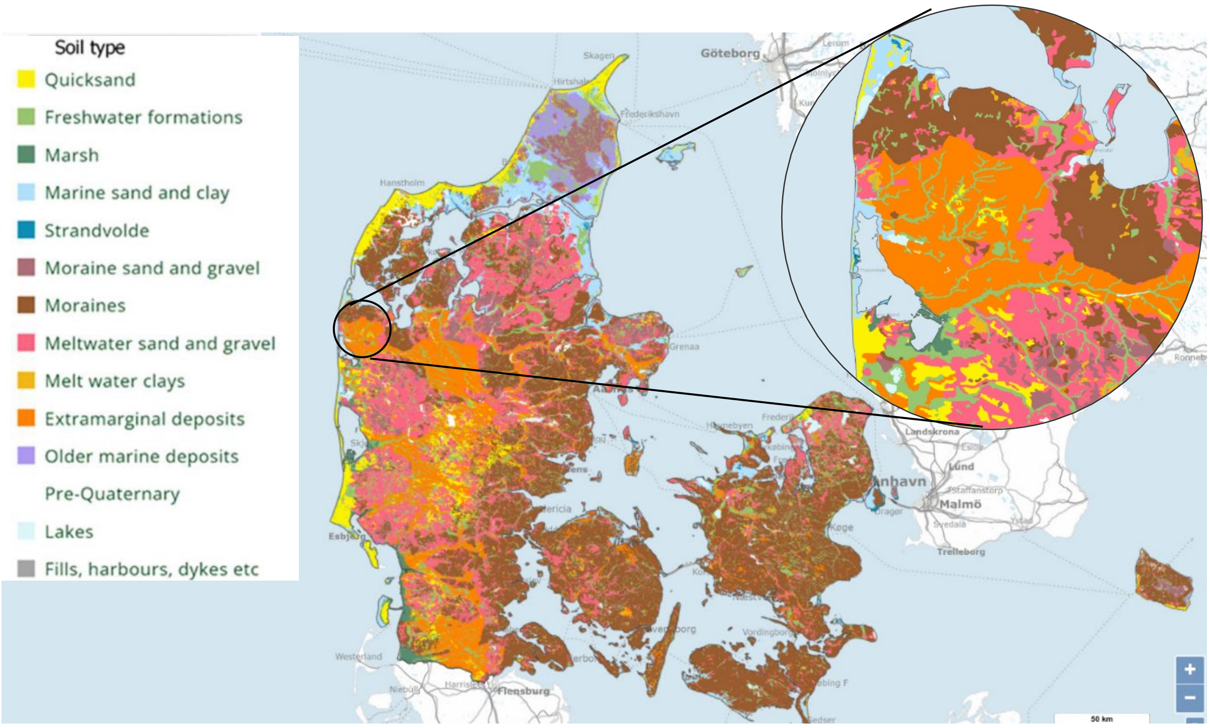

Figure 7: Soil types, with inset of Lemvig municipality and surroundings (source: Kranendonk et al., 2025. NBRACER D1.1 baseline document; Denmark's Geology Portal)

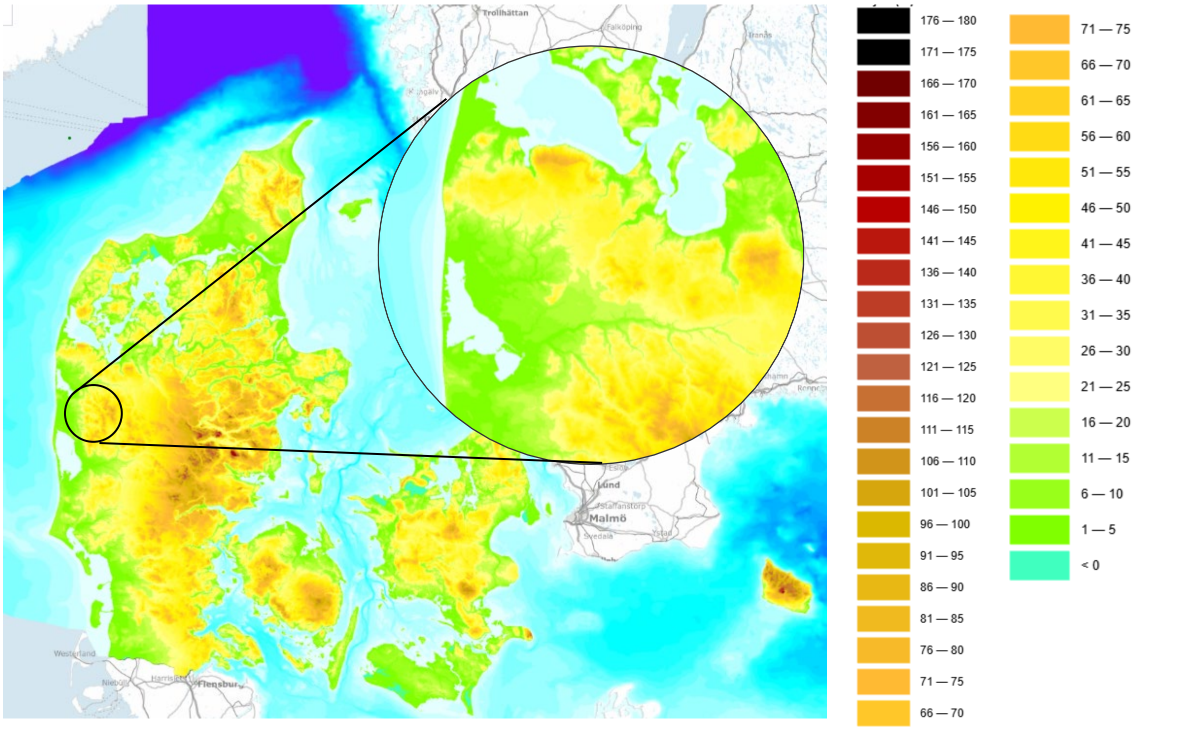

Figure 8: Elevation map with inset of Lemvig municipality and surroundings (source: Denmark's Geology Portal).

Land use in Central Denmark consists of an important part of agricultural activities (Figure 9). Urban areas and infrastructure are scattered over the landscape as consistent networks.

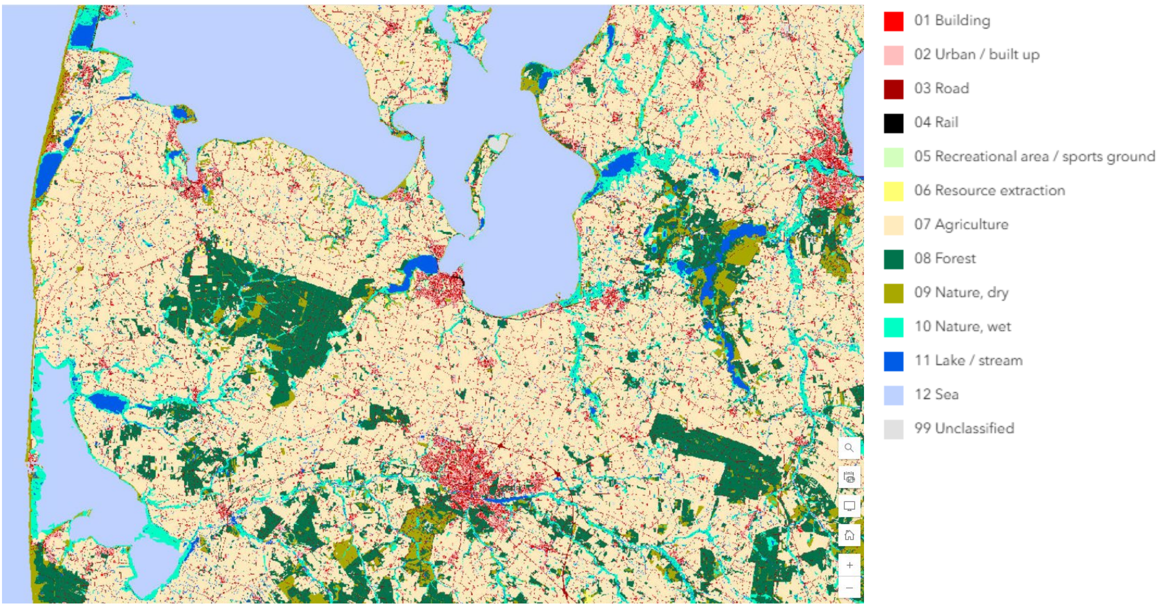

Figure 9: Land use in Lemvig municipality and surroundings (source: GIS Map Viewer).

5.1.2 West Flanders

As there are several focus areas with demonstrators in West Flanders, we focus on one of them: Male-Lieve. Within this area, several constructed wetlands have been realised as Urban Demonstrators.

The following map (Figure 10) shows the actual land use at 10-meter resolution within the Flemish Region for the reference year 2022. 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. The land use in this area is quite diverse in function. Apart from more densely populated areas, built-up areas are scattered throughout the landscape, along ribbons or in small groups of houses.

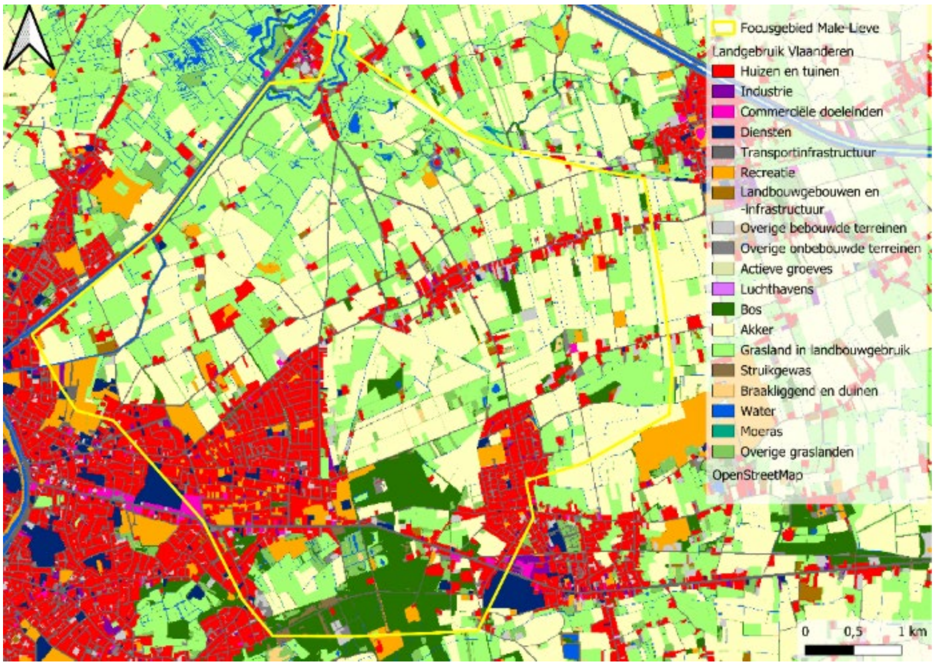

Figure 10: Land use in the focus area Male-Lieve.

Within the Male-Lieve focus area, two ecoregions are present: the ecoregion of the *polders and the tidal Scheldt*, and the ecoregion of the *Pleistocene river valleys* (Figure 11). An ecoregion is an area that is relatively homogeneous in terms of its physical-geographical (soil characteristics, topography) and ecological (nature and environment) conditions. Climate, topography, and soil are particularly influential in determining the types of natural habitats that can occur within a given ecoregion.

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 characterised by a history of artificial land reclamation and clay soils lacking distinct profiles. The ecoregion of the *Pleistocene river valleys* is a low-lying sandy plain where the Tertiary geological substrate was deeply eroded by

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Pleistocene rivers and subsequently filled with a thick layer of sandy aeolian and fluvial deposits. Furthermore, a permanent groundwater table is present almost everywhere.

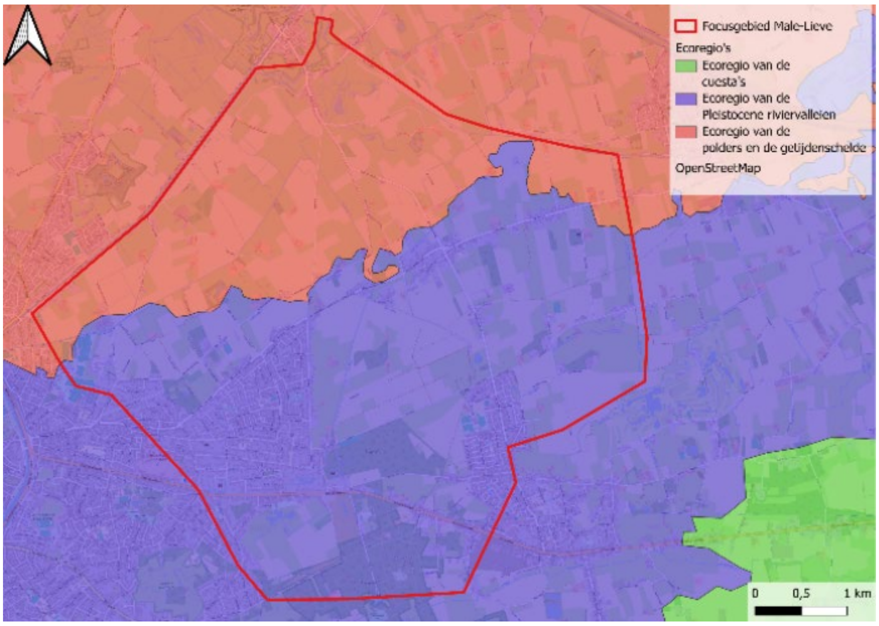

Figure 11: Ecoregions in the focus area Male-Lieve.

Figure 12 shows the watercourses in the focus area of Male-Lieve. 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). The VHA maps all categories of watercourses in Flanders, 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.

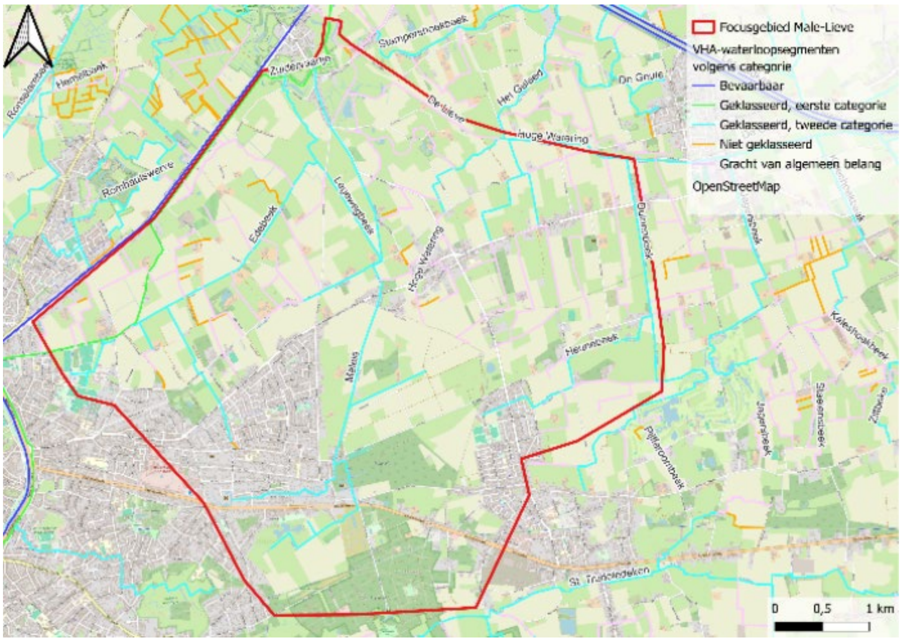

Figure 12: Watercourses in the focus area of Male-Lieve.

5.1.3 Porto

The landscape of Porto mainly consists of urban areas (Figure 13). The altitudes differ significantly throughout the area, with low altitudes near the coast and the Douro river, and high altitudes in the area where the demonstrator is located: the Campañha neighbourhood (Figure 14).

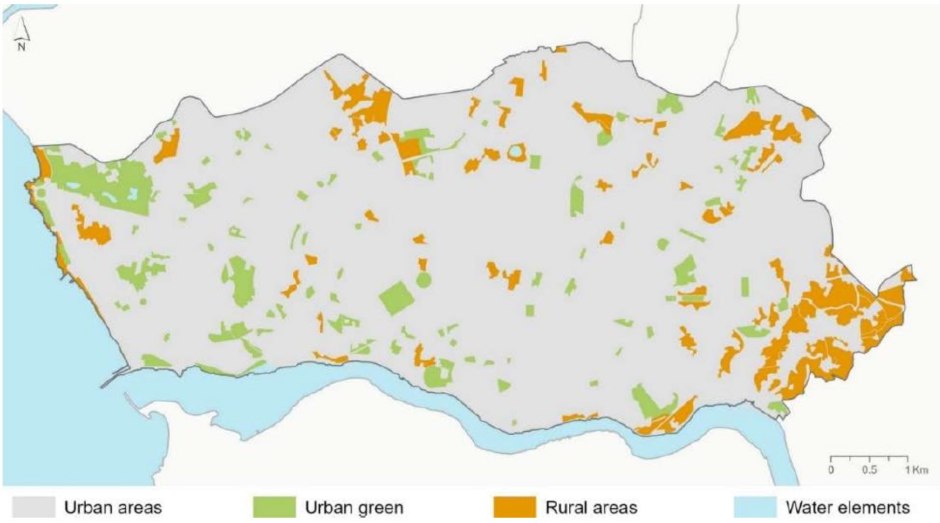

Figure 13: Land use of Porto (source: Kranendonk et al., 2025. NBRACER D1.1 baseline document).

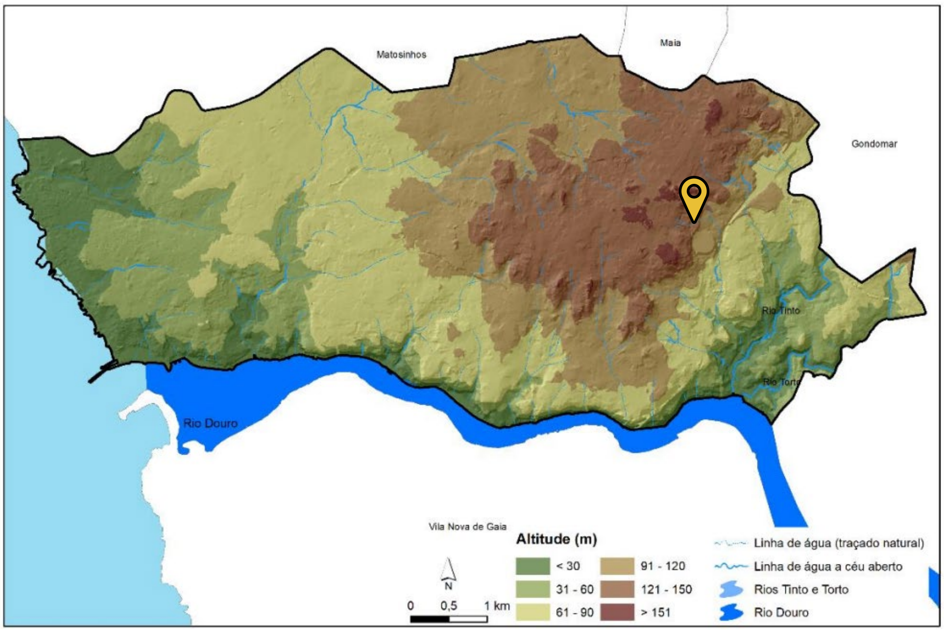

Figure 14: Altitude map of Porto. The location of the urban demonstrator is indicated by the yellow marker (source: Kranendonk et al., 2025, NBRACER D1.1 baseline document).

As Figure 15 shows, the majority of the landscape has a low permeability, which may pose challenges for retaining and infiltrating in the area.

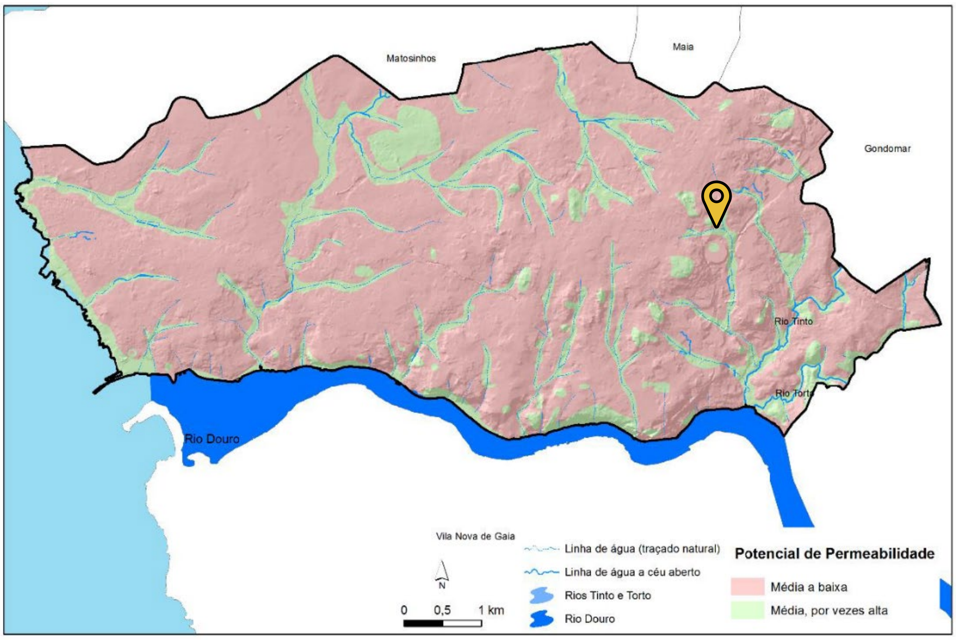

Figure 15: Permeability - around 80% of the municipality has a low permeability (source: 2.ª Revisão do PDM do Porto).

5.1.4 Cantabria

The Cantabria region is situated in the North of Spain (see Figure 16). Due to bordering the Atlantic Ocean, annual precipitation amounts are high, resulting in lush green natural areas throughout the region. The majority of built-up areas are located in the North. This includes the capital city, Santander, where the urban NBRACER Demonstrator is situated (see orange pointer on the map). The city is concentrated in a densely built area along the southern and eastern coastline, with more extensive urban areas bordering natural areas to the north (see also Figure 17).

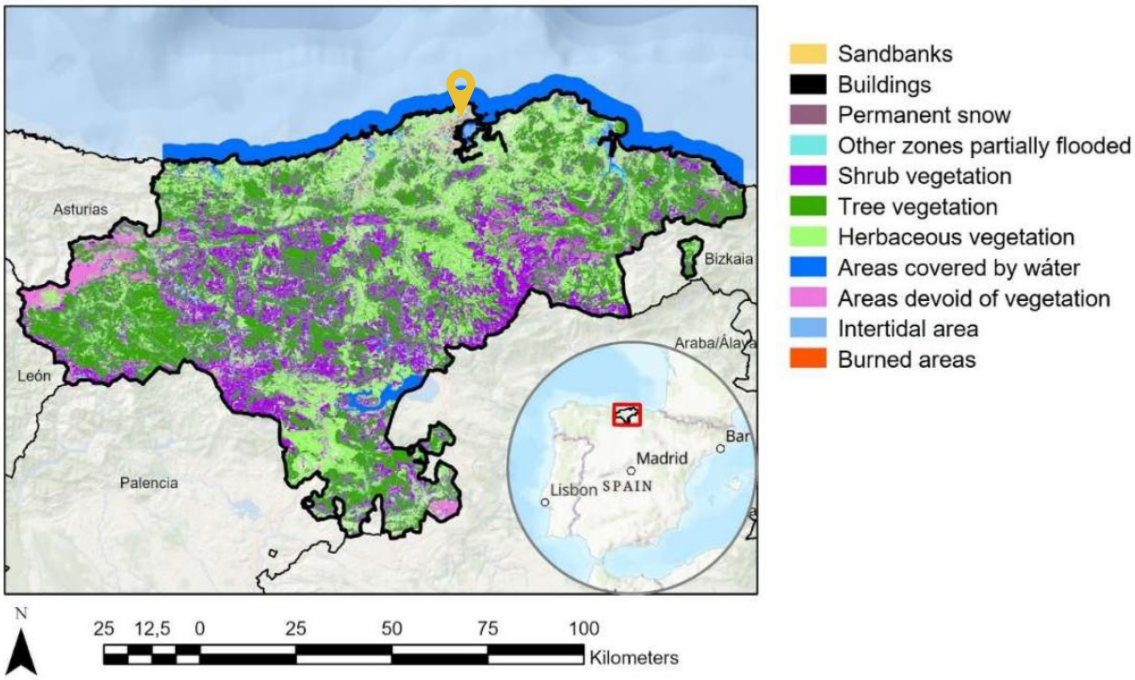

Figure 16: Land use in Cantabria. The city of Santander is located by the orange pointer (source: Kranendonk et al., 2025, NBRACER D1.1 baseline document; Mapas Cantabria).

The Avenida Dr. Diego Madrazo is located in an urban area of Santander, sloping down towards the coast (Figure 17 and Figure 18). The coastal area is a valuable tourist area, as it contains the lighthouse of Santander.

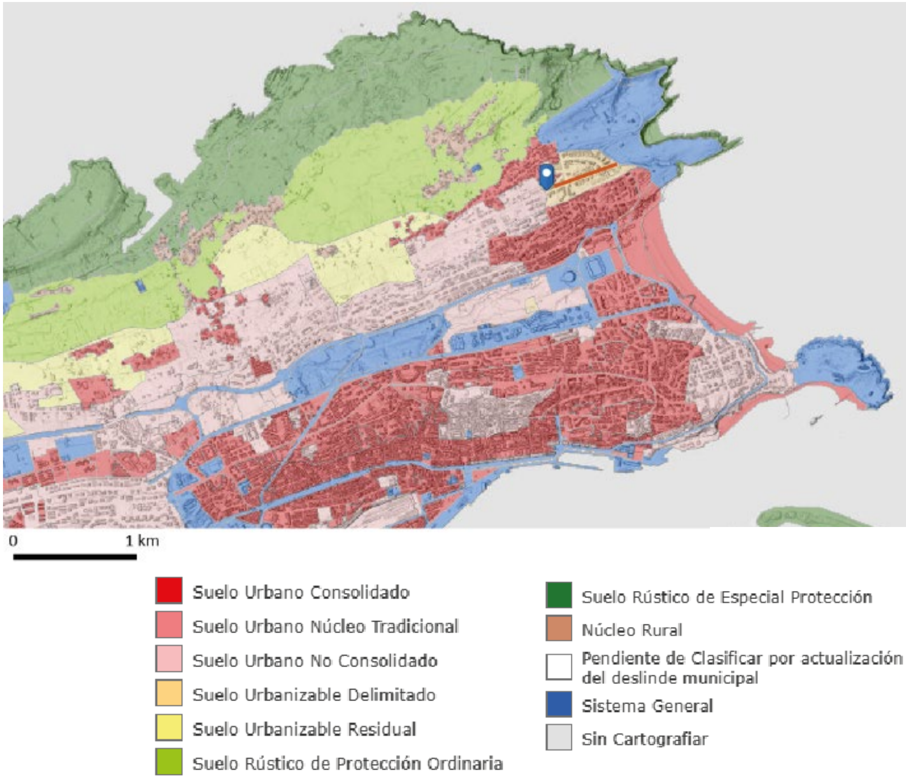

Figure 17: Santander land use (source: [Mapas Cantabria]).

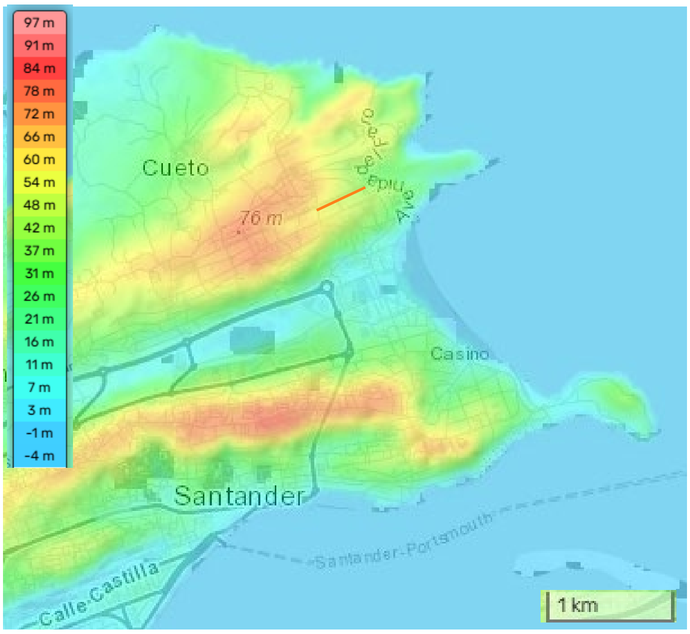

Figure 18: Elevation in Santander, the orange line indicates the location of the demonstrator (source: [Cantabria topographic map, elevation, terrain]).

5.2 Climate risks

The further mapping of Urban Landscapes is focused on the risks regions face, providing a basis for NbS, setting up the Demonstrators, and creating a portfolio of solutions. Regarding the Urban Landscape, the main risks are the *water-related challenges*, such as flooding due to run-off from rivers and extreme rainfall. In coastal cities, the risk of sea-level rise is also present. NbS, sometimes in combination with more technological solutions, should contribute to capturing, storing and managing water run-off. Next to water issues, *heat* stress is a relevant climate risk in urban landscapes, due to rising temperatures and longer periods of extreme heat. We will describe these risks and start collecting maps to show current situations in the NBRACER Urban Landscapes (Table 1).

Table 1: Overview of Climate Risk of NBRACER Urban Demonstrators. 'X' = relevant, ' ' = less relevant

	Pluvial flooding	**Fluvial flooding**	**Drought**	**Water quality**	**Heat**	**Soil erosion**
1 DK – Climate Road	X	X		X		
2 WFL – Constructed wetland	X		X	X		
3 WFL – Constructed wetland industry			X	X		
4 Porto - BioLab	X		X	X	X	X
5 Cantabria - Dr Madrazo	X			X	X	

As all Demonstrators are located in coastal or delta areas, they show some similarities in the challenges they face. However, there are also differences due to, e.g. different locations, climatic circumstances, soil characteristics, elevation differences and altitudes.

5.2.1 Water-related challenges

Water management is a challenge for all Demonstrators; however, not all of them are for the same reasons.

West-Flanders and Central Denmark generally have lower and more gradual altitude differences than the demonstrator regions of Porto and Cantabria, leading to slightly different water-related challenges.

In the lowest areas (Central Denmark and West-Flanders), flooding risk comes from four directions:

- Flooding from the sea (storms, sea level rise)
- Flooding from rivers (rising surface water levels, heavy precipitation)
- Flooding (streets, cellars, etc.) due to heavy precipitation events
- Rising groundwater levels

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Figure 19 illustrates different flooding events and the number of affected buildings for each event, for the West-Flanders region.

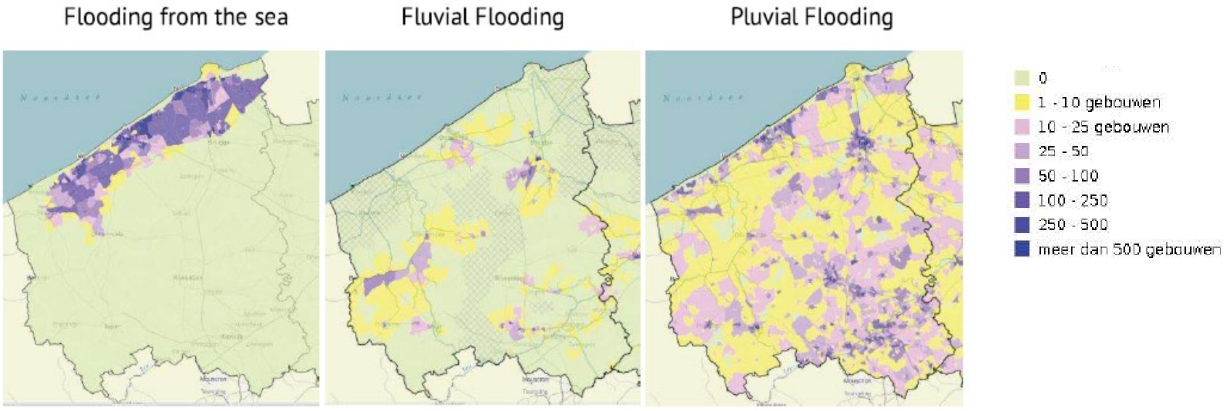

Figure 19: Three types of flooding and how many buildings are affected (not including high groundwater levels), illustrated for the West-Flanders region (source: Kranendonk et al., 2025, D1.1 Baseline report).

Figure 20 and Figure 21 show the risks for the focus area Male-Lieve. Figure 20 shows the water depth in case of fluvial flooding events associated with a T1000 event (overflowing of a waterway), while Figure 21 shows water depth in case of flooding due to heavy precipitation events, for the current climate (left) and 2025 (right).

The maximum water depth resulting from pluvial flooding due to intense precipitation presents slight variations when comparing both climate scenarios. Under the 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), the valley of Heunebeek (Sijsele), the 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.

Vulnerable institutions at risk of pluvial flooding (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).

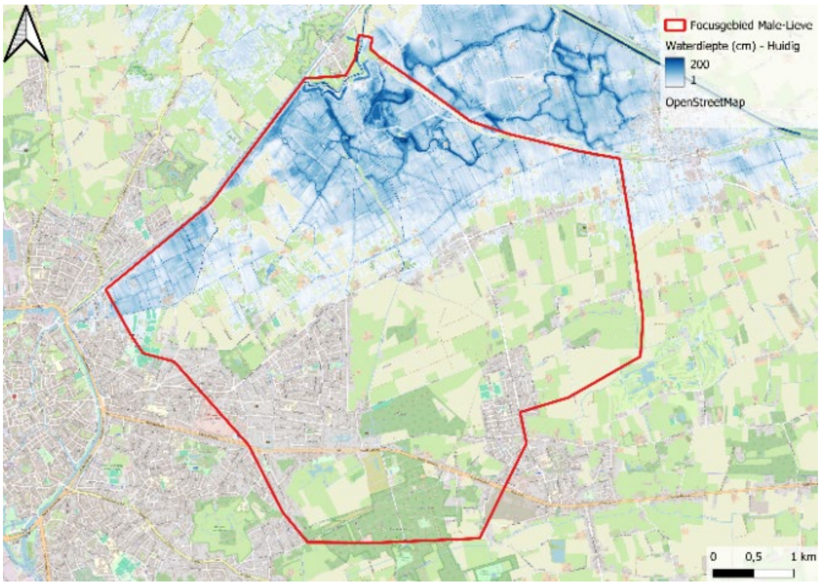

Figure 20: Water depth at fluvial flooding events, for the current climate.

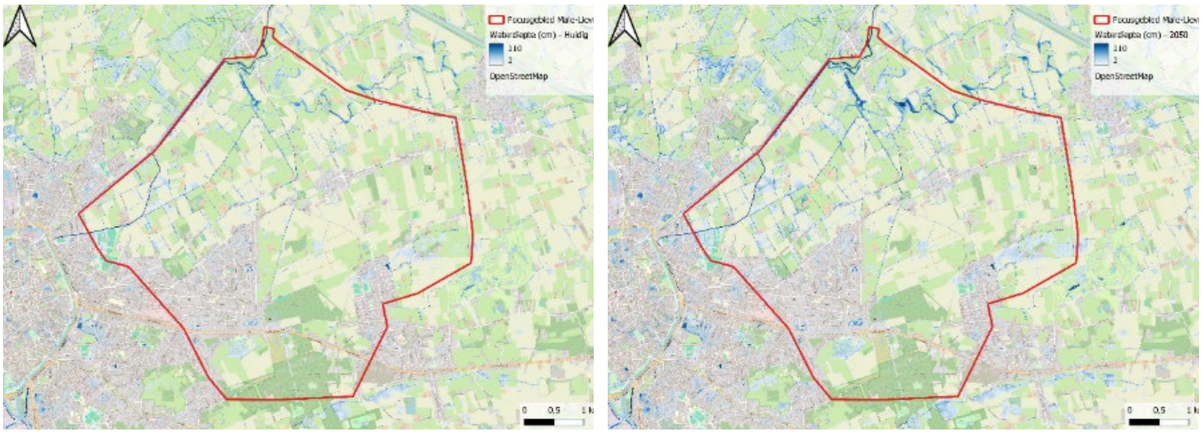

Figure 21: Water depth in the case of pluvial flooding, for the current climate (left) and 2050 (right).

For the Central Denmark region, Figure 22 shows an overview of flood risk locations, from coastal and river flooding.

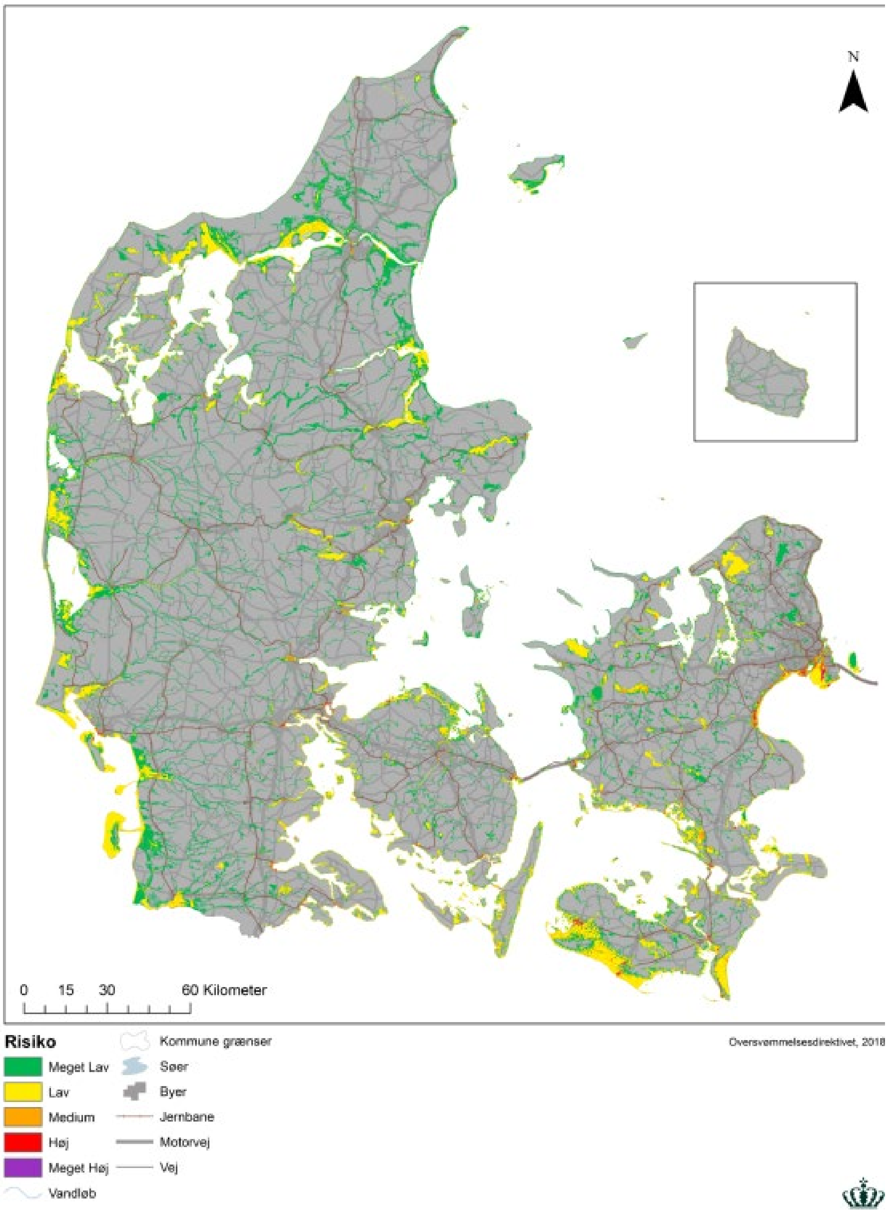

Figure 22: Flood risk areas of Denmark (source: Main report of the Danish Flood Directive 2018).

The maps below (Figure 23) shows a more specified flood risk indication. These maps were published by the National Bank of Denmark and show the fraction of single-family houses exposed to flood risk.

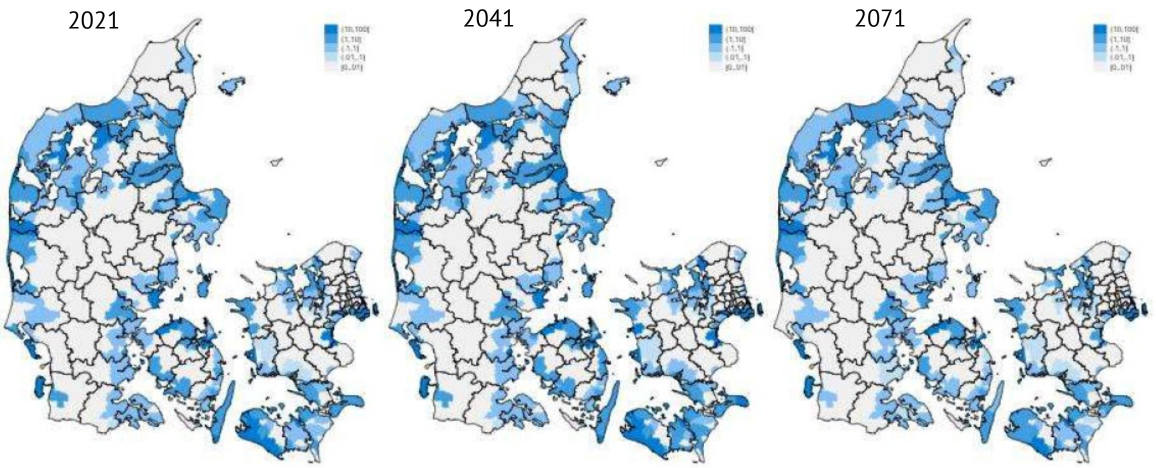

Figure 23: Exposure to 100-year flood events per 100 (single-family) houses in 2021, 2041 and 2071. Darker shades of blue show greater risks (source: [Risiko for oversvømmelse på det danske boligmarked]()).

Also in lower areas, drought issues can occur after long periods of little precipitation. See Figure 24 for an indication of dry periods for the Male-Lieve area, for the current and future climate.

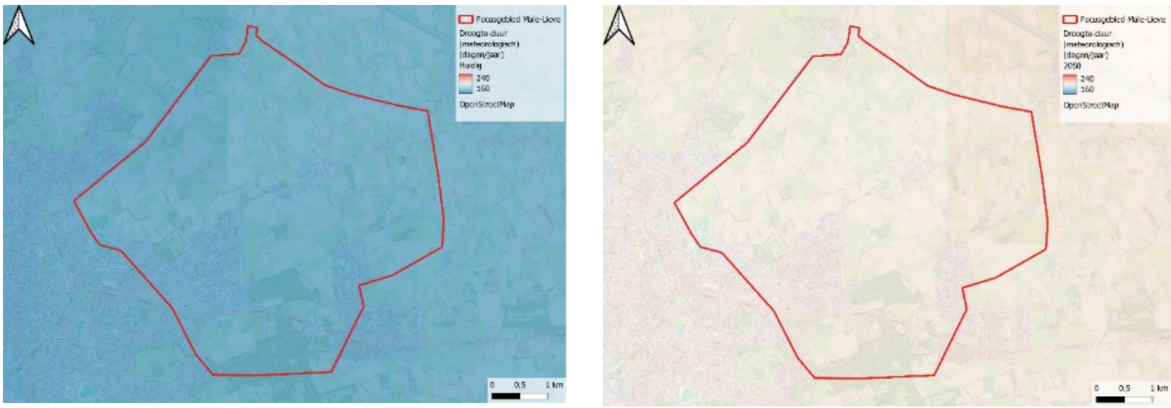

Figure 24: Drought duration (meteorological) in the focus area Male-Lieve, for the current climate (left) and 2050 (right).

Drought stress can impact agricultural crop growth (see Figure 25), as well as natural areas (Figure 26) and urban green.

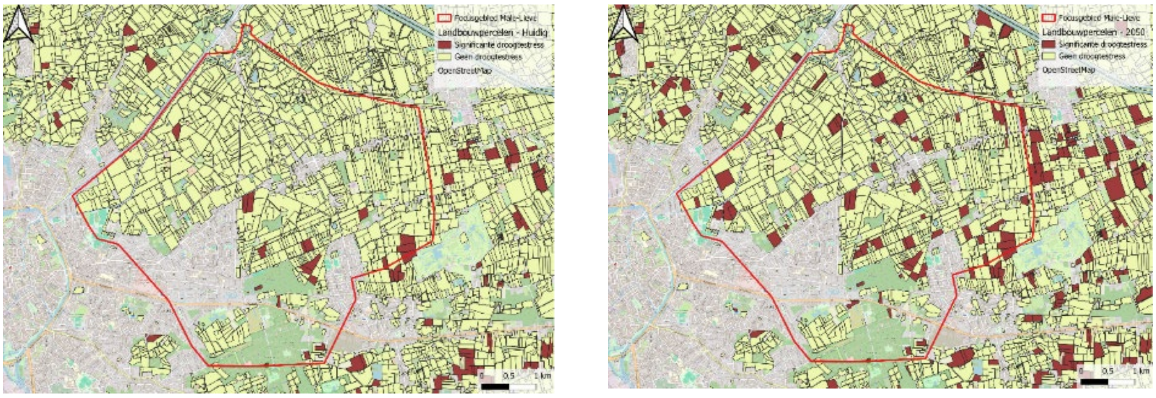

Figure 25 Agricultural parcels with significant drought stress in the focus area Male-Lieve: Current climate (left) & future climate (2050) (right).

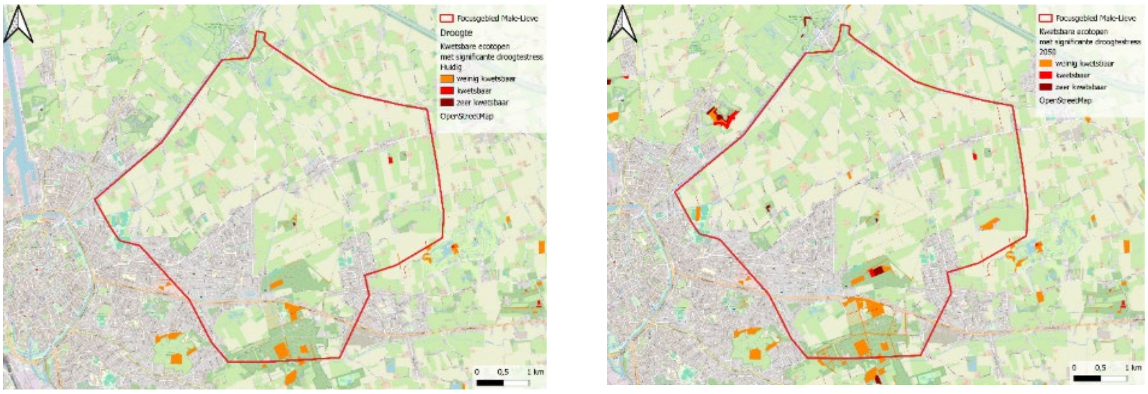

Figure 26 Vulnerable ecotopes with significant drought stress in the focus area Male-Lieve: Current climate (left) & future climate (2050) (right).

The Demonstrators in the region of West-Flanders focus on constructed wetlands aimed at water filtration and filtration of drinking water for households which are not connected to the sewer network. A further advantage of wetlands over technical solutions is (amongst others) also the mitigation of droughts.

The Climate Road Demonstrator in Central Denmark focuses on permeable asphalt paving to prevent road flooding and for infiltration of rainwater. Similar to the Demonstrators in West-Flanders, planting (and soil) will be used as a means of water purification.

In the Urban Demonstrators of Porto and Cantabria (Santander), elevation differences and steep slopes play an important role.

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At the Dr. Diego Madrazo Avenue in Santander, rainwater flows down the avenue towards the lowest point along the Mataleñas park, where it floods the road (Figure 27).

Figure 27: The Dr. Diego Madrazo avenue in Santander is sloped, causing flooding at the downhill end of the road (the figure on the right shows the flooding area, indicated with a road sign).

The flooding risk in Porto is mainly located at the larger, lower lying waterways (Figure 28). Runoff from the higher areas, and water flowing to the lower valleys where the water accumulates, may contribute to such increased flooding risks.

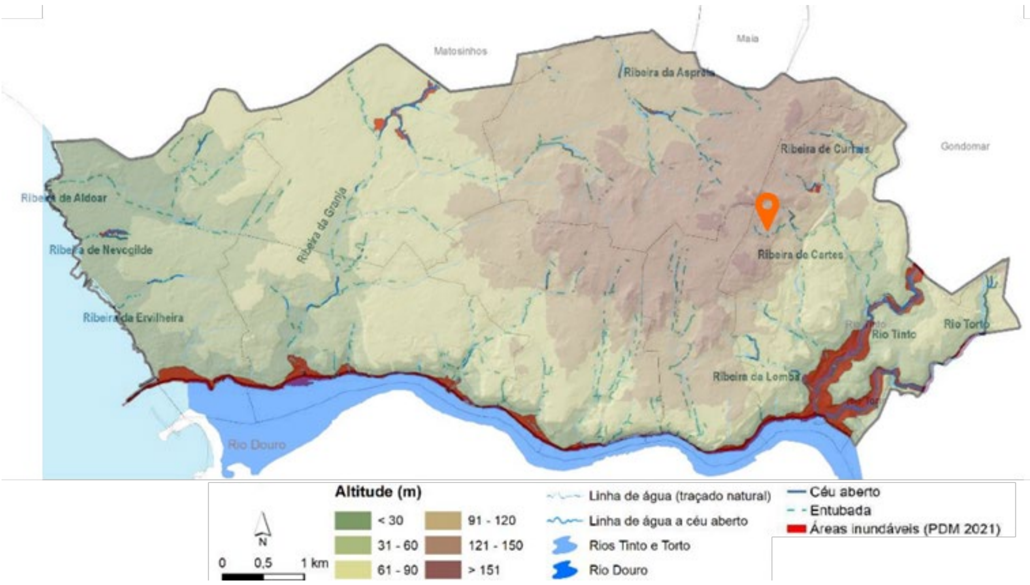

Figure 28: Porto altitude map, combined with indication of flood risk areas (source: Kranendonk et al., 2025, D1.1 Baseline report).

Rainwater running downhill not only causes flooding in lower areas, but also causes erosion on vulnerable slopes. Furthermore, it may increase drought risks in the higher altitude areas if insufficient water can be stored and infiltrated there.

The map below (Figure 29) shows areas prone to drought in Porto.

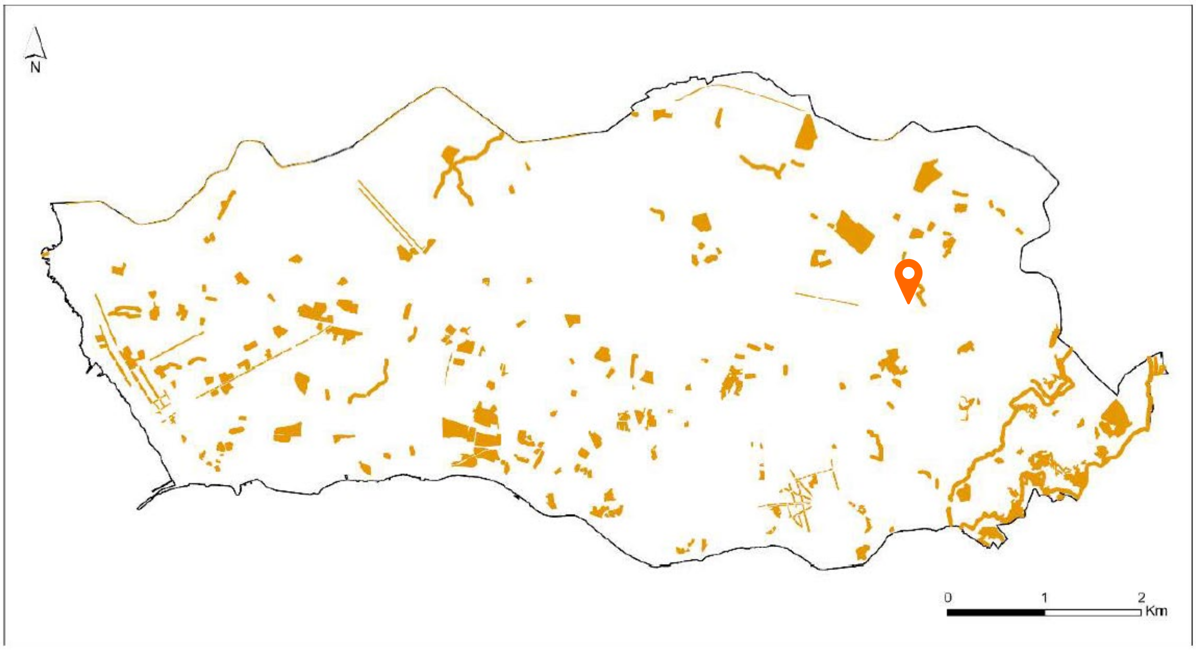

Figure 29: Areas prone to drought issues in Porto (source: Kranendonk et al., 2025, D1.1 Baseline report). The Urban demonstrator location of Quinta de Salgueiros is indicated by the pointer.

Drought can result in vegetation dying, a shortage of freshwater for drinking or irrigation, and an increased risk of forest fires.

To mitigate drought and flooding further downhill, it is important to harvest and store water. This is especially important in the higher areas. This can, for example, be achieved by directing the water to infiltration areas and increasing vegetation, to improve the infiltration capacity of the soil and prevent erosion.

As the city of Santander is located at the coast, this city and its surrounding area are not only at risk from rainwater flooding events, but also from coastal flooding events (Figure 30).

Figure 30: Coastal flooding risk (source: Mapas Cantabria).

5.2.2 Heat stress

Heat stress is particularly relevant for the more southern regions, with generally warmer climatic conditions, and even more in urban environments. This is due to the urban heat island effect, which results in significantly higher temperatures in urban areas.

The urban heat island effect is caused by a combination of factors: buildings, pavement and similar materials take up heat from solar radiation and radiate it back to the environment. As this process continues after sunset, the built environment takes much longer to cool down. Cooling is further hampered by factors such as a lack of open spaces and lower wind circulation. In addition, there is less evaporation in built areas, and anthropogenic heat sources, such as traffic, contribute to further temperature increases.

Important measures to mitigate heat stress include shading (to prevent solar radiation from passing through) and increasing vegetation (with sufficient root space and water) to increase plant evapotranspiration, which helps cool the air. The urban Demonstrators of Cantabria and Porto have included both shading and vegetation to address heat stress in their plans. Figure 31 and Figure 33 show heat stress in Male Lieve and Porto, respectively.

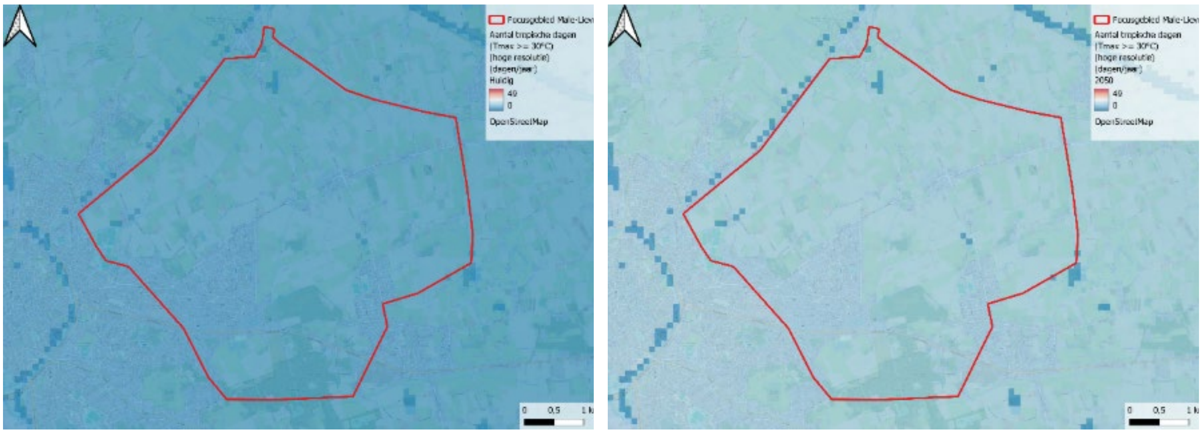

Figure 31 Number of tropical days (Tmax >= 30°C) in the focus area Male-Lieve (high resolution: 100 m): Current climate (left) with a mean of 4 tropical days per year & future climate (2050) (right), with a mean of 12 tropical days per year.

Heat stress is particularly impactful for vulnerable individuals, such as the very young, the elderly, and people with (chronic) illness. The following maps (see Figure 32) depict the number of vulnerable residents exposed to heat stress in the focus area of Male-Lieve. For these maps, vulnerable individuals are defined as those aged 0 to 4 and those aged 65 and older. More specifically, this concerns vulnerable individuals for whom the daily maximum and minimum apparent temperatures during an extreme heat day (with a 20-year return period, T20) are exceeded to such an extent that serious adverse health effects are anticipated.

- Current climate: 0 vulnerable residents exposed
- Future climate (2050): 780 vulnerable residents exposed

Exposed residents are mainly located within the urbanised zone east of Bruges.

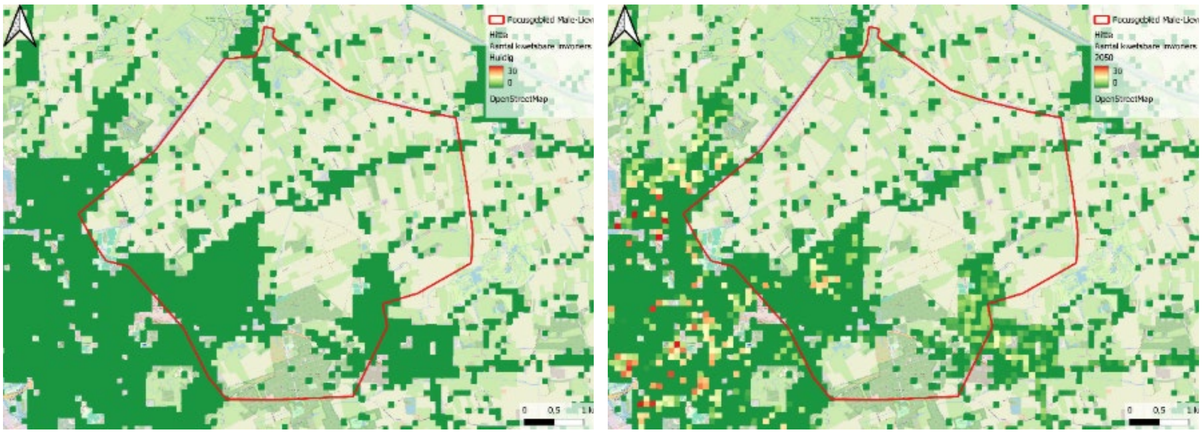

Figure 32 Number of vulnerable residents exposed to heat stress in the focus area Male-Lieve: Current climate (left) & future climate (2050) (right).

The map of Porto clearly shows that more densely built areas are at higher risk, illustrating the urban heat island effect. The maps of Male-Lieve show the expected increase in tropical days (with temperatures above 30°C) between the current situation and 2050.

Figure 33 Critical areas in Porto for extreme heat in summer, from not critical at all (lighter colours) to extremely critical (darker colours) (source: Kranendonk et al., 2025, D1.1 Baseline report).

6 Discussion

6.1 Key principles for the co-design process

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, which 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, and 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, Inclusive, Adaptive and Pluralist.

<u>*Integrative*</u>

Co-design leads to 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.

Most of the Demonstrators are balancing the interests of sectors and governance levels. The current NBRACER Demonstrators of NbS fit well with existing frameworks for Climate Adaptation, Urban policies, and have an innovative approach. Decision making and formal procedures for planning NbS in the Demonstrators in Porto and Santander are a governmental responsibility, with limited room for co-design. However, in both cases, various frameworks and sectors have been taken into account. In Flanders, representatives of stakeholders play a role in the decision making and agreement of the NbS. In Central Denmark, the initiative for developing the Climate Road came from Aalborg University, which conducted the ideation and exploration phase. Alignment with regional frameworks is taking place after this phase. Klimatorium is actively promoting and supporting the Demonstrator, while local governments show interest in the testing and experimentation.

<u>*Inclusive*</u>

Co-design invites diverse voices, especially those often left out, like marginalised communities. It creates space for open dialogue, helping to address power imbalances and differing values.

The Urban Demonstrators face challenges to involve communities in their early phases of development. In the Porto Demonstrator, there are clear objectives and initiatives to reach out to civil society. After the design and master-planning phase, many initiatives are undertaken to inform stakeholders and incorporate their perspectives. In Cantabria, a participation process has been designed at the regional level. At the level of the Santander municipality, the program "Santander Natural" has focused on informing citizens. However, during the development of the design of the Dr Madrazo plan, only experts participated. Similarly, in the Demonstrators of West Flanders and Central Denmark, experts have mainly participated so far.

Adaptive (iterative)

Co-design is an ongoing process that learns and improves over time. It supports climate resilience by including feedback, adjusting plans, and working with a wide network of stakeholders.

The Demonstrator of Porto is set up as a BioLab, showcasing various Urban NbS. Different partners can learn from the demonstrations at the site and contribute to validating the solutions. Additionally, new solutions can be tested in the future. The Demonstrator in Central Denmark will also be set up as an experimental site, where three Climate Road solutions will be tested at the same time.

Pluralist

Co-design values different kinds of knowledge: scientific, local, and traditional. It brings together various perspectives on nature and climate, encouraging new ways of thinking and working together.

The Masterplan in Porto and the Dr Madrazo Avenida in Santander are mainly designed by architects who are capable of combining various knowledge domains and disciplines. The Porto Masterplan has been developed by academics from the Faculty of Landscape Architecture of the University of Porto. In the various experiments which will take place, researchers from other disciplines will become involved. Social scientists are to analyse the perspectives of inhabitants. The Climate Road Demonstrator experiment in Central Denmark was mainly developed by the experts from the University of Aalborg, who collected knowledge and designed the experiment. When testing the plans and designs, other partners will be involved. The constructed wetland initiatives in West Flanders have integrated stakeholders and representatives from various sectors, bringing in local knowledge and interests. Overall, they ultimately commonly agree on the NbS.

6.2 Key steps in the co-design process

NBRACER has defined the following five 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 for debate on 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 informed by 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 directly perceive the benefits brought by their implementation.
5. **Decision-making and agreement** – The gathered knowledge allows for comparing and validating different solutions, upon which an agreement or consensus can be reached among stakeholders, pending their different opinions and perspectives.

Table 2: Overview of Key steps in the co-design process of NBRACER Urban Demonstrators. 'X' = undertaken, '(X)' = semi undertaken, ' ' = not undertaken.

	Issue framing	**Knowledge gathering**	**Options co-design**	**Stakeholder validation**	**Decision making and agreement**
1 DK – Climate Road	(X)	X	X	(X)	
2 WFL – Constructed Wetlands	X	(X)	X	X	(X)
3 WFL – Constructed Wetlands Industry	X	(X)	(X)	X	(X)
4 Porto – BioLab	(X)	(X)	X	(X)	
5 Cantabria – Dr Madrazo Avenue	(X)	(X)	(X)	(X)	X

The initiative of and the process steps taken in the NbS development of the urban Demonstrators in the NBRACER regions have been very different (see Table 2). No single initiative has followed the "ideal" phase model, as used for the co-design process.

In Central Denmark, the initiative came from the knowledge domain and started with exploring the potential and the design through 'knowledge gathering'. In a later stage, the phase 'issue framing' was started.

Urban Demonstrators of West Flanders have focused on 'issue framing' with partners and on 'stakeholder validation' of the solution. Both demonstrators almost reached the 'decision making and agreement' phase.

The Demonstrator of Porto started from an initiative of landscape designers from the University of Porto, with an exploration of 'design options'. Afterwards, the designed solutions are being shared ('issue framing' and 'stakeholder validation') with stakeholders and knowledge disciplines.

The Urban Demonstrator of Santander started with the initiative to find an integrated solution for dealing with the effects of climate change at the level of a local avenue. The project is designed by a landscape architect and will be implemented. Design of the issue, the 'knowledge gathering', exploring the 'co-design options' and 'stakeholder validation' have implicitly taken place. Sharing the design and informing citizens and stakeholders is taking place alongside the implementation.

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 3 synthetises the most relevant KCSs that are impacted by climate risks in each one of the NBRACER Urban Demonstrators.

Table 3: Overview of relevant KCS of NBRACER Urban Demonstrators. 'X' = undertaken, '(X)' = semi undertaken, ' ' = not undertaken.

	Critical infrastructure	Water management	Land use & food system	Health & wellbeing	Biodiversity	Local economic system
1 DK – Climate Road	X	X				
2 WFL – Constructed Wetlands		X		(X)	X	
3 WFL – Constructed Wetlands Industry	X	X			X	
4 Porto – BioLab	(X)	X	X	X	X	(X)
5 Cantabria – Dr Madrazo Avenue	X	X		(X)	X	

The Climate Road in Denmark will contribute to the protection of infrastructure against flooding. The Demonstrator will also contribute to improving water management, to deal with run-off water and harvest it when facing heavy rainfall and flooding. With the design of the Climate Road, other functions can be added, contributing to an increase in biodiversity.

The constructed wetlands Demonstrators in West Flanders contribute to improving the water management by capturing and storing the water naturally, both enhancing biodiversity. The industrial Demonstrator will also contribute to projecting the critical infrastructure at the industrial site.

The BioLab project in Porto will test various NbS, relevant to protecting the KCSs in the city, such as water management against flooding, contributing to local food production within the park and stimulating healthier lifestyles by offering natural recreation zones. Furthermore, the park development will enhance biodiversity with the growing of trees that are to be planted in other parts of the city.

The NbS on the Dr. Madrazo Avenida in Santander, Cantabria, will contribute to better water management in the city, as well as protecting the infrastructure from flooding and enhancing biodiversity.

6.4 Types of stakeholders involved

Success in co-design is achieved by aligning with the key principles and **engaging stakeholders from the various domains in the Demonstrator**. Table 4 provides an overview of the domains involved in the current state of development of the Urban Demonstrators, and their recommended degree of involvement throughout the co-design process.

Table 4: Overview of the types of stakeholders of NBRACER Urban Demonstrators. 'X' = strong involvement, '(X)' = medium involvement, ' ' = no involvement.

	Public sector	Private sector	Knowledge partners	Citizens and NGOs
1 DK – Climate Road	(X)	(X)	X	
2 WFL – Constructed Wetlands	X		X	X
3 WFL – Constructed Wetlands Industry	X	X	X	
4 Porto – BioLab	X		X	(X)
5 Cantabria – Dr Madrazo Avenue	X	X	X	(X)

The Climate Road Demonstrator in Denmark originated from the research domain. In the current phase, the connection with the private sector is made, and public sector partners are approached in order to create a test location. The University of Aalborg is teaming up with Klimatorium.

The constructed wetland projects in Flanders are developed in close cooperation between the government and the knowledge partner. In the constructed wetland Demonstrator in the peri-urban area, sewage companies are involved in developing the NbS. Inhabitants are also involved, as well as NGOs. For the Demonstrator at the industrial site the private sector is involved, such as drinking water and waste companies.

The BioLab project in Porto is designed by landscape architects of the University of Porto, in close collaboration with the municipality of Porto. The main objective is to test the NbS. Therefore, there is active involvement of various researchers and representatives of the different sectors within the municipality. Another objective is to enhance the social functions of the park for the neighbourhood: the Demonstrator is focused on engaging citizens in its implementation. The initiators of the Demonstrator have conducted studies on the social aspect. Several initiatives have already been taken to reach out to citizens as well as local schools within a 100-500m radius around the park – these groups will be involved in the Demonstrator. For the research activities, a network of local knowledge institutions and several disciplines has been involved. Further private municipal companies, from the sector of Culture & Sports (Ágora), Environmental (ambiente), the Environmental agency (national), and the Nature Conservation & Forestry Institute are part of the network of the Demonstrator. The private sector has limited involvement in the BioLab, although they may be interested in upscaling and commercialising the NbS. Public authorities and academia are involved in co-design. At this stage, the general public or civil society is only being informed.

The Dr. Madrazo Climate Road in Santander is a public work of the local government. The design is made by a landscape architect, and the works are implemented by a construction company. The local university is a partner in the broader context of the “Santander Natural” program. Citizens have been informed about the project.

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 the **Technology Readiness Level (TRL)**, to estimate the technical maturity of the 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 5 summarises the current readiness level of the NBRACER Urban Demonstrators.

Table 5: Overview of the TRL phase of NBRACER Urban Demonstrators.

	Current Readiness level
1 DK – Climate Road	TRL 3 – There is consensus among academia. Testing and demonstration site to be prepared SRL 3 - Involvement of main partners has started; private sector; Klimatorium; search for location in one of the municipalities
2 WFL – Constructed Wetlands	TRL 5 - Technical knowledge; demonstration implemented SRL 4 - Stakeholder involvement
3 WFL – Constructed Wetlands Industry	TRL 5 - Technical knowledge; demonstration implemented; some citizens are informed SRL 4 - Stakeholder involvement
4 Porto – BioLab	TRL 4 - Technical knowledge; design of the Biolab and the park is ready. Implementation of the first phase of the demonstrator is waiting for permission. SRL 4 - Participation trajectory with citizens has started
5 Cantabria – Dr Madrazo Avenue	TRL 5 - Technical knowledge; design of the project plan has been finalised. Implementation of the demonstration has started, to be finalised in December 2025 SRL 3 - Participation process has started

7 Conclusions and recommendations

Conclusions on Co-design of the demonstrators in Urban Landscapes

The co-design on Demonstrators between the WP3 team and the coordinators of the regional Urban Demonstrators worked well. The MIRO board was a suitable co-design environment to work on the Canvas and to discuss all relevant aspects of the Demonstrators. The Canvas has been developed by WP2, WP3 and WP4 partners. The Canvas has been filled by the WP3 lead, based on information provided by the regional coordinators and the project leads of the Demonstrator. The regional partners have made corrections and have contributed additional descriptions. With the regional coordinators and the Demonstrator project leads, multiple conversations have been organised, not only focusing on the Canvas, but also commonly exploring next steps, exchange among experts (urban adaptation, green city development) and expression of support needs.

Regarding the co-design of the Demonstrators with partners within the regions, the regions differ from one another. West Flanders and Cantabria the local government took the lead in the phases of ideation and exploration of solutions, and have involved partners and citizens (co-design). In Central Denmark and Porto, the academia took the lead in developing the solutions and are actively searching for understanding, acceptance and support by partners. In Central Denmark, the solutions are shared with some regional partners from the public and private sectors, as well as with private owners of roads. In Porto, the solutions are shared with the general public with a focus on neighbourhood associations, schools and citizens.

Comparing the Demonstrators we found three topics of common interest, which will be put on the agenda of WP3. Within the Urban Landscape we will organize exchange between the Demonstrators, we will create a knowledge base with articles and examples of Climate Road initiatives in other parts of Europe, and external experts are invited to the consortium, as a mechanism to support the Demonstrators, to apply to other locations in the urban areas and to inspire other cities in the Atlantic biogeographical region.

The cross cutting topics are:

- Climate Road
- Community Based Initiatives
- Urban Living Lab

Common interest Climate Road

As the urban area is a man-made environment where nature and natural processes have been cultivated, technically managed or removed, it will be difficult to re-naturalise the urban areas completely. Complicating factors are the limited space in urban areas for implementation of NbS and, at the same time, taking into account landscape characteristics which are relevant with regard to the functioning of NbS. Cities cope with water-related challenges and with heat stress. Partners are challenged to search for integral and multifunctional solutions, to address various effects and aspects at the same time. Next to heat and solutions to water challenges (storing and harvesting water), there is a growing attention for biodiversity, health and energy, among others.

As a solution for flooding in peri-urban and industrial environments in West Flanders, constructed wetlands have been created in order to store and purify polluted water. Several Demonstrators include filtering polluted water through the use of plants/wetlands, which is aimed at reducing industrial use or runoff from streets in urban areas. In the NBRACER regional demonstrators, there is a common interest in the effects of Climate Change on the road infrastructure in urban areas. Municipalities and researchers are searching for (nature-based) solutions to deal with run-off, capturing and harvesting the water, and adding functionalities to the solutions. Within WP3 Urban Landscapes, we see Climate Road as a cross-cutting topic.

Common interest Community Based Initiatives

Urban NbS are relevant to citizens, and NbS implementation relies on the willingness of citizens to adopt the solutions their selves. The Demonstrators contribute to enhancing the safety and health of the inhabitants. In the early phases of the exploration of the Demonstrators, in most cases, citizens are not involved. However, understanding, acceptance and active support (participation and behavioural change) of citizens is challenged by Porto and Cantabria Demonstrators. Central Denmark will aim at proposing local road owners (public and private) to adapt current roads to climate roads. Within WP3, the topic of civil society engagement and community-based initiatives will be seen as a cross-cutting topic (together with the Climate Road). Exchange between the Demonstrators, creation of a knowledge base and involvement of experts on this issue will be organised within WP3, to inspire the NBRACER regions and to bring the Demonstrators to the next phase of development.

Common interest Urban Living Labs

In the implementation of the Demonstration, in Porto and Cantabria, the regulations and procedures regarding the planning and implementation of NbS take a lot of time due to formal steps. Other organisations and citizens can only formally react in consultation procedures. The NbS constructed wetlands at the premises of industrial or private partners in West Flanders are not delayed by procedures; however, it takes time to convince stakeholders and inhabitants to accept and trust the effectiveness of the NbS.

Demonstrations in Cantabria and Porto are part of a larger experiment. The city (Santander) and the park environment (Porto) are seen as a (smart) city living lab environment, in which various NbS are explored, tested and demonstrated, to cope with the main urban effects of climate change and objectives of adaptation: heat and flooding. Within the Living Labs, experimentation and demonstration will take place with various partners from the quadruple helix. Creating an urban living lab environment is a cross-cutting topic in the WP3 Urban Landscape, which will be further elaborated and supported by WP3 exchange and scoping activities. The Living Lab approach will be explored as a mechanism to optimise the solutions, to optimise outreach to various partners and to apply it in other parts of the city, contributing to upscaling and mainstreaming the solutions.

Recommendations

Based on the insights gained from the co-design phase of the Urban Demonstrators, we have formulated the following recommendations for the next steps of co-design within the Urban Landscapes:

1. **Ongoing design meetings between WP managers and project leads** of the Demonstrators: the co-design between experts of WP3 partners, with their expertise, and experiences on Urban NbS, with the regional project leads and the networks of the Demonstrators worked well at the level of the Demonstrator. In the next phase, we will deepen the collaboration on implementation, mainstreaming and development of a regional portfolio.
2. **Extend the partnership of the co-design sessions**. Co-design sessions have taken place in a small partnership between initiators (municipality, research, etc.). In addition, the co-design between the region and the WP3 leads took place in a small partnership. In order to bring the Demonstrator further into implementation and to develop a portfolio of solutions, broader partnerships and co-design activities are recommended.
3. **Bring the demonstrator into the next phase of development**. Most of the demonstrators are still in early phases of development. Demonstrators have just been set up and designed. Often, partners and knowledge are still missing, and decision making has not taken place. Much effort should be put into completing the conditions for really demonstrating the solution in the regional practice, create the right conditions for implementation.
4. **Built portfolio of projects**. Next to the current initiative, put effort in creating multiple initiatives, identifying comparable initiatives and connecting NbS, search for synergies and common narratives:
    a. Connect with other Urban NbS initiatives
    b. Connect with other NbS initiatives in the region, as well as coastal and rural NbS
5. **Collaborate on thematic issues**. When comparing the Urban demonstrators, we identified three topics relevant to various NBRACER Urban Demonstrators, also relevant to Atlantics and other urban and metropolitan environments. It is recommended to share and exchange on these topics in order to gain relevant insights for optimal implementation, mainstreaming and upscaling. The following topics have been defined:
    a. Climate Road
    b. Community based initiatives; urban demonstrators are implemented in densely populated environments, which will directly affect citizens. Expand stakeholder involvement to include civil society organisations, citizens, youth, etc.
    c. Living lab approaches for integrated co-design
6. **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.
7. **Improve governance coordination.** Connect the organisation of the Demonstrators, the project leads and the partners, to urban, metropolitan and regional governance structures and mechanisms. Create commonly optimal governance conditions for proceeding with the implementation of the demonstrators and building the regional portfolio, to optimally manage the mainstreaming and upscaling of solutions. Align with regional and national

strategies. Long-term commitment and funding arrangements help to ensure reliability and continuity.

8. **Leverage digital tools and visual platforms.** Continue using collaborative platforms like MIRO to visualise co-design progress, facilitate remote participation, and document stakeholder inputs in a transparent and accessible manner.

Overall, the co-design exercise has started to lay a foundation for mainstreaming of urban 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 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 6).

Table **6**: An extensive list of 36 major climate risks was 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 well-being 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 the 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 34): (1) **knowledge and data** to reveal what is happening and 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 34): (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**. A detailed list of KCSs as defined within NBRACER can also be found in T5.1 Annexe (KCS).

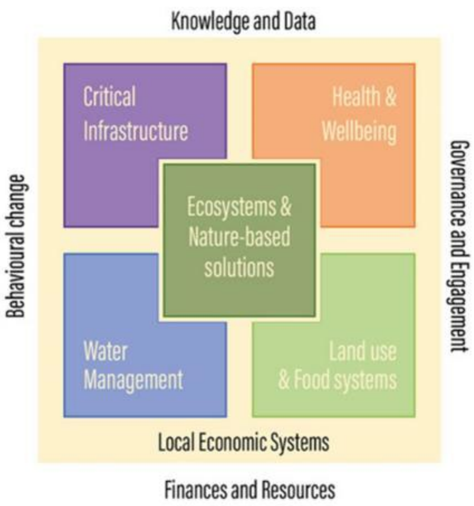

Figure 34: Key innovation areas mentioned in the EU Mission for adaptation to climate change. Source: [A solutions-focused approach to adapting Europe to the climate crisis | Research and Innovation.]

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 35).

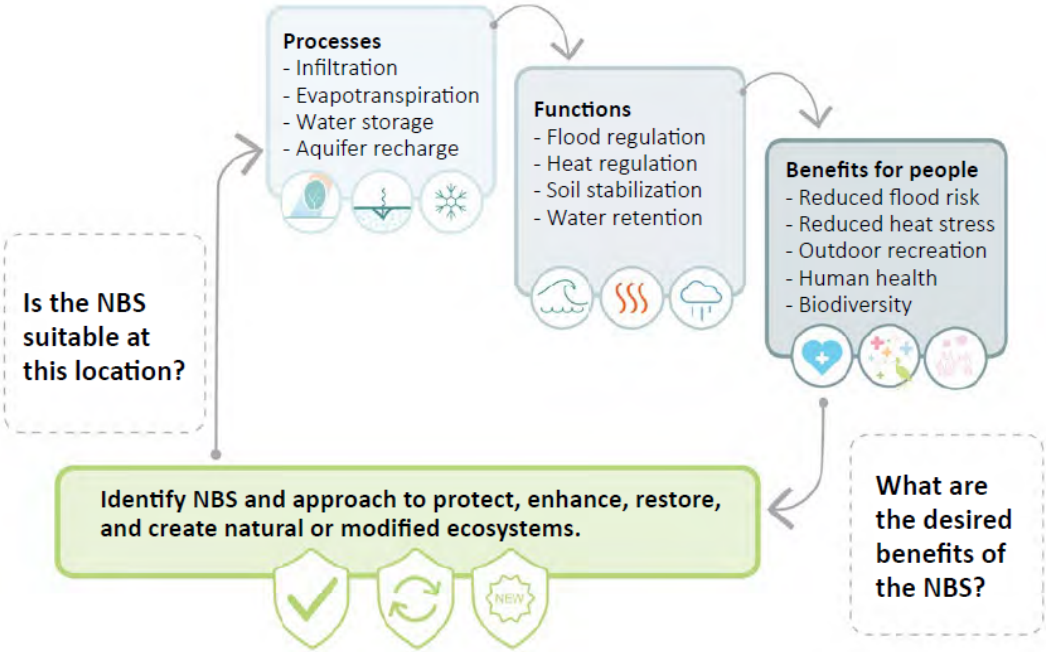

Figure 35: Framework to support the identification of suitable implementation of NbS at a given location based on the processes taking place, providing functions and benefits for people. Source: World Bank, 2021 (adapted).

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 36):

- **Provisioning:** which covers material or energetic outputs from ecosystems, including food, water and other resources;
- **Regulation and maintenance:** 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:** 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
		Renewable abiotic energy sources
Regulation and Maintenance	Regulation of wastes	Bioremediation
		Dilution and sequestration
	Flow regulation	Air flow regulation
		Water flow regulation
		Mass flow regulation
	Regulation of physical environment	Atmospheric regulation
		Water quality regulation
		Pedogenesis and soil quality regulation
	Regulation of biotic environment	Lifecycle maintenance & habitat protection
		Pest and disease control
		Gene pool protection
Cultural	Symbolic	Aesthetic, Heritage
		Religious and spiritual
	Intellectual and Experiential	Recreation and community activities
		Information & knowledge

Figure 36: 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) (UNCEEA/5/7) Introduction to the CICES proposal.]

A detailed list of ES, as defined within NBRACER, can also be found in D5.1 Annexe (Ecosystem Services). The **Ecosystem Services provided by NbS** can be subdivided into the **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. Nonetheless, NbS often provide other ES beyond their design purpose – these are referred to as **co-benefits**. See the example below (Figure 37) 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).

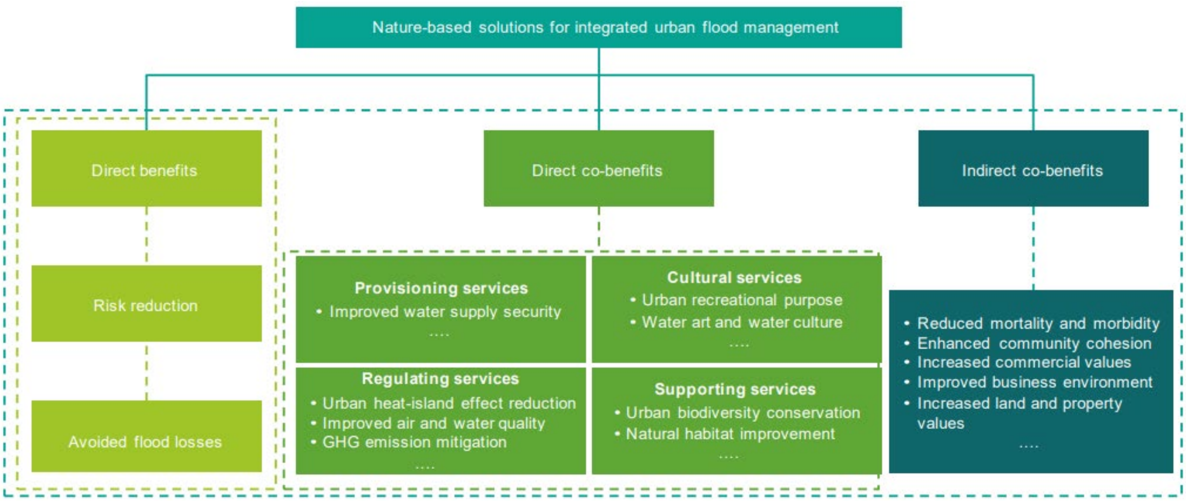

Figure 37: Example of benefits and Ecosystem Services provided by NbS for integrated urban flood management. Source: Wishart et al., 2021.

9.4 Readiness level

The readiness level refers to the maturity of a solution for full-scale implementation, i.e., the maturity level of an NbS demonstrator and its potential for mainstreaming. It can cover both the **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. The schemes below illustrate what each readiness level corresponds to in terms of TRL (Figure 38) and SRL (Figure 39).

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 38: Technology Readiness Level (TRL) scale diagram. Source: What are Technology Readiness Levels (TRL)? - TWI (adapted).

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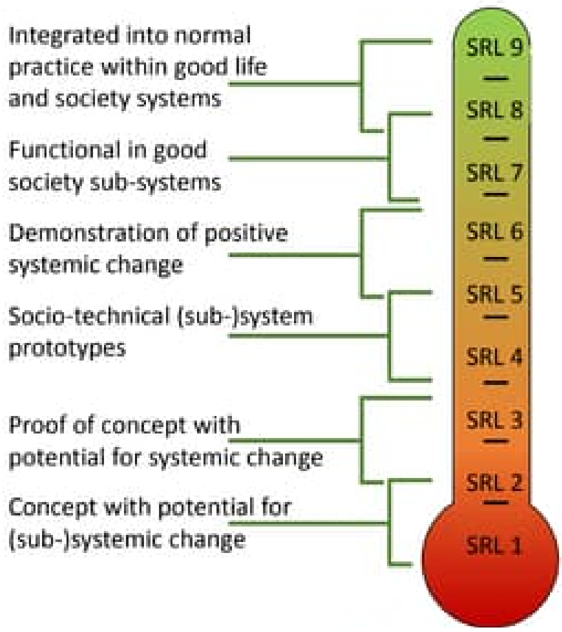

Figure 39: Societal Readiness Level (SRL) scale diagram. Source: Cut Carbon Symposium: Societal Readiness Levels | PPT (adapted).

9.5 Landscape (Sub)Archetypes

NBRACER considers 3 landscape types: **marine & coastal**, **urban**, and **rural**. Nonetheless, it is relevant to further characterise landscape (sub)archetypes 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 (**Error! Reference source not found.**); (ii) the landscape archetypes are translatable and relate to all the **functional units of the conceptual model formulated in Task 5.1** (Table 8); and (iii) whenever data is available, **base layers are also considered** for specific landscape characterisation relating to **geomorphology, soil type, groundwater levels, elevation**, etc.

Table 7: 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 **8**: 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. A positive relief generated by bedrock bedding (modified after Huggett, 2017).	(Nanson, et al., 2022) Solid Earth BGU: **Tectonic high** BGU-T: Compressional ridge; tectonic dome 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). 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.	(Haskins, et al. 1998) [Landscape Term] **Hill** [Landscape Term] **Mountain**

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Table 8 (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). 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).	*(Haskins, et al. 1998)* [Fluvial Landform and Microfeature] Stream Processes (Subprocess Modifiers: Undifferentiated, Eroding, Transporting or Depositional) • **Channel** • **Bank**

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Table 8 (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 8 (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) 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)	(Haskins, et al. 1998) [Landscape term] **Delta** [FLuvial Landform] Stream Processes (Subprocess Modifiers: terminal deposition) • **Delta** ○ **Delta plain**

Table 8 (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 Iacono 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**

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Table 8 (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) 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)	(Haskins, et al. 1998) [Landscape term] **Coast** [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)	

10 Appendix B: Structure of the demonstrator canvas on MIRO

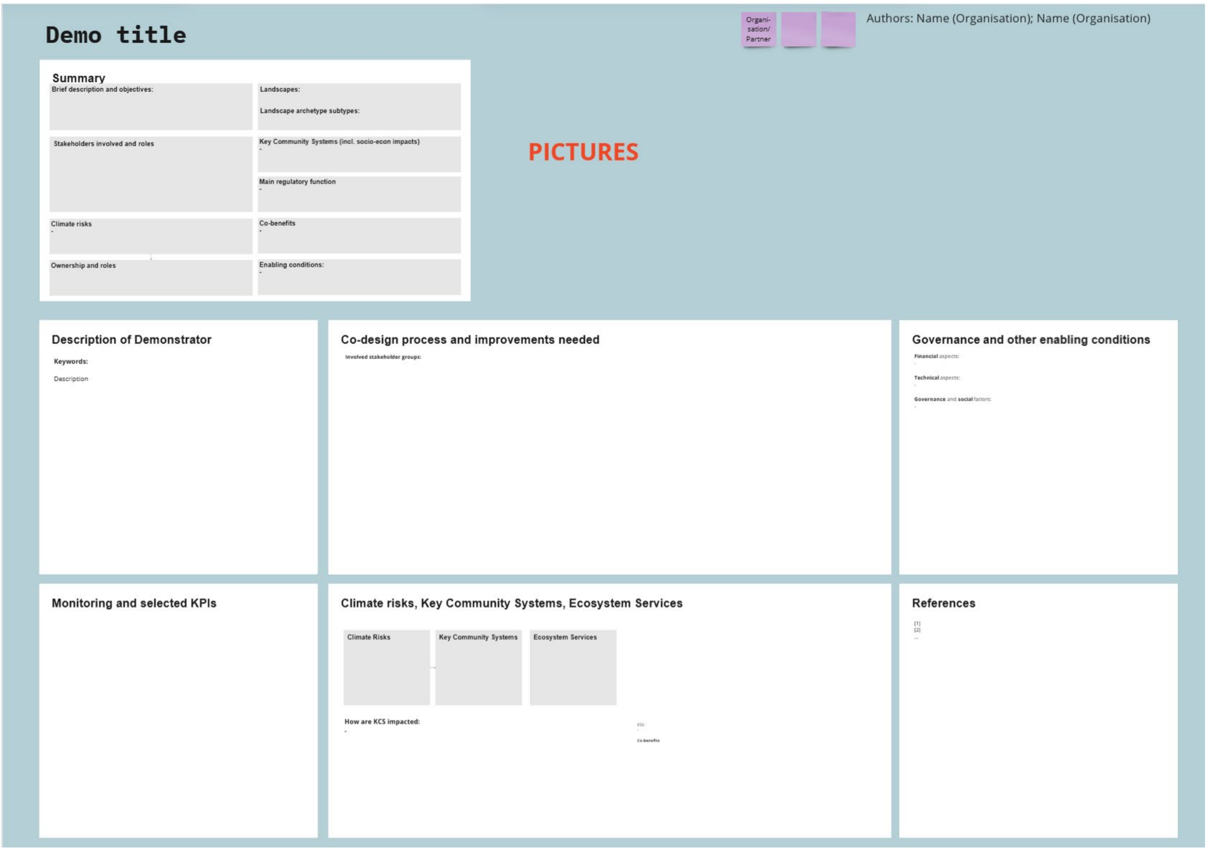


Figure 40: Structure of the MIRO canvas for co-design (illustrative blank).

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

Briefly describe your case and its research objectives. Make sure to use terms for a non-expert reader.

Landscape types and (sub)archetypes

*Select the landscape types of the project and the (sub)archetypes (see the **Error! Reference source not found.** section for more information). If the case addresses more than one landscape, make sure to mention it here.*

Stakeholders involved and roles

Mention which stakeholders have been involved in your demonstrator and which role they have (e.g., involved, informed, decision maker).

Key Community Systems

*Refer to the 6 Key Community Systems (KCSs) as mentioned in the EU Mission on Adaptation to Climate Change (see the **Error! Reference source not found.** section for more information).*

Main regulatory function

*Describe which regulatory function that your demonstrator is addressing, i.e., which is the propose of design of your NbS (see the **Error! Reference source not found.** section for more information on the concept of Ecosystem Services).*

Climate risks

*Refer to the climate risks as mentioned in the European Climate Risk Assessment (see the **Error! Reference source not found.** section for more information).*

Co-benefits

*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 **Error! Reference source not found.** section for more information on the concept of Ecosystem Services).*

Ownership and roles

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.

Enabling conditions

*Refer to the 4 Enabling Conditions as mentioned in the EU Mission on Adaptation to Climate Change (see the **Error! Reference source not found.** section for more information).*

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 extend 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 ***Error! Reference source not found.*** *section for more information):*

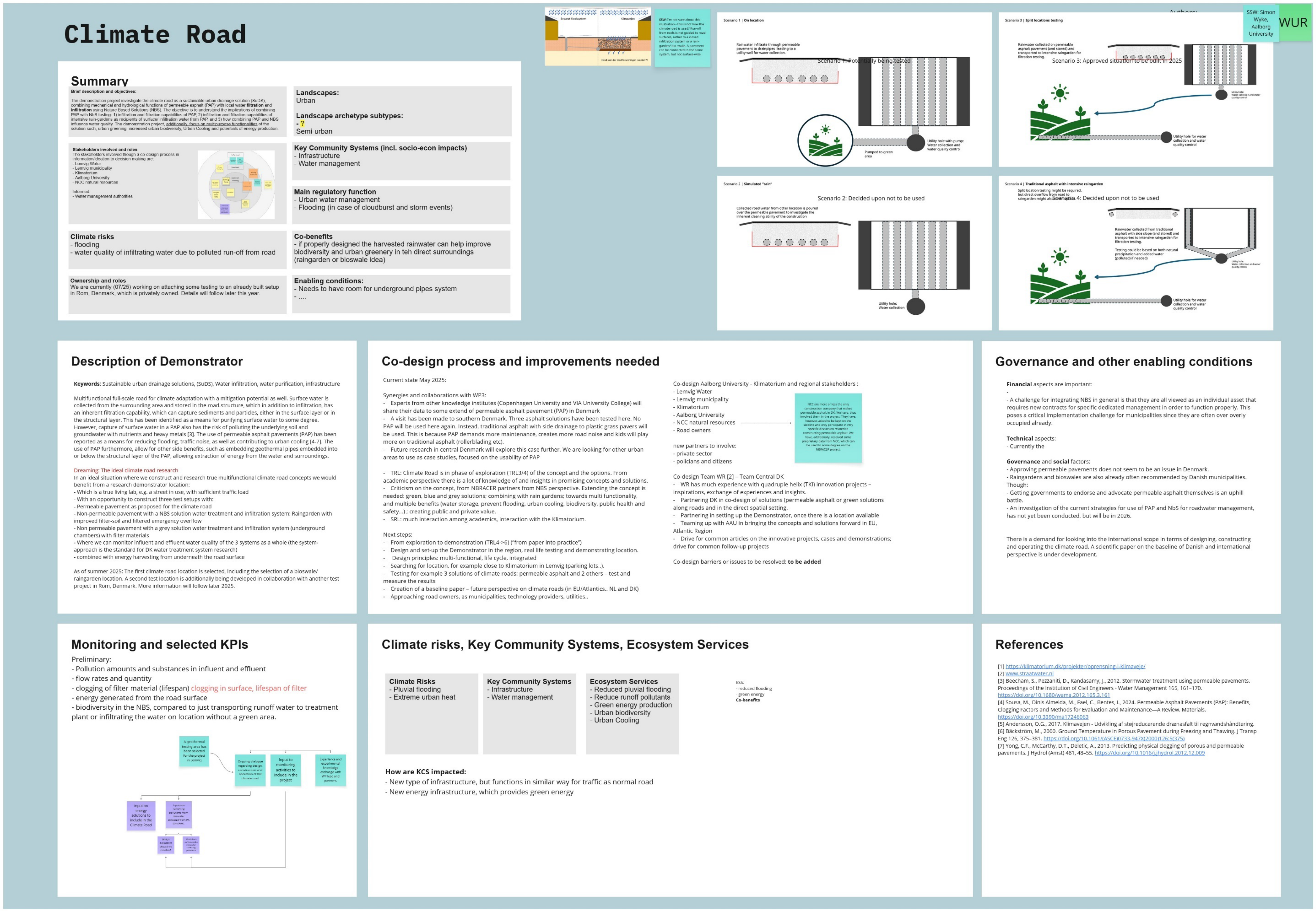
- *Describe further the climate risks tailored to the demonstrator*
- *Describe how the identified KCSs relate to the demonstrator*
- *How are the identified KCSs impacted by the climate risks in the context of the demonstrator?*
- *Does the demonstrator address risks for maladaptation?*
- *How does 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]").

11 Appendix C: MIRO canvases of the demonstrators



Constructed wetlands for decentralized water treatment

Prov WFl

VITO

INAGRO

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

Scale: local

Summary

Brief description and objectives
Use of constructed wetlands/ reed fields to treat domestic wastewater from villages/house not connected to the sewer network. Additional knowledge is needed on the technical aspects.

Landscapes: Rural; Peri-urban

Landscape archetype subtypes: Not relevant

Stakeholders involved and roles
- different governance levels (house owner, local municipality or village, province)
- research (VITO and UGent Kortrijk)
- industry (sewage network company - Fluvius; wastewater company - Aquafin; local business - e.g. Kruiderie)
- citizens (e.g. visitor center Blankaart)

Key Community Systems
- Ecosystem
- Water system

Main regulatory function
- water purification

Climate risks
- water pollution (nutrients)
- drought

Co-benefits
- cooling
- biodiversity / habitat creation
- educational purpose (e.g. information plates, walking paths, ...)

Ownership and roles
- different levels (owner? maintenance?)
- important role VMM: regulatory agency
- possible support to apply for subsidies by Province West-Flanders

Enabling conditions
- legal framework
- subsidy framework
- make time available (e.g. apply for subsidies by municipalities)

Description of Demonstrator

Keywords: constructed wetlands; household wastewater; decentralized, reedfields, helophytes

Due to fragmented land use and urbanisation, Flanders (including West-Flanders) has a household wastewater treatment rate of about 85%, with even less in rural areas (more information, see [7]). Connection to the central sewage system is too expensive. Some existing grey technologies (like IBA) exist but at insufficient implementation rate.
Small constructed wetlands (reed fields) can provide an alternative for these traditional IBAs. In this demonstrator, we demonstrate the technical and societal aspects of small wetlands for the treatment of individual households or small neighbourhoods (less then 150 inhabitants). As such their wastewater is treated, while expensive piping networks are avoided.

Co-design process and improvements needed

Involved stakeholder groups:
- The **Province** as a government plays a pilot role through implementation of such systems in their domains (e.g. Blankaart, Beernem). Technological aspects of these implementations are monitored.
- Some **municipalities** have invested in constructed wetlands at neighbourhood level (e.g. Diksmuide). With support from the Province, possibilities for monitoring are being evaluated, taking into account IP and other regulations.
- Some **citizens** have taken up a frontrunner role, installing small wetlands in their garden/ private house (e.g. Sijsele, Ichtegem). Through interviews, we monitor the non-technological drivers. Also technological aspects of these implementations are monitored.

Since most of these systems have already been build (sometimes a long time ago), the **co-design process within NBRACER is more focused on mainstreaming and replication potential**, i.e., how to increase the implementation of this type of solutions in other locations. We do this by providing scientific evidence on the effectiveness of these reed fields and interviews.

The **main barrier** identified is the lack of **technical knowledge** of the system owners (e.g. provinces, municipalities, citizens), and lack of **proper monitoring** to follow up performance of these systems according to the regulations.

The co-design is targeted at **bridging the technical knowledge gap**, in which research (VITO) provides evidence to citizens and local governments representatives (municipalities, Provinces, Flemish government).

This is done through **workshops, discussions tables and interviews** [1,4,5,6,8,10] where the scientific rationale behind this systems is presented, together with performance results and interpretation to **increase the overall understanding**. These actions are also targeted at **raising awareness** on CWs and their suitability for decentralized water purification.

These systems have a **generally high TRL** (6-7, technology demonstration and deployment in relevant or operational environment). The **SRL is still behind** due to lack of awareness and limited societal acceptance (4-5, proof of concept for systemic change and socio-technical system prototypes). NBRACER is exactly focusing on increasing the SRL by providing evidence and addressing the identified barriers / enabling conditions.

Governance and other enabling conditions

- There is a lack of a suited **legal framework** to support these (and other small-scale grey) solutions, enforce implementation of treatment at household level, and to deal with possible temporal variations in effectiveness [1,10]. The current legal framework demands to meet pollutant concentration levels designed for grey solutions [1,9,10]. It is not taking into account the effect of evapotranspiration or seasonal variability in CWs [1]. Systems can be monitored by regulators and, when not reaching the norms, there are possible fines. This results in a risk for the owner (while there is no sanction for not treating household wastewater) [1,10] - as such, it is often preferred not to treat instead of using CWs [1,9,10].
- Local water treatment is a municipal competence, often taken over by **intermunicipal companies** [1,9,10]. At these companies there is a **lack of trust** in NbS performance [1], also because of a lack of knowledge [10]. Organisational processes are very standardized and tailored at traditional grey solutions, discouraging new/innovative solutions [9].
- There is a **lack of technical knowledge** and trust on the long-term performance and reliability [9,10], including which maintenance actions are necessary [9,10]. More experience is needed on dimensioning and practical engineering competences [9]. There is a need for more exchange of experiences with other regions [10]. Academic knowledge in insufficiently transfered to government and consultants [10].
- There is also a lack of trust from **citizens**, often because of few bad examples, while the good examples are insufficiently promoted [10].
- The need for land/space is perceived as an important barrier at individual and collective scale [10], while at collective scale also questions around land and infrastructure ownership, and responsibilities for maintenance and performance, are a barrier [10]
- **Governance framework**: it is based on **zonation plans**, where to-be-implemented solutions have been defined. The rigid implementation of these plans is an important barrier for innovations, such as CWs at neighbourhood level [9,10]. Though these plans were initially a catalysator for increased household treatment rates, there is now a need for another framework that is less rigid and responds to today's needs [9]. Current zonation plans will only be fully implemented on the very long-term (often after 2050) [10]. CWs could serve as an interim solution, or even final solutions, if plans would allow more flexibility [10]. The entire framework of prioritizing and mandating water treatment, the financial aspects such as subsidies, and enforcement of plans is perceived complex [10], and there are few incentives for investments by citizens (private systems) and municipalities (collective systems) [1,10]. A better and clear subsidy framework by the regional (Flemish) government is suggested as a solution [1,9,10], also taking into account the particularities of non-grey solutions [9,10]. A clear framework and responsibilities for maintenance of these systems also lacks [1], which is sometimes taken up by municipalities [9].
- Some stakeholders argue that the current framework does not provide long-term **legal certainty** for investors (e.g. obligation to disconnect a CW when a sewer system is installed) and offers no guarantees regarding decommissioning [1,4]. This was contradicted by some experts [9].
- Water governance and WFD set targets at water basin level, resulting in prioritized investments in larger residential areas; whereas individual CWs might have a larger impact in the most vulnerable streams and specific species protection plans [1, 9].
- While **prices** per inhabitant are equivalent or cheaper than grey individual solutions [1,2,3], prices for collective solutions are lower according to some stakeholders [1] - though not consensual to all stakeholders [10]. Thus, local governments invest first in collective solutions to increase their removal rate targets [1]. Not only investment prices but also maintenance and co-benefits have to be compared to make CWs more competitive [10].
- The **value chain** is poorly developed and there is a lack of competition at the supply side for construction and maintenance [1]. This was contradicted by the experts who claim that the value chain is present when framework contracts are organized by municipalities [9].
- A main enabler could be further raising awareness on CWs as a solution among citizens and municipalities [1, 10].

Based on these different sources [1,4,8,9,10], following **steps** can be proposed:
- changes in the governance and subsidy framework of water treatment, with a complete revision of zonation plans that also take into CW, with clear roles and regulations around CW implementation and maintenance, and a subsidy framework that is adapted to CWs [1,10,9]
- transfer of research results to policy and practice, and knowledge exchange with other regions [10]
- showcasing best practices and awareness raising around water quality challenges and solutions [10]; focus on and being creative with co-benefits, such a recreation and a green environment [10]
- searching for alternative ways to finance solutions [10]

Monitoring and selected KPIs

We monitor the performance for water treatment (water quality) for different parameters:
- nutrients (COD, N, and P)
- pH, conductivity, solids content
- flow rate (planned)

The demonstrator cases will be monitored until 2026 (during the course of the NBRACER), and a follow up plan will be considered for beyond the project.

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks
- Water pollution (nutrients)
- Drought / flooding

Key Community Systems
- Ecosystem
- Water system

Ecosystem Services
- water purification
- biomass production (plants)
- cooling / evapotranspiration
- biodiversity / habitat creation
- recreation / education (e.g. information plates, walking paths, ...)

How are KCS impacted:
Constructed wetlands can provide a solution for very sensitive streams with specific target species [1]. These are under increasing threat due to a combination of climate change induced drought and soil erosion. CWs decrease household nutrients and micropollutant specifically for those small streams, offering a treatment solutions for decentralized households that are not connected to the sewer network.

References

[1] NBRACER East-Flanders Regional Workshop - infomarket session and table discussion on constructed wetlands (24/02/2025)
[2] BAT on reed constructed wetland, emis VITO, consulted 25/2/2025 LINK
[3] IBA information by Aquafin LINK
[4] NBRACER interview with owner of reed field (23/09/2024)
[5] NBRACER GA Cantabria - knowledge session on constructed wetlands (24/10/2024)
[6] NBRACER Cávado Regional Workshop - knowlegde presentation on constructed wetlands (12/02/2024)
[7] VMM-site on sewage system https://vmm.vlaanderen.be/feiten-cijfers/water/riolering-en-waterzuivering/indicator-zuiveringsgraad
[8] NBRACER Internal Workshop Flanders - project kickoff and NBS factsheets (15/12/2023)
[9] NBRACER interview with water (treatment) policy experts at Flemish and Provincial level
[10] NBRACER workshop on barriers and enablers of CWs, at the CircSyst Constructed Wetland Event (24/06/2025)

Funded by the European Union

Constructed wetland for treatment of industrial concentrate - Koksijde

VITO

Authors: Bastiaan Notebaert (VITO); Catarina Baptista (VITO)

Scale: local

Summary

Brief description and objectives Use of a constructed willow field to treat brine from membrane filtration at a drinking water company. Additional knowledge is needed on the technical performance aspects.	**Landscapes:** Coastal, urban, rural **Landscape archetype subtypes:** Not relevant
Stakeholders involved and roles Co-design process: - Research (VITO) - Industry (drinking water company Aquaduin) - Partners of the FRESH4Cs project (industry, research, government) Informed: - Industry (drinking water companies; wastewater company) - Citizens	**Key Community Systems** - Critical infrastructure (drinking water) - Water management - Biodiversity **Main regulatory function** - Water quality
Climate risks - Drought - Water quality	**Co-benefits** - Biodiversity enhancement - Carbon storage
Ownership and roles Privately owned and maintained Relies on subsidies for construction	**Enabling conditions** - Financial aspects

Description of Demonstrator

Keywords: water treatment; constructed wetland; industrial scale

The constructed wetland is a horizontal sub-surface flow willow field with gravel substrate of around 0.7 ha. A plastic liner is used to separate treated water from groundwater, preventing leaching contamination.

The constructed wetland in Koksijde treats about 500.000 m³ brine per year. This brine originates from the UF-RO membrane filtration processes at the Aquaduin drinking water plant, where (treated) municipal wastewater (Aquafin) is used to produce drinking water (indirect potable reuse).

This demo site has been selected because of its potential for replication in Flanders, while there are still research questions around performance and optimization of the wetland (with particular focus on micropollutants and nutrient removal).

The main impact of the wetland are on water quality (with the effectiveness to be monitored in NBRACER) and for drought mitigation. Depending on performance of the wetland, the water can be used as an additional resource for drinking water production or nature.

Co-design process and improvements needed

Involved stakeholder groups:
- industry: drinking water company - Aquaduin (construction, maintenance, operation)
- research: VITO, universities (design and monitoring)
- citizens, regulator and other industries: informed

The co-design is aimed at improving technological performance, creating a support base for this type of solution and with a focus on replication. In NBRACER, we aim especially at improving the readiness level by better understanding the wetlands performance. This should leverage regulators and societal support for this kind of solutions. Currently, TRL 7 (demonstration in operational environment) and SRL 4-5 (socio-technical system prototype).

The **main barrier** tackled by co-design in NBRACER is the **limited technical knowledge** available in Flanders (and Europe) on CWs for industrial brine treatment. Co-design thus links lower TRL research with higher TRL applied research and industrial applications.

The system was initially constructed through the Interreg FRESH4Cs project, which was also targeted at increasing the **societal acceptance**, and this work has been continued since by Aquaduin. Next to active online communication targeted at a professional audience, different field days and information sessions have been organized, both for professional audience (industry, research, government) and for the general public.

At a **technological** level, co-design has helped bridging the gap between theoretical knowledge and practical application. During the construction, research organizations (including VITO, HZ University) and the drinking water company, Aquaduin, have been actively working together. Co-design workshops have been organized during this project for the engineering of the wetland, and included Belgian, Dutch and UK government, research and industry partners.

Within NBRACER we focus on monitoring and evaluation. the limited monitoring during FRESH4Cs is now complemented with a more thorough monitoring, also adding a much larger set of parameters focusing on micropollutants. This NBRACER work is a close cooperation between research (VITO) and industry (Aquaduin).

Another Horizon Europe project (CircSyst) focusses on improving the wetland design by testing other substrates for the wetland on small-scale pilots, while also testing the options for reuse through a membrane filtration. Also here theoretical research is put into practice in co-design between research (VITO) and industry (Aquaduin). These activities also connect to the CAPTURE platform, in which universities (mainly UGent) are active on this topic at a lower TRL level. During a CircSyst event (24/6/2025), NBRACER organized a discussion table on the barriers and enablers for this solution, during which different government levels, industry and citizen nature NGOs were present [6].

Governance and other enabling conditions

Financial aspects:
- Interreg 2 Seas funding (60%) was an important lever for construction [1,2]
- water quality determines the discharge costs charged by the regulator, partially counterbalancing investment costs [5]
- a main cost compared to grey solutions is the high amount of space required (1 ha for this exmaple) [5,6]

Technical aspects:
No chemicals are required for this NbS, which is an important environmental benefit but also a supply chain benefit compared to grey solutions. Acquiring chemicals for water treatment is challenging for smaller drinking water companies. [5]

Variability in pollutant removal rates and uncertainty on this variability is a barrier for this solution compared to grey solutions [5,6].

Buidling up of practical experience, tranfer of (academic) knowledge to the industry and knowledge exchange with other regions are mentioned as an important potential enabler [6].
Thinking out of the box, and for instance combining green and gray solutions might be a good way forward [10].

Governance and **social** factors:
- trust in the NbS as an alternative to grey solutions (which are perceived as more costly performing and more reliable) is a main enabler [5]
- lack of chemicals required can improve the social acceptance (compared to grey solutions) for some stakeholders [5]

Monitoring and selected KPIs

We monitor the performance for water treatment (water quality) for different parameters:
- nutrients (COD, N, and P)
- micropollutants including selected pesticides and pharmaceuticals

The demo has been monitored since March 2024 until April 2025. Another Horizon Europe project (Circsyst) will further study and monitor this system.

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks	Key Community Systems	Ecosystem Services
Drought Water quality	Critical Infrastructure (drinking water production) Biodiversity (through water quality) Water management	Wood provision Biodiversity Water quality regulation Food production (negative)

ecosystem services
- water treatment
- (fresh) water provision

Co-benefits
Natuurwaardeverkenner.be is used to estimate the ecosystem services
Benefits
- improvement of air quality (kg PM10 / year)
- C storage: increase from 2.7 ton C/year to 7.7 ton C/year

Trade-offs / disservices
- a decrease in food production (because farmland was converted to the wetland)

How are KCS impacted:
- critical infrastructure: water production: in the long run the constructed wetland can provide an additional resources for drinking water production, making the existing reuse scheme more efficient and robust
- water management: the water treated by the wetland is an additional fresh water resource, avoiding the use of other water resources
- biodiversity: this contributes to better water quality and thus improvment of aquatic biodiversity

References

[1] FRESH4Cs lessons learned: LINK
[2] FRESH4Cs project website: LINK
[3] Van Houtte et al., 2023. Desalination and Water Treatment. LINK doi: 10.5004/dwt.2023.30091
[4] Natuurwaardeverkenner.be, used on 18/12/2024
[5] based on interviewing the Aquaduin process engineer
[6] NBRACER workshop on barriers and enablers of CW, at the CircSyst CW event (24/6/2025)

Quinta de Salgueiros Project

Authors:

Summary

Brief description and objectives:
Objective is to create the first urban laboratory forest in the country, the Quinta de Salgueiros is owned by the municipality. The total area of the site is 6,36 hectares, and the ruins of the house, chapel and walls are consolidated and protected, to prevent degradation [1].

Landscapes:
Urban

Landscape archetype subtypes:
- ?

Stakeholders involved and roles
Co-design process:
- Municipality of Porto (urban planning, education, social, green space, water management)
- Porto City Council
- Environmental agency (national)
- GO Porto
- Nature conservation & forestry institute
- Social housing
- Landscape Architecture team from University of Porto
- Students
- Private municipal culture and sports company (Ágora)
- Private municipal environmental company Porto Ambiente
- Norte Portugal Regional Coordination and Development Commission (CCDR-N)
Informed:
- Social organisation
- People from 500-100 m radius area around park
- involvement of school

Key Community Systems (incl. socio-econ impacts)
- Infrastructure (highway and electricity are crossing over the area)
- Ecological system
- Water management (2 streams, pollution and flooding)
- health & wellbeing
- economic system: new varieties of trees and plants
- food system

Main regulatory function
- water storage
- CO2 capturing
- cooling

Climate risks
- heat
- drought
- flooding
- biodiversity loss

Co-benefits
- Biodiversity enhancement
- Safeguarding heritage
- social function

Ownership and roles
Owned by the municipality of Porto
financed by the COMPETE 2020 program [1]

Enabling conditions:
-Strong support of the Municipality. Strategic project for Climate Adaptation; realization of an attractive new green area for the population and creation of a Laboratory for NBS in the City.

Focus area of the project part (Phase 1) that is included in NBRACER [5]

1. Creation of water retention areas
2. Renaturalization of watercourses
3. Promotion and restoration of riparian woodlands
4. Promotion and restoration of native woodlands
5. Promotion and restoration of meadows
6. Planting of tree barriers
7. Integration of biodiversity-friendly spaces for the community

Overview of planned NbS implementation [6]

Description of Demonstrator

Keywords: accessible for population; urban biolab; socio-ecological research

Transform Quinta de Salgueiros (6ha plot) into an urban park-laboratory; BioLab concept: demonstrating NBS, measuring climate adaptation and preferences; communicating the concept and the progress; urban park for improving mobility and accessibility conditions, as well as quality of life, by creating sports and leisure areas for the population. The area and project are part of a larger strategy, to invest in the Campanha area.

Several NBS will be implemented, namely habitat restoration, water retention basin creation, community gardens. The project implemention will be done in two phases, with phase 1 involving 3ha (within NBRACER), in which is planned the restoration of woodlands, planting a tree barrier, the creation of water retention and infiltration sites. In phase 2 is planned the restoration of water lines and the meadows, and the creation of community gardens. The project is already ongoing from 10 years ago, and is now entering a new phase with the creation of the park: https://goporto.pt/noticias/quinta-de-salgueiros-preparada-para-o-inicio-das-obras-de-consolidacao

the site is not accessible to the public. the status of the project is on development with licensings needed to be approved

other side 'software projects' are being developed namely:
- socio perception survey, 235 responses, to evaluate people's perception about the site and the ideas for the site. Outcome: overall people agreed with the ideas for the site, being specially happy hat will be a green space and not another building; in general, people demonstrated worries with safety;
- community project: evaluate the comfort perception of different areas of Quinta, based in temperature air quality, noise and wind). Outcome: identified areas where is more comfortable than other, which can be helpful to adjust in the final project (for eg, to decide where to plant more or less trees)
- educational program: an educational program will be implemented in september in two primary schools, being Quinta de Salgueiros the site for fieldwork by students
- scientific community engagement and kick off of the laboratory component during the next autumn/winter

Co-design current state and next steps

- Current state

TRL: The Masterplan of Bio Lab is ready, studies have been conducted and preparations have been made for starting the implementation of the Demonstration site (TRL4-5). There is budget from municipality for the first phase of the implementation of the Bio Lab. License is applied and waits for approval. For the second phase the contracting and licensing process will be more complex, because the water infrastructure is planned to be altered.

- SRL: Bio Lab has been set up in a strong collaboration between the Municipality and the Faculty of landscape architecture of the University of Porto. Some research has been done on social innovation and citizens perceptions. Involvement of future users, the inhabitants of Quinta de Salgueiros is key objective. So far, workshops and open days have been organised to involve different stakeholders and a study has been carried out to assess citizens' perceptions of Quinta de Salgueiros [5]. More initiatives will be set up in 2025. Started with informing people; an email newsletter sent to people who left their email address. The project team is aware of that forming a community helps build a sense of ownership and belonging. The site is not yet open to the public (without supervision) for safety reasons, which is typical for closed-off area, as well as concerns about soil contamination and absence of basic infrastructure. Sometimes activities are organised at Quinta de Salgueiros and at those moments people can access the site, but only when accompanied by the project team. There is already an active community in the area, from the Urbinat project, where the community members are already aware of concepts like NbS.

Next steps

Next steps Living Lab
- From exploration to demonstration and (partly) implementation (TRL4->7): Full implementation of the real life testing and the demonstrator will be finalized only in 2028, see Cronogram
- Gaining permits for starting the implementation of the lab environment
- From informing people, to create awareness, involvement and engagement and participation; also to stimulate the active use of the environment and build up the sense of belonging. (SRL3 ->7)
- Building the narrative – emphasis on the multi-functionality, the integrated area-based approach, the testing of various NBS at the same location, the contribution to urban resilience to climate change, creating a green and healthy environment for the citizens, conducting relevant research and innovation activities and the promising contribution to broad value creation for the city, their inhabitants, research community and the private sector, as well the interplay within the innovation ecosystem.
- Extending the partnership: knowledge sharing with other disciplines (currently ecology, landscape architecture, ...), aligning with research programs, projects and other universities connect to the BioLab testing; co creation at the living lab site among disciplines and with end-users
- Governance: management of the site, management of the collaboration and the partnership - the interplay between partners, managing the initiatives and the dynamics on the site. Find suitable organizational structure and strategies and means for operations.

Co design Porto Team and local partners is aimed at involving partners and citizens to create a pleasant environment for the people that work, visit and live in the area, and raise awareness for biodiversity.
- Porto City Council, Municipality of Porto, public and private organisations and research centers are involved for the project [2]
- Águas do Porto (municipality water department?) are involved for the water analysis
- Currently (june 2025), the site is already in use as a lab for cultural (Porto Photography Bienal) and environmental projects (COOLSCAPE/Communicity) [5].
- Several partners with similar interests are working together, for example on achieving locally produced native plants for the site, and possibly a small scale waste water treatments with local plants will be implemented and tested on the site. By working together, communicating and looking for links and similar interests, opportunities can be spotted and brought into practice.
- Citizens are informed about the project through a.o. national news on TV and newspapers [5].
- Workshops and Open days have been organised to involve the different stakeholders and local residents (july 2025)
- A social study has been carried out to assess citizens' perceptions of Quinta de Salgueiros; by AGrupa
- An educational programme is already prepared to run in the next school year, involving two schools in the neighbourhood. This should also help in engaging the community.

Insights & lessons learned from this project will be used in the creation of new municipal regulations to add to the new municipal masterplan and the climate action plan for Porto. To help create a more climate resilient environment and achieve neutrality in 2030.

Quinta de Salgueiros project is alive, dynamic and responding effectively to the objectives of the municipality and the NBRACER project.

Co-design WP3 team and Porto Team - support from WP3
- examples from other Bio Labs; Exchange on Living Lab experiences (with Santander..)
- Exchange on community based initiatives (Friesland, Santander, WP6 representatives)
- Reflections and directions regarding TRL and SRL, regarding upscaling and co-design
- Contributing to building the narrative and bringing forward this within NBRACER and the EU Atlantic Region
- Porto is interested in learning more on water retention (could be in collaboration with other NBRACER partners)
- Porto has implemented multiple NbS projects within the city, but a clear strategy for translating into replicable models without major adaptation for other cities, or upscaling those solutions, has not been developed. To be elaborated within NBRACER 3.3 and 3.4.

Cronogram

Phase/Terminal month	June 25	October 25	May 26	September 26	Mars 27	Mars 28
1. Project contracting	5 months					
2. Preliminary project		4 months				
3. Licensing – CMP and other entities			7 months			
4. Construction Project development				4 months		
5. Public procurement					6 months	
6. Construction work						12 months

Phases explanation:
1. Procurement of the specialities needed for the construction project development. [illegible] (June 25).
2. Preliminary project development by the project team in articulation with the hired specialities.
3. Involves the submission of all the licensing processes needed to the construction work to be legal. [illegible] May 26.
4. Involves the development of the construction project.
5. Procurement of all the teams needed for the construction work. Public procurement it is a process that takes a long time, and we feel we are being optimistic with 6 months, however, we will do everything possible to meet this deadline.
6. All the construction work, namely terrain modelling, NbS implementation, tree plantation, paths, and so on.

Governance and other enabling conditions

https://pactoparaoclima.portodigital.pt/?page_id=5850

Financial aspects:
- cost/financing of managing, qualifying and maintaining the spaces [3]
- Funding for phase 1 of the project comes from Horizon 2020, the second phase will be funded by the municipality. This is similar to an earlier project: URBiNAT.
- To convince people of the project: presentations & promotions in the news
- After the park is completed, it will be open to the scientific community (universities & research centers), to keep testing solutions in the urban biolab. This should also help with the upscaling. The site is already in use for cultural and environmental projects, this should be ongoing.

Technical aspects:
- there is a high urban pressure in the area (high urban expansion areas) [3,4]
- the interactions between all the solutions,
- soil and vegetation in part of the site is contaminated
- difficulty of minimising the impact of the ecocentre.[3]
- Topographic barriers [4]

Governance and **social** factors:
- new local climate adaptation policy and plan
- the planning and legal factors: formal rules and regulations, and licensing processes can take up a lot of time. The waiting time is used to strengthen the partners network, sharing ideas and making plans for the implementation. Project partners are brought together when new and relevant updates need to be shared.
- Public access (might impact the tests, and possible risk of vandalism)
- potential lag between the climate emergency and the time it takes to consolidate solutions
- political cycles and public involvement [3]
- connection and mobility issues

Monitoring and selected KPIs

A monitoring plan is under implementation.
- FCUP for biodiversity monitoring; fauna and flora, monitoring has started and is ongoing. Counting species, including vascular plants, amphibians, reptiles, birds, invertebrates, small mammals, bats
- Monitoring of temperature and humidity with CommuniCity, Builtcolab, Porto Domus; Temperature and humidity: 8 sensors & questionnaire on site for public perceptions, two visits in March & May
- Social (social domain of the municipality(?)), Porto Digital: - socio- environmental context: open days and in-person & online survey, 150 visitors & 235 responses to survey

- Soil analysis is ongoing
- Carbon analysis to be done
- Water analysis of the water line in the area is ongoing (one sample / month), rainwater analysis to be done

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks
- heat
- drought
- flooding
- biodiversity loss

Key Community Systems
- Infrastructure (highway and electricity are crossing over the area)
- Ecological system
- Water management (2 streams, pollution and flooding)
- health & wellbeing
- economic system
- food system

Ecosystem Services
- water storage
- CO2 capturing
- cooling
- Biodiversity enhancement
- Safeguarding heritage
- social function

How are KCS impacted:
In general, all the solutions have an impact on all the basic systems, by improving water and air quality, increasing biodiversity and ecosystem services, usefulness for the population, circularity of resources, health and well-being condition for those who use it as green space. [3]

ESS:
- water storage
- CO2 capturing
- cooling

Co-benefits
- Biodiversity enhancement
- Safeguarding heritage
- social function

References

[1] https://goporto.pt/noticias/quinta-de-salgueiros-preparada-para-o-inicio-das-obras-de-consolidacao
[2] https://www.porto.pt/pt/noticia/novo-parque-laboratorio-instalado-na-quinta-de-salgueiros
[3] report of the first regional workshop Porto (4 july 2024)
[4] Presentation Regional Journeys with WP1: Porto (3rd GA)
[5] Presentation (PDF) for the PMO Meeting of 03-06-2025
[6] WPLRC Meeting 07-05-2025 Presentation

Funded by
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Renaturalization of Dr. Diego Madrazo Avenue (Santander)

Authors:
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- Cantabria coordinator
- Celia Gilsanz and Juan Echevarría (Santander City Council)

Santander Ayu

Summary

Brief description and objectives:
Improving climate resilience of the Dr. Diego Madrazo Avenue, Santander. This is a sub-project under the umbrella of Santander Capital Natural project: Renaturalisation of the city and restauration of the current nature in the city of Santander.

Landscapes:
Coastal Urban

Landscape archetype subtypes:

Stakeholders involved and roles
Co-design process:
- Santander City Council: road and parks and gardens services and innovation area
- Spanish Ornithological Society (SEO/BirdLife)
- Amica Association (private non-profit organisation, for equal opportunities and rights for people with disabilities)
- University of Cantabria (UC)
- Foundation for Climate Research (FIC)
- (Urban residents)

Informed:
- Urban residents
- Neighborhood associations

Others:
- Architect of the project: Joaquín Bustamante
- Landscape designer of the proyect:Luís González
- Company being awarded to do the works: RUCECAN S.L.
- Company awarded the parks and gardens service: Légamo

Key Community Systems (incl. socio-econ impacts)
- Ecological system
- health & wellbeing
- Critical infrastructure in an urban context
- Transportation related structures
- Water management

Main regulatory function
- Wellbeing of citizens
  - Flood management (pluvial flooding)
  - Heat stress

Climate risks
- heat stress
- flooding (pluvial)

Co-benefits
- Biodiversity
- Climate regulation
- Air quality regulation
- Natural hazard regulation
- Aesthetic value
- Pollination

Ownership and roles
Santander City Council coordinating role

Enabling conditions:
- Budget for the works (successfully achieved and contract awarded)
- Sensors budget and awarding process
- Available budget for sensor maintenance

Description of Demonstrator

Keywords: Dr Madrazo Avenue, flood management, reducing heat stress, enhancing biodiversity, climate resilient road

The Dr. Diego Madrazo Avenue will be transformed into a climate resilient road, under the umbrella project of Santander Capital Natural.
In the current situation, the Avenue is largely paved, with little vegetation. Between two roads for motorized traffic on both sides, is a pedestrian (and cycling?) area in the middle of the Avenue. There are trees present, but they are small and offering little shade. Presumably, they have too little rootspace to grow much larger. An effort will be made to improve this (for the new trees) when the new design will be implemented.

The Avenida slopes down towards a city park (Parque de Mataleñas) and the road alongside it (Faro/Lighthouse Avenue). In case of a heavy rain event, the water flows downhill and floods the Faro Avenue (see https://eltomavistasdesantander.com/2020/09/25/pues-parece-que-llueve-inundacion-en-la-subida-del-faro/).

As the park is also a touristic place (it leads to the lighthouse of the city), improving the area will not only benefit the citizens living in the area, but also tourists vising the area, and the city of Santander.

The plan is to add more diverse vegetation, suitable for the area. This will include a wide variety of trees and shrubs. To improve the infiltration of rainwater into the ground, cool the area and enhance biodiversity.

Co-design process and improvements needed

Description of current state of the Demonstration:
- TRL 7 : System prototype demonstration in an operational environment
- SRL 6 : The solution is tested in a relevant societal environment

Involved stakeholder groups:
- The design for the Avenue was created by an architect and landscape designer
- For the umbrella project of Santander Capital Natural, a participatory approach was set up, for the Avenue not (yet). A subset of the stakeholders involved in the Santander Capital Natural (Santander City Council, Spanish Ornithological Society (SEO/BirdLife), Amica Association, University of Cantabria (UC), Foundation for Climate Research (FIC), events at municipality meeting center to involve and inform citizens [3]) will be applicable for the Avenida as well. Mainly: Santander City Council, University of Cantabria, FIHAC, Technalia. In addition, a contractor and landscape architect are involved.

- There is no structured approach to ask citizens on their opinions of the road developments. The expectation is a more informal evaluation, a.o.: there will be articles in the news about the road, which will also include or reflect citizens' opinions. Activities might be organised for citizens at the road.

Co-design barriers or issues to be resolved:
- Siloes (applicable to academics, various departments and policy fields) can be a barrier for effective co-design.
- Each project needs it's own contract and has it's own project boundaries, which may in some cases hamper collaboration/sharing activities between projects. For example, in parallel projects, citizens were involved and asked for their opinion. But in the implementation of the Dr Madrazo Avenue, the aspect of involving citizens is not included, and there is no option to combine the activities from the parallel projects with this project.

Timeline:
- Contract has been awarded (in May 2025), from there it will take a few months to complete the administrative procedure, after that the project will start.
- Contractor started Civil works in June 2025
- to be finalised in December 2025

Next steps:
- For the action itself:
  - Defining and installing the sensors and start gathering information
  - Taking photo's of the current situation, before the works start
  - Doing a follow-up of the works
  - Make the data assesment to get objective information of improvements and get insight
- For the city in the future:
  - Obtain learning lessons, cost-benefit parameters, etc. for use in subsequent similar projects

Support from NBRACER:
- Through the NBRACER project, it is possible to also learn from other regions and similar projects. Another project under the umbrella project of Santander Capital Natural is focusing on Green Infrastructure for Santander. It may be valuable to share information and insights from the NBRACER project with this project as well.

Governance and other enabling conditions

Financial aspects are important:
- Carrying out the works
- Installing sensors to objectively measure improvements
- Civil works funded by the Recovery and Resilience Plan of Spain under the EU next Generation fund (competetive call)
- The project of the avenue renaturalisation falls within the umbrella project of Santander Capital Natural, and also contributes to the national goal of renaturalisation of a certain amount of hectares within the country. This provides opportunities to get funding for similar projects. An important funder (Fundacion Biodiversidad) also brings various sister projects together to learn from each other.

Technical aspects:
- Design challenges
- Maintenance & performance challenges
[4]

Governance and **social** factors:
Project is part of the program "Santander Natural", which has been finalized in 2025
New program has started Green Infrastructure Plan Santander:
project results contribute to the National goals on City Renaturalization and resilience support

- Long-term vision (governance)
- Climate change policies (governance)
- Societal perception of NbS (social cultural)
- Impacts on future land use (social cultural)
[4]

Knowledge conditions: current Research programs and projects supporting the Demonstrator
- General knowledge on NbS
- Institutional experience
- Technical guidance
- Clear cause-effect relationships
[4]

Monitoring and selected KPIs

Monitoring:
- Tecnalia will create a microscale temperature model for the area along the Avenue. The model will benefit from the measures taken before and after the action.
- Tecnalia will also provide with a whole city temperature model (macro scale model) to make predictions about significant atmospheric events, like heatwaves or intense rainfall.
- Run off (micro-scale model by FIHAC)
- Sensors to be deployed
- Photo's will be taken before and after the design is implemented

KPIs: Average surface temperature reduction. Increase in rainwater retention capacity.

Middle part (foot/bike path?) of the avenue - before

Photo taken from the car infrastructure on the avenue - before

The city park close to the avenue

The flood zone, where the roads come together near the park, which is flooded in cases of (heavy) precipitation - before

Climate risks, Key Community Systems, Ecosystem Services

Climate Risks	Key Community Systems	Ecosystem Services
- heat stress - flooding (pluvial)	- Ecosystems & nature-based solutions - health & wellbeing - Critical infrastructure in an urban context - Transportation related structures - Water management	- Flood management - Mitigating heat stress - Biodiversity increase - improved health & wellbeing for citizens

How are KCS impacted:

Critical infrastructure & Water management
Currently the infrastructure is affected by flood events due to pluvial flooding. This will be addressed by increasing the infiltration opportunities and capacity of the street.

Ecosystems & nature-based solutions
Currently, the street consists mainly of hard (paved) surfaces, with little planting. This will be improved, by replacing paving by planting. By planting a wide variety of species, biodiversity will be addressed.

Health & wellbeing
By replacing paving by planting and adding trees that can grow bigger to provide shade, the temperature in summer will be lower, there will be less flooding events, and people living near the Avenue will have a greener living environment.

ESS:
- Local climate regulation (e.g., cooling effect from vegetation)
- Flood control

Co-benefits
- Biodiversity
- Climate regulation
- Air quality regulation
- Natural hazard regulation
- Aesthetic value
- Pollination

References

[1] https://santandernatural.es/objetivos/
[2] https://santandernatural.es/actuaciones/plan-adaptacion-urbana-escenarios-climaticos/
[3] https://santandernatural.es/socios/
[4] NBRACER NBS Survey

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