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CARDIMED

CLIMATE ADAPTATION AND RESILIENCE DEMONSTRATED IN THE MEDITERRANEAN REGION

Deliverable
2.1

Landscape report of NBS

Catalogue of NBS solutions for demo sites, discussing their applicability for climate resilience

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Glossary

Acronym	Full name
Approx.	Approximately
AMU	University of Marseille
ANRI	Alchemia Nova
BOD5	Biological Oxygen Demand
BVOC	Biogenic volatile organic compound
CAPEX	Capital expenditure
Cd	Cadmium
CH_4	Methane

CIRCE	Center for Research on Energy Resources and Consumption
cm	Centimetre
C/N ratio	Carbon:Nitrogen ratio
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
Cu	Copper
d	Day
DEMOs	Demonstrations
DEYAL	Municipal Water Supply and Sewerage Enterprise of Lesbos
DO	Dissolved oxygen
DOGA	Doga Dernegi
EBOS	Ebos Technologies Limited
g	Gram
GIS	Geographic Information System
GOTF	Gardens Of The Future
GPS	Global Positioning System
ha	Hectare
HALCOR	Elvalhalcor Hellenic Copper And Aluminum Industry Limited Company
HLR	Hydraulic Loading Rate
ICLEI	ICLEI European Secretariat GmbH
IRIDRA	IRIDRA S.r.l
IZMIR	Izmir Institute of Technology
kg	Kilogram
km^2	Square kilometre
L	Litre
m	Metre
m^2	Square metre

MedINA	Mediterranean Institute for Nature and Anthropos
mg	Milligram
mm	Millimetre
NBS	Nature-Based Solutions
NBSbi	Nature-Based Solutions biodiversity interventions
NBSi	Nature-Based Solutions interventions
NBSri	Nature-Based Solutions river interventions
NBSsi	Nature-Based Solutions soil interventions
NBSsu	Nature-Based Solutions spatial units
NBStu	Nature-Based Solutions technological units
NBSu	Nature-Based Solutions units
NH_3	Ammonia
NH_4+-N	Ammonium nitrogen
NTUA	National Technical University of Athens
NO_2	Nitrogen dioxide
NO_3-N	Nitrate nitrogen
O_2	Oxygen
O_3	Ozone
OLR	Organic loading rate
ORP	Oxidation-reduction potential
OPEX	Operating expense
PAHs	Polycyclic aromatic hydrocarbons
Pb	Lead
pe	Population equivalent
PM10	Particulate matter smaller than 10 micrometers
PO_4^{3-}	Phosphate
s	Second

SO_2	Sulfur dioxide
SRL	Societal Readiness Level
SSF CWs	Subsurface Flow Constructed Wetlands
T	Temperature
TN	Total Nitrogen
TP	Total Phosphorus
TRL	Technology Readiness Levels
TSS	Total Suspended Solids
UASB	Up flow Anaerobic Sludge Blanket
UEVORA	University of Évora
UNIBO	University of Bologna
UNIVPM	Marche Polytechnic University
UU	University of Utrecht
UV	Ultraviolet
y	year
Zn	Zinc

Executive summary

The CARDIMED NBS catalogue is a groundbreaking resource that advances the understanding and documentation of nature-based solutions (NBS), aiming to empower informed decision-making, foster collaboration, and inspire innovation and uptake in NBS projects across various contexts, especially in the Mediterranean region. The CARDIMED catalogue is organised into three main sections. The first section, the **CARDIMED NBS catalogue (Section 1),** explains the main aspects of the methodological framework used to develop the catalogue. It includes a classification system that recognizes the diverse functions of NBS and allows for customization to suit specific needs and circumstances. Additionally, this section presents detailed information on the procedures regarding data collection analysis, as well as inputs from experts and representatives of demonstrations.

The **CARDIMED NBS factsheets (Section 2)** feature detailed factsheets on NBS deployed across CARDIMED's 9 demonstrations (DEMOs), providing a wealth of information to diverse stakeholders. The factsheets introduce CARDIMED NBS classification. Firstly, NBS interventions are divided into *units* and *interventions* (CARDIMED has 18 NBS units and 15 NBS interventions). NBS units are further split into *Technological units* (14 in CARDIMED) and in *Spatial units* (4 in CARDIMED). Finally, Technological units are as *Advanced ecological treatments, Bioretention systems, Permeable surfaces, Vertical greening* systems and *Farming practices,* while Spatial units are clustered into *Greenery elements* and *Farming practices.*

On the other hand, NBS interventions are divided into *Biodiversity interventions* (4 in CARDIMED)*, Soil interventions* (6 in CARDIMED)*, Aquatic interventions* (4 in CARDIMED) and *Land use interventions* (1 in CARDIMED). Similarly as units, also interventions are further clustered. Biodiversity interventions have 2 clusters: *Conservation and restoration of flora* and *Conservation and restoration of fauna.* Soil interventions are clustered into *Permeable surfaces*, *Organic soil amendments, Farming practices* and *Land management techniques.* Aquatic interventions are clustered into *Riverbank measures, River management techniques* and *Rehabilitation of aquatic ecosystems.* At the end Land use interventions are clustered as *Sustainable communal grazing.*

The **CARDIMED NBS systems factsheets (Section 3)** introduce "NBS systems," which integrate diverse nature-based solutions together with supportive units distributed across 9 DEMOs across the whole Mediterranean, in Portugal, Spain, France, Italy, Greece, Turkey and Cyprus. Because the NBS interventions will be implemented at different locations within these DEMOs, a further 19 sub-DEMOs have been defined to address climate resilience challenges holistically throughout the Mediterranean region. In this sense, the catalogue evaluates the effectiveness of diverse NBS systems that combine various types of NBS across different climates and social contexts, offering valuable insights into their resilience building potential. In summary, the CARDIMED NBS catalogue represents a comprehensive and innovative approach to documenting, evaluating, and promoting nature-based solutions in the Mediterranean region. Through meticulous organisation, data collection, and analysis, the CARDIMED catalogue delivers standardised insights into the potential and performance of NBS within the Mediterranean region.

NBS units distributed across 19 sub-DEMOs to address climate resilience challenges holistically throughout the Mediterranean region. In this sense, the catalogue evaluates the effectiveness of diverse NBS systems that combine various types of NBS across different climates and social contexts, offering valuable insights into their resilience building potential. In summary, the CARDIMED NBS catalogue represents a comprehensive and innovative approach to documenting, evaluating, and promoting nature-based solutions in the Mediterranean region. Through meticulous organisation, data collection, and analysis, the CARDIMED catalogue delivers standardised insights into the potential and performance of NBS within the Mediterranean region.

The summary table below, organized using the classification system described in Section 1, provides a direct link to the NBS factsheets developed in Section 2 (click on the NBS name to access the direct link); a summary of KPIs per NBS is provided at the beginning of Section 2.

NBS Technological units: Advanced ecological treatments	
 **Subsurface flow constructed wetland**: Natural system treating wastewater through vegetated subsurface filtration flow. **Main challenges targeted:** Freshwater and groundwater supply and quality, Biodiversity & renaturalization	 **Electroactive constructed wetland**: Generation of electricity via microbial electroactive processes. **Main challenges targeted:** Freshwater and groundwater supply and quality, Biodiversity & renaturalization
 **Free water surface constructed wetland**: Engineered shallow wetland treating wastewater through natural surface processes. **Main challenges targeted:** Freshwater and groundwater supply and quality, Biodiversity & renaturalization	 **Sludge treatment wetland**: Natural system dewatering and stabilising sludge through biological and physical processes. **Main challenges targeted:** Resources recovery & valorization, Soil restoration & protection
 **High rate algae ponds**: Engineered pond treating wastewater while cultivating nutrient-absorbing algae. **Main challenges targeted:** Sustainable practices, resources recovery & valorization	*Picture not available.* **Biofiltration columns**: Vegetated system filtering stormwater and wastewater, reducing pollutants and runoff. **Main challenges targeted:** Freshwater and groundwater supply and quality, Rainwater management & flood protection
Picture not available. **Photo bio reactor**: Closed system cultivating photosynthetic microorganisms to treat wastewater and produce biomass. **Main challenges targeted:** Freshwater and groundwater supply and quality, Sustainable practices	
NBS Technological units: Bioretention system and permeable surfaces	
 **Bioretention cell (rain garden)**: Shallow vegetated depressions capturing and treating stormwater runoff naturally. **Main challenges targeted:** Rainwater management & flood protection, Biodiversity & renaturalization	 **Bioswale**: Vegetated, sloped channel capturing and filtering stormwater runoff naturally. **Main challenges targeted:** Rainwater management & flood protection, Air quality
 **Filter drain**: Shallow gravel-filled trench storing, conveying, and filtering surface water runoff. **Main challenges targeted**: Rainwater management & flood protection, Freshwater and groundwater supply and quality	 **Porous asphalt**: Permeable system allowing water infiltration to reduce runoff. **Main challenges targeted:** Rainwater management & flood protection, Freshwater and groundwater supply and quality
NBS Technological units: Vertical greening systems & farming practices	

 **Wall-based green facade**: Vertical greening panels supporting diverse plants on building or wall surfaces. **Main challenges targeted**: Thermal regulation, Air quality	 **Vegetated pergola**: Architectural structure providing shade and supporting climbing plant growth. **Main challenges targeted**: Biodiversity & Renaturalization, Thermal regulation, Air quality
 **Aquaculture**: Farming aquatic organisms with controlled management for food production. **Main challenges targeted**: Biodiversity & renaturalization and Local Development & Economic	
NBS Spatial units: Greenery elements & Farming practices	
 **Green corridors**: Linear green spaces converting unused areas to enhance connectivity and wildlife. **Main challenges targeted**: Biodiversity & Renaturalization, Freshwater and groundwater supply and quality, Societal benefits	 **Urban micro forest**: Small urban green areas mimicking natural forests with diverse vegetation. **Main challenges targeted**: Biodiversity & Renaturalization, Rainwater management & flood protection
 **Urban parks**: City green spaces providing recreational and social opportunities for residents. **Main challenges targeted**: Biodiversity & Renaturalization, Rainwater management & flood protection and Societal benefits	 **Agroforesty**: Integrated land system combining trees and crops for sustainability and biodiversity. **Main challenges targeted**: Biodiversity & renaturalization, Local Development & Economic Enhancement
NBS Biodiversity interventions: Conservation and restoration of flora and fauna	
Picture not available. **Invasive alien species control**: Management practices aimed at reducing or eradicating harmful non-native species. **Main challenges targeted**: Biodiversity & Renaturalization	*Picture not available.* **Restoring native vegetation**: Reestablishing native plants to restore ecosystems to healthy conditions. **Main challenges targeted**: Biodiversity & Renaturalization
Picture not available. **Techniques for fauna refuge and nesting**: Structures and habitats providing shelter and nesting to support biodiversity conservation. **Main challenges targeted**: Biodiversity & renaturalization	*Picture not available.* **Reintroduction of native fauna**: Returning native animal species to their natural habitats to restore biodiversity. **Main challenges targeted**: Biodiversity & renaturalization
NBS Soil & Land Use interventions: Permeable surfaces	
Picture not available. **Surface unsealing**: Removing impermeable surfaces to restore soil permeability and reduce runoff. **Main challenges targeted**: Air quality, Soil restoration & protection, Societal benefits.	*Picture not available.* **Organic soil amendments**: Applying organic compost to improve soil fertility, structure, and water retention. **Main challenges targeted**: Soil restoration & protection, Societal benefits.

Picture not available. **Mulching Application**: Applying a protective soil layer to conserve moisture, reduce erosion, and weeds. **Main challenges targeted**: Biodiversity & renaturalization, Rainwater management & flood protection, Soil restoration & protection	
NBS Soil & Land Use interventions: Farming practices & Land management techniques	
 **Cover crops**: Crops planted to protect soil, improve fertility, prevent erosion, and weeds. **Main challenges targeted**: Biodiversity & renaturalization and Societal benefits	*Picture not available.* **Crop rotation**: Alternating different crops on the same land to improve soil and yields. **Main challenges targeted**: Biodiversity & renaturalization, Societal benefits, Soil restoration & protection
Picture not available. **Terracing**: Constructing stepped platforms on slopes to reduce erosion and retain water. **Main challenges targeted**: Rainwater management & flood protection, Biodiversity & renaturalization, Societal benefits.	*Picture not available.* **Sustainable communal grazing**: Collaborative grazing management ensuring fair, balanced, and sustainable pasture use. **Main challenges targeted**: Biodiversity & renaturalization, Societal benefits
NBS Aquatic interventions: Riverbank measures and river management techniques	
Picture not available. **Riparian buffer**: Vegetated strip along waterways reducing runoff, sediments, and pollutant flow. **Main challenges targeted**: Biodiversity & renaturalization, Freshwater and groundwater supply & flood protection.	*Picture not available.* **Diversion Channels**: Artificial channels redirecting water to prevent flooding, erosion, and landslides. **Main challenges targeted**: Freshwater and groundwater supply and quality, Rainwater management & flood protection, Biodiversity & renaturalization.
Picture not available. **Dams**: Low-cost structures capturing rainwater to boost groundwater and land productivity. **Main challenges targeted**: Rainwater management & flood protection, Biodiversity & renaturalization, Societal Benefits	*Picture not available.* **Lagoon Restoration**: Restoring degraded lagoon ecosystems to improve biodiversity and ecological resilience. **Main challenges targeted**: Biodiversity & renaturalization, Local Development

1. The CARDIMED NBS Catalogue

The CARDIMED NBS catalogue put forward a conceptual advancement by offering updated factsheets on 34 Nature Based Solutions (NBS) implemented across 9 DEMO sites. This catalogue provides substantial added value by comprehensively addressing each NBS (section 2). Each factsheet offers a wealth of information, encompassing synonyms, a brief description, tackled challenges, ecosystem services, applicability criteria as design and planning intricacies, operational and maintenance considerations, replicability, potential synergies with other NBS, supportive units and smart technologies, as well as cost-related insights covering both capital and operational expenditures alongside potential by-products. Furthermore, it encompasses 19 additional factsheets spotlighting the holistic approach to NBS deployment within each CARDIMED demonstration site (section 3). These factsheets intricately outline the combination of various NBS types with supportive units and smart technology. They include a concise description, Technology Readiness Level (TRL), Scale Readiness Level (SRL), implemented scale, estimated capital and operational expenditures, supportive actions or measures aimed at maximising impacts, potential contributions to Sustainable Development Goals (SDGs), targeted challenges, ecosystem services provided, and potential limiting factors. Therefore the CARDIMED NBS catalogue aims to serve as a comprehensive resource for diverse stakeholders such as policymakers, urban planners, environmental organisations, researchers, and community groups, to engage NBS projects across diverse contexts. It seeks to facilitate informed decision-making, promote collaboration, and support innovation and uptake. By catering to this diverse range of stakeholders, the project aims to maximise the impact of the NBS catalogue. Moreover, the CARDIMED NBS catalogue sets a path towards a common understanding of the concept of NBS and its complexity by providing a flexible and dynamic classification system. This system is designed to evolve beyond the lifetime of the project, ensuring its relevance and usability in addressing emerging challenges and opportunities in the field of NBS.

1.1 CARDIMED NBS classification system

NBS are defined by the European Commission (EC) in a broad sense, considering their economic, environmental, and social aspects. The International Union for Conservation of Nature (IUCN) focuses more on actions related to conservation and restoration of biodiversity. With the concept of NBS gaining popularity, there have been various definitions emerging in recent years. Some highlight sustainability pillars, while others emphasise resource circularity in urban areas. However, the abundance of definitions and a lack of agreement on what makes NBS unique has caused confusion within the NBS community. This confusion is compounded by the fact that NBS often overlaps with established environmental concepts like ecological engineering, green infrastructure, urban green (and blue) spaces, and ecosystem-based adaptation. While some argue that NBS is an umbrella term encompassing these approaches, others advocate for a distinct definition of NBS in order to differentiate them from other similar approaches and most important for those that are not nature-based.

Furthermore, most existing classification systems for NBS often categorise them based on their intended purpose. However, given that NBS are multifunctional, these classifications tend to be inconsistent, as one NBS can serve multiple purposes. Therefore, the CARDIMED classification approach first aims to differentiate NBS from other Non NBS. To do so, based on definitions of [1]EU (2015) and [2]IUCN (2016), a series of criteria to determine if a certain solution can be considered a NBS has been established: **Replicating or supporting natural processes; Providing**

[1] Solutions that are inspired and supported by nature, which 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.
[2] Nature-based solutions address societal challenges through actions to protect, sustainably manage, and restore natural and modified ecosystems, benefiting people and nature at the same time.

social, economic, and environmental benefits; Benefiting both people and biodiversity; Strengthening resilience and promoting sustainable resource management. However, it is important to note that although biodiversity is a key criterion when defining an NBS, it is not considered an intrinsic attribute of each NBS. Instead, biodiversity is viewed as a cross-cutting design feature that should be incorporated across all NBS or through the combination of different NBS. Next, we have developed a 3-level hierarchical classification system (adapted from Castellar et al., 2021), with the primary principle being that an NBS cannot belong to more than one group at the same level. The distinction between NSB and other non NBS and the 3-level hierarchical classification were applied for classifying 34 NBS, deployed across the 9 CARDIMED DEMOs, by consulting a group of CARDIMED NBS experts. Experts were asked to reach a consensus on which group each NBS best suited for each level. They approached this decision with a simple question: What is this NBS? For answering this simple question, experts took into consideration the descriptions provided below for each level.

1. LEVEL 1

At Level 1, the distinction is made between two types of NBS by simply answering the question: Is it an environmentally friendly technology, green spaces, or techniques and management approaches? This question is answered based on the description provided below.

1. NBS units (NBSu)

NBSu are environmentally friendly technologies and green spaces that replicate natural processes and conditions found in nature, these units may function independently or be integrated into larger systems, including other NBS, grey infrastructures, or conventional technologies. Forming complex "living" systems that mimic natural processes, these units offer a wide array of ecosystem services and co-benefits. **CARDIMED NBSu: Subsurface flow constructed wetland, Electrowetland, Free water surface constructed wetland, Sludge constructed wetland, High rate algae pond, Biofiltration columns, Photo Bioreactor, Bioswale, Bioretention cell (rain garden), Filter drain, Porous/Pervious asphalt, Wall-based green facade, Vegetated pergola, Aquaculture, Green corridors, Urban micro forest, Agroforestry.**

2. NBS interventions (NBSi)

NBSi refers to the act of intervening within natural ecosystems, agricultural lands, other NBS, or other green spaces to enhance ecological processes and promote biodiversity. While they serve diverse purposes and offer multiple benefits, these techniques and management approaches are typically customised to achieve specific objectives and are adaptable to the local context, including physical, social, and biological factors. Overall, NBSi contributes to conserving and restoring flora, fauna, aquatic ecosystems, soil quality, and promoting resilient management of diverse land uses. **CARDIMED NBSi: Terracing, Compost application, Mulching application, Cover crops, Crop rotation, Surface unsealing, Sustainable communal grazing, Invasive alien species control, Reintroducing native fauna, Restoring native vegetation, Techniques for fauna refuge and nesting, Dams, Diversion channels, Riparian buffer, Lagoon restoration.**

2. LEVEL 2

At Level 2, for those NBS assigned at Level 1 as NBS units, the distinction is made between technological and spatial NBS units by simply answering the question: Is it an environmentally friendly technology or a green space? The question is answered based on the description provided below:

1. NBS technological units (NBStu)

NBStu encompasses environmentally friendly technologies that include tangible structures designed to deliver targeted features and services, including water infiltration or treatment, thermal and acoustic insulation, and even food production. These structures require attention to design, implementation, operation, and monitoring. They

are versatile and can be deployed across various scales, from ground-level installations to vertical spaces and rooftops. **CARDIMED NBStu: Subsurface flow constructed wetland, Electrowetland, Free water surface constructed wetland, Sludge constructed wetland, High rate algae pond, Biofiltration columns, Photo Bioreactor, Bioswale, Bioretention cell (rain garden), Filter drain, Porous/Pervious asphalt, Wall-based green facade, Vegetated pergola, Aquaculture.**

2. NBS spatial units (NBSsu)

NBSsu consists of the combination of diverse types of vegetation, including arboreal-dominant compositions or mixtures of different vegetation types, to create resilient, and for instance productive, spaces where humans and nature can not only coexist but reconnect. In contrast with NBStu, which can be implemented across different scales, NBSsu is typically presented at ground level. **CARDIMED NBSsu: Green corridors, Urban micro forest, Agroforestry, Urban park.**

Furthermore, at Level 2, for those NBS assigned at Level 1 as NBS interventions, the distinction is made between aquatic, soil, biodiversity, or land use NBS interventions by simply reflecting on the following questions: Is it a technique applied in soil ecosystems, aquatic ecosystems, or is it a technique to enhance fauna and flora? Or is it a management approach for fostering sustainable land use? This reflection is supported by the description provided below.

3. NBS soil interventions (NBSsi)

NBSsi involves intervening in soil ecosystems, utilising diverse techniques applied in natural ecosystems for restoration, as well as in other NBS to amplify their effects, and in agricultural lands for sustainable production. It encompasses bioengineering, soil amendments, and land management techniques aimed at enhancing soil quality by improving its physical, chemical, and biological characteristics. **CARDIMED NBSsi: Terracing, Compost application, Mulching application, Cover crops, Crop rotation, Surface unsealing.**

4. NBS aquatic interventions (NBSai)

NBSai involves intervening in aquatic ecosystems. It includes various fluvial bioengineering techniques applied at both the riverbed and riverbank levels. At the riverbed level, NBSai aims to regulate flow dynamics, divert flow for flood control, prevent erosion, and enhance flow distribution and connectivity. Meanwhile, at the riverbank level, the focus is on conservation and restoration efforts. In both cases, these interventions can significantly contribute to restoring the natural capacity of rivers to recharge aquifers. NBSai can also refer to broader approaches that include a combination of techniques to restore aquatic systems such as rivers, lakes and lagoons. These efforts aim to enhance the resilience and capacity of aquatic ecosystems to support ecological processes and foster preservation of biodiversity. **CARDIMED NBSai: Dams, Diversion channels, Riparian buffer, Lagoon restoration.**

5. NBS biodiversity interventions (NBSbi)

NBSbi encompasses various techniques, either individually or in combination, aimed at enhancing and preserving fauna, flora, microorganisms, and overall increasing the resilience of terrestrial and aquatic systems. Their overarching goal is to foster the restoration, or conservation of resilient ecosystems, ensuring the enduring provision of ecosystem services crucial for humans, wildlife, and the environment. Restoration endeavours also include efforts to mitigate the detrimental impacts of human activities such as deforestation, pollution, and habitat destruction, striving to reinstate the natural equilibrium and functionality of ecosystems. **The impact of all types of NBS (units and interventions) and the resilience of their surroundings can be significantly maximised by their combination with NBSbi**. **CARDIMED NBSbi: Invasive alien species control, Reintroducing native fauna, Restoring native vegetation, Techniques for fauna refuge and nesting.**

6. NBS land use interventions (NBSli)

NBSli includes holistic and integrated approaches to land use management, primarily aimed at enhancing the

resilience and sustainability of urban, peri-urban, and rural landscapes while preserving biodiversity. These approaches are carefully tailored to ensure the proper management and utilisation of NBSsu, NBStu, agricultural lands, and other green spaces, encompassing both public and private lands. Furthermore, they are commonly developed and implemented collaboratively to ensure equity, environmental justice, and accessibility. **CARDIMED NBSli:** **Sustainable communal grazing.**

3. LEVEL 3

At level 3 is made across the following 10 categories build up from past H2020 projects (NATURE4cities, URBANGreenUP, UNALAB and NATURVATION etc):

1. Advanced Ecological Treatments

It encompasses various NBS designed to replicate natural processes for treating diverse types of wastewater and stormwater runoff. Advanced ecological treatments, unlike conventional methods, rely on biological, physical, and chemical mechanisms inherent in natural ecosystems to purify water. Moreover, they are recognized for their ability to offer sustainable, cost-effective alternatives to conventional treatment methods while minimising environmental impact. **CARDIMED NBS:** **Subsurface flow constructed wetland, Electrowetland, Free water surface constructed wetland, Sludge constructed wetland, High rate algae pond, Biofiltration columns, Photo Bioreactor.**

2. Bioretention Systems and Vegetated Buffers

This category includes various nature-based solutions (NBS) designed for sustainable rainwater management. Bioretention systems are engineered to capture and treat stormwater runoff using natural processes. They help reduce runoff, prevent flooding, and support aquifer recharge, surface water discharge, and onsite reuse (e.g., irrigation, industrial uses). Additionally, this category includes vegetated buffers, which intercept pollutants, reduce erosion, and manage runoff. These solutions sustain biodiversity, support ecosystem services, and enhance landscape resilience to climate change. Unlike traditional grey infrastructure, both bioretention systems and vegetated buffers mimic natural hydrological processes, offering additional benefits such as habitat creation, aesthetic enhancement, and improved climate resilience. **CARDIMED NBS:** **Bioswale, Bioretention cell (rain garden), Filter drain, Riparian buffer.**

3. Permeable Surfaces

Includes innovative solutions for enhancing rainwater management by reducing impermeable surface areas compared to traditional paving. This category encompasses solutions aimed at replacing impermeable surfaces with more previous alternatives, which replicates the natural process of infiltration, or techniques to increase the natural capacity of the soil to infiltrate water. Both types of solutions aim to control stormwater, minimise runoff, prevent surface water stagnation, and if applicable enhance water quality through additional filtration mechanisms. While these solutions are often associated with urban settings, including pedestrian pathways, cycling routes and car parks, due to the pressing need for effective stormwater management in cities, they can also be implemented in non-urban areas. **CARDIMED NBS:** **Porous/Pervious asphalt, Surface unsealing.**

4. Vertical Greenery Systems

Includes functional structures designed to incorporate vegetation into vertical surfaces or overhead structures. These systems enhance aesthetic value, provide thermal regulation and shading effects, acoustic isolation, and increase air quality and biodiversity. They typically consist of modular panels or trays containing a variety of plants, or plants can be planted in vessels on the ground and allowed to climb the structure using specially designed elements such as trellises, wire meshes, or climbing frames. They can be installed indoors or outdoors, in a range of settings including residential, commercial, and public spaces. Additionally, feature overhead structures adorned with climbing plants can provide shade, greenery, and a natural ambiance to outdoor spaces. These systems are

adaptable and can be customised to suit specific design requirements, with options for different plant species, irrigation methods, and maintenance regimes. Overall, these systems represent an innovative and sustainable approach to urban design, contributing to the creation of healthier, more livable cities. **CARDIMED NBS: Wall based green facade, Vegetated pergola.**

5. Greenery Elements

These NBS are designed to enhance green spaces and promote wildlife conservation across diverse landscapes, including urban, peri-urban, and rural areas. These solutions aim to create natural habitats, bolster the resilience of ecosystems, and enhance the aesthetics of spaces, while providing benefits such as improved air quality, stormwater management, mitigation of the urban heat island effect, and support for biodiversity. **CARDIMED NBS: Green corridors, Urban micro forest, Urban park.**

6. Farming Practices

Encompass diverse techniques and technologies designed to enhance productivity while ensuring sustainability. Additionally, resilient and productive spaces aim to promote the sustainable use of natural resources such as land, water, and nutrients for various agricultural activities. These solutions typically involve methods that enhance soil health, conserve water, reduce reliance on synthetic inputs, and mitigate the adverse environmental effects of farming. **CARDIMED NBS: Aquaculture, Agroforestry, Cover crops, Crop rotation, Sustainable communal grazing.**

7. Organic Soil Amendments encompass

NBS aimed at enhancing soil structure and fertility to improve soil health, support biodiversity, and reduce reliance on synthetic inputs, leading to more resilient and environmentally-friendly practices compared to conventional chemical soil amendments. **CARDIMED NBS: Compost application, Mulching application.**

8. Slope Stabilisation and Erosion Control

This category comprises a variety of NBS focused on sustainable land use and conservation, incorporating diverse engineering techniques. These methods are designed to prevent soil erosion and manage rainwater runoff efficiently while minimising disruption to the surrounding landscape. Some techniques focus specifically on effectively managing sloped terrain while other techniques such as vegetative stabilisation and bioengineering are often employed to enhance biodiversity and ecosystem resilience, ensuring that interventions align with long-term environmental sustainability objectives **CARDIMED NBS: Terracing.**

9. Aquatic Ecosystem Management Strategies

These NBS aim to balance human needs with ecosystem health while promoting sustainable water resource management and flood control across aquatic ecosystems. Unlike conventional approaches that heavily rely on structural interventions, these techniques emphasise nature's inherent ability to regulate aquatic systems, enhancing resilience and minimising negative environmental impacts. By implementing these solutions, aquatic ecosystems can better adapt to changing conditions, ensuring long-term sustainability for both human communities and the local environment. **CARDIMED NBS: Dams, Diversion channels.**

10. Conservation and restoration of ecosystems

This category includes diverse techniques for preserving and restoring both fauna and flora within ecosystems. It encompasses the management and removal of non-native plants that disrupt native ecosystems, and techniques for reintroducing indigenous plant species to their natural habitats to enhance biodiversity and ecosystem resilience. Additionally, it involves techniques for fauna refuge and nesting, which aim to provide habitats and nesting sites for various animal species, and the reintroduction of indigenous animal species to their natural habitats. Moreover, this category also includes NBS that combines several techniques for the restoration and conservation of both aquatic and terrestrial ecosystems, ensuring a holistic approach to ecosystem health and stability. **CARDIMED NBS: Techniques for fauna refuge and nesting, Reintroducing native fauna. Invasive alien species control, Restoring native vegetation, Lagoon restoration.**

Note that at Level 3, different NBS may be assigned to the same category. For instance, Aquaculture (NBStu), Agroforestry (NBSsu), Compost and mulching application (NBSsi), and sustainable communal grazing (NBSli) were all assigned to the category of **farming practices** at Level 3, despite belonging to different types of NBS at Levels 1 and 2. The same principle applies to permeable surfaces, which include porous asphalt (NBStu) and surface unsealing (NBSsi). This underscores the significance of the CARDIMED classification system, as it recognizes the multifunctionality of NBS from a broader perspective. Different types of NBS can contribute in various ways to a common application, showcasing the versatility and effectiveness of incorporating diverse NBS solutions. Finally, an overview of the classification systems used to classify CARDIMED NBS can be seen in Figure 1.

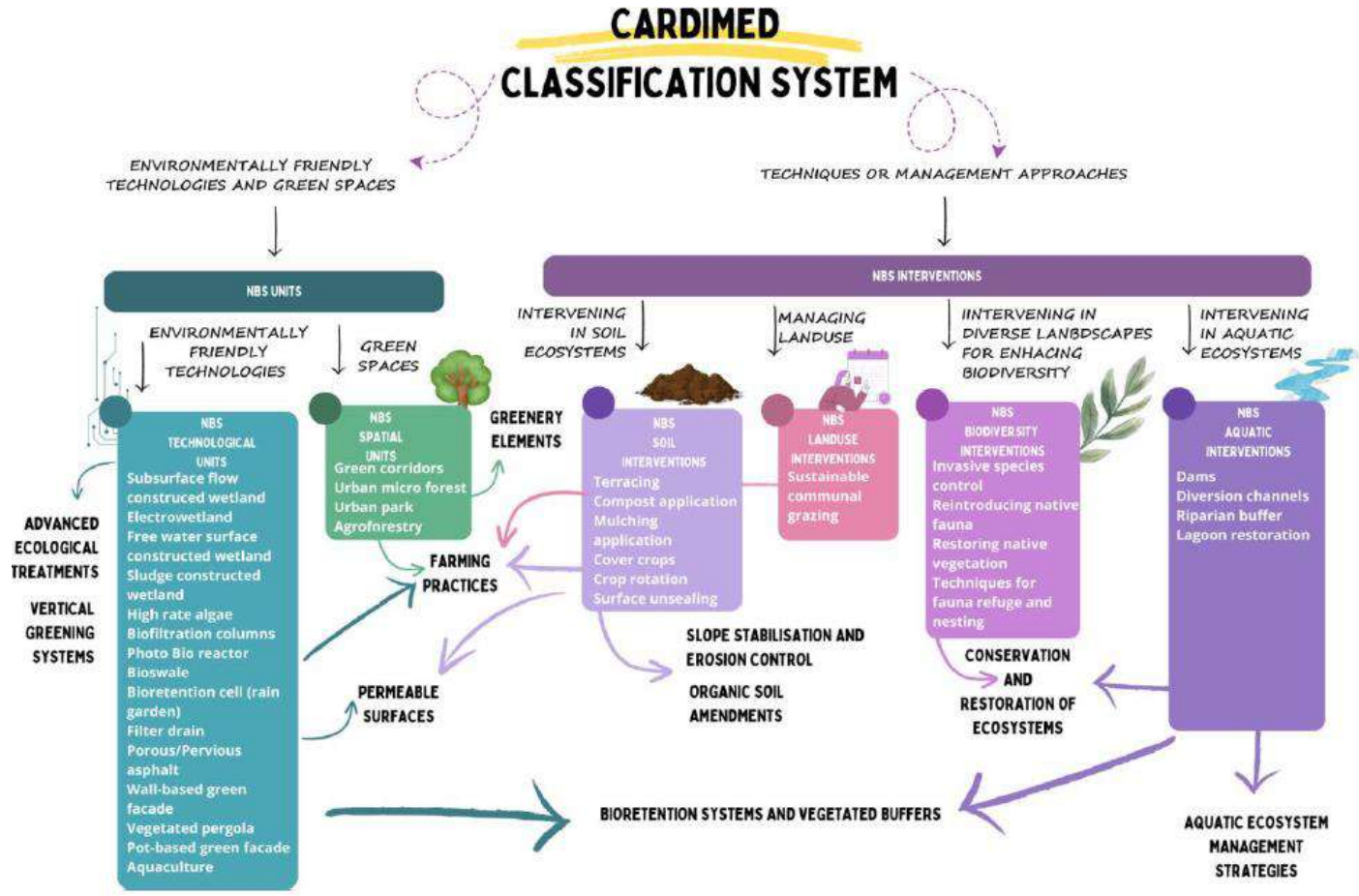


Figure 1. CARDIMED NBS classification system.

1.2 Methodology

As shown in Figure 2, the CARDIMED NBS catalogue is meticulously organised into two sections: CARDIMED - NBS factsheets, featuring 34 NBS factsheets (section 2) and CARDIMED - NBS systems factsheets featuring 19 NBS systems factsheets, which showcases information regarding the diverse combination of NBS deployed in each of the 9 CARDIMED DEMOs (section 3). For each type of factsheet, a distinct methodological framework was adopted, as explained in sequence.

For the **NBS factsheets**, a systematic expert-literature based approach was employed, ensuring accuracy and consistency. Initially, input from CARDIMED partners was collected via a survey to identify preferred content. An initial draft of the factsheets was then developed, prioritising information drawn from scientific literature, NBS Horizon 2020 project reports, and technical guidelines. Subsequently, experts from various NBS domains were

selected through a consortium-wide survey, with 15 experts chosen to contribute to the development of generic NBS factsheets. CARDIMED experts refined the draft and harmonised any discrepancies. Finally, a normalisation process was applied to ensure data uniformity across different fields, facilitating easy comparisons between the differences in NBS factsheets. This mixed approach ensures the catalogue offers comprehensive and standardised insights into NBS within the CARDIMED project, effectively consolidating expert perspectives and existing knowledge.

For the **NBS systems factsheets**, an interactive approach was employed, leveraging a dedicated database with normalised options wherever possible to maintain consistency. Normalisation was conducted based on literature findings (see references section) and expert inputs, covering aspects such as types of water sources, water applications, types of supportive units, stakeholders, and more. Additionally, a list of potential barriers for NBS implementation was defined based on (Castellar et al. 2024). DEMO representatives actively contributed to filling in the database. Based on this primary data, initial drafts of the sub-DEMOs factsheets were meticulously crafted (some CARDIMED DEMOs consist of NBS implementations at different geographical locations, denoted as sub DEMOs). Sub-DEMO representatives then conducted thorough reviews, making adjustments as necessary. In addition, a semi-qualitative/quantitative assessment was conducted to evaluate each sub-DEMO's potential in addressing diverse challenges. First, this process yielded a thorough inventory of 10 challenges to be addressed by NBS derived from relevant frameworks and scientific research on the topic (Past Horizon projects - NATURE4Cities (2020), UNALAB (2019), URBANGreenUP (2018), and NATURVATION (2022) - Raymond et al. 2017 , Castellar et al. 2021, and Langergraber and Castellar et al. 2021). A brief description of the CARDIMED challenges can be seen below:

1. **Freshwater and groundwater supply and quality:** This challenge contemplates the potential contributions of NBS to promote both natural and artificial aquifer and surface water recharge, improve the quality of surface and groundwaters, reduce water withdrawals, enable onsite water reuse, reduced water footprint and ensure efficient treatment of various water types (i.e. combined sewage overflow, agricultural, industrial, and domestic wastewater, greywater, landfill leachate, agricultural, urban runoffs and rainwater.
2. **Rainwater management and flood control:** This challenge contemplates the potential contributions of NBS to stormwater source control and reducing flood risk, sediment flow into drainage systems, combined sewer overflows, landslide events, urban and agricultural runoff, and protecting against river and coastal floods, while also restoring permeability and promoting the harvesting, storing, and treatment of rainwater.
3. **Biodiversity and renaturalization:** This challenge contemplates the potential contributions of NBS to create or restore habitats, recover degraded areas, fauna, and flora, mitigate desertification, support pollination, create and restore wetlands, forests, and mangroves, provide nutrition sources for birds and insects, connect green and blue spaces, develop resilience of green spaces, support free movement of species, provide nesting and breeding habitats, refuge for farm and wild animals, restore natural forest fire regimes, and promote coastal restoration and resilience against natural disasters.
4. **Aquatic ecosystems restoration and protection:** This challenge contemplates the potential contributions of NBS to re-establish hydrologic connections, improve hydromorphological functioning, restore aquatic habitats, reduce sediment flow and deposition in rivers, and enhance and stabilise water flow to sustain river systems. 5. **Soil restoration and protection:** This challenge contemplates the potential contributions of NBS to reduce changes in soil characteristics, stabilise soil and substrate, improve soil fertility and biodiversity, enhance and stabilise water retention, and rehabilitate polluted soil.
6. **Air quality:** This challenge contemplates the potential contributions of NBS to improve carbon sequestration, reduced carbon footprint, reduce particles (PM10), enhance dry deposition of aerosol particles, and reduce or avoid BVOC emissions.
7. **Thermal Regulation:** This challenge encompasses the potential contributions of NBS to providing thermal regulation and cooling, as well as offering thermal isolation solutions.
8. **Societal benefits:** This challenge contemplates the potential contributions of NBS to improving health and well-being, increasing recreational and socialisation value, enhancing aesthetic, cultural, and patrimonial value,

ensuring accessibility to green spaces, preserving cultural and historic heritage, facilitating education, reducing undesired behaviours, activities, and vandalism, supporting social cohesion and justice, fostering environmental awareness, increasing stakeholder engagement, enhancing acoustic comfort, promoting physical and mental health, reconnecting people with nature, promoting healthy habits, and reducing the risk of pests and diseases. However, it is worth mentioning that even though some NBS have inherent potential to contribute to many societal benefits, it's extremely important to consider that these benefits do not solely depend on the NBS itself. They also rely on potential supportive actions that can be implemented during the design, implementation, and operation of the NBS, such as hands-on events, co-design/participatory sessions, open-door events, capacity building and training initiatives, social gatherings, and more. These supportive actions are crucial for maximising the social impact of NBS.

9. **Local Development & Economic Enhancement:** This challenge considers the potential contributions of NBS to local employment, increased land/property value, tourism growth, business support, cost-effectiveness compared to alternatives, promotion of the green economy through local by-product reuse, and production of biochemicals, natural medicines, and pharmaceuticals.

10. **Sustainable Practices, Resource Recovery and Valorization:** This challenge encompasses the potential contributions of NBS to various aspects, including the production of biomass, provision of raw materials, nutrient recovery, energy production or demand reduction, material reuse, provision of genetic resources and promotion of sustainable food production.

Figure 2. CARDIMED - climate resilience challenges.

After the challenge`s definitions were set, DEMO representatives assessed the contribution of different NBS within their sub-DEMOs using a cross-referenced matrix that aligned each challenge with each NBS. By collecting the perceptions of the people involved in the implementation and operation of the NBS in the DEMOs, we gain valuable insights into their potential to address pre-established challenges, especially those related to social benefits, biodiversity, renaturalization contributions, and local development and economic enhancement. The latter aspects are highly dependent on the specific local context in which these NBS are being implemented. Following this, NBS experts conducted a thorough evaluation of each NBS's potential contribution to the challenges, drawing on practical experience, perceptions collected from DEMO representatives (cross-referenced matrix), and information provided in NBS factsheets and sub-DEMO factsheets. Any ambiguities were clarified with DEMO representatives, ensuring the reliability and accuracy of the evaluation process. In this evaluation process, the contribution of each NBS within sub-DEMOs to the challenge was attributed a score as follows: not significant (Score 0), low (Score 0.25), medium (Score 0.5), high contribution (Score 1.0). The overall contribution of an NBS to a specific challenge was measured as their averaged contribution to all specific challenges within that challenge category (excluding those rated as not significant). The overall contribution of the sub-DEMOs for the general challenges was estimated by averaging the results of each NBS. The potential provision of ecosystem services of each sub-DEMO was determined based on the results of the challenges assessment, specifically focusing on challenges where any NBS from the sub-DEMO made a high contribution. These specific challenges were further categorised as the highest level of CICES classification: provisioning, regulating and maintenance, and cultural (EEA, 2018). Finally, a consensus of experts also assigned the potential contribution of sub-DEMOs to SDGs using a binary logic (*yes*, if it has a contribution or *no*, if it does not).

Figure 3 provides a summary of the procedures undertaken to develop the factsheets. In addition to these procedures following CARDIMED internal deliverable reviewing systems, the deliverable underwent internal review by partners, and necessary changes were made before submission to the European Commission.

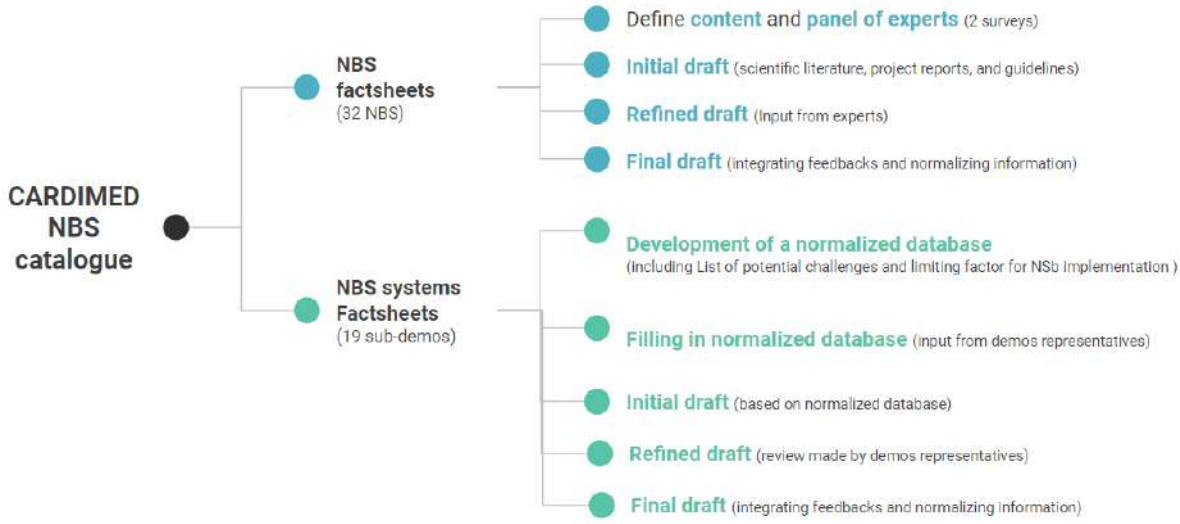


Figure 3. CARDIMED NBS catalogue: structure, data collection and analysis.

2. CARDIMED - NBS factsheets

This section showcases 34 factsheets (18 NBS units & 15 NBS interventions) that will be deployed across the 9 DEMOs of CARDIMED. These factsheets are crafted to offer comprehensive insights into the diverse array of NBS interventions and units employed within the project, fostering a deeper understanding of their efficacy and impact. In the table below, some of the main information is summarized and then reported in more detail in the specific NBS factsheet (section 2). Each name of the NBSs is linked with the corresponding factsheet.

Name & description	Synonyms	Main challenges targeted	Combinations with other NBS	Treatment Efficiency	CAPEX	OPEX
NBS Technological units: Advanced ecological treatments						
Subsurface flow constructed wetland: Natural system treating wastewater through vegetated subsurface filtration flow	Constructed wetland, vertical flow treatment wetland	Freshwater and groundwater supply and quality, Biodiversity & renaturalization	Wetland systems, or compost application	COD: 80-95%; BOD_5: 85-98%; TSS: 80-95%; NH_4^+: 85-99%; NO_3-: > 80%; TP: 35-75%	80-200 €/m^2	2-5 €/m^2 y
Electroactive constructed wetland: Constructed wetland generating electricity via microbial electroactive processes	Electroconductive wetlands; Electroactive biofilm-based constructed wetland (EABB-CW)	Freshwater and groundwater supply and quality, Biodiversity & renaturalization	Subsurface flow constructed wetland, compost application, agroforestry	COD: 80-90%; BOD_5: 85-90%; NH_4^+: > 90%	930 €/m^2	n.a.
Free water surface constructed wetland: Engineered shallow wetland treating wastewater through natural surface processes	Free water surface treatment wetland; surface flow constructed wetland.	Freshwater and groundwater supply and quality, Biodiversity & renaturalization	Wetland systems, compost application, agroforestry	COD: 41- 90%; BOD_5: ~54%; TN: 30- 80%; NH_4-N: ~73%; TP: 27-60%	30 - 70 €/m^2	0.5 - 2 €/m^2 y.
Sludge treatment wetland: Natural system dewatering and stabilising sludge through biological and physical processes	Sludge Drying Reed Beds; Sludge Treatment Reed Beds	Resources recovery & valorization, Soil restoration & protection	Compost application, agroforesty	n.a.	100 - 200 €/m^2	2-5 €/m^2 y
High rate algae ponds: Engineered pond treating wastewater while cultivating nutrient-absorbing algae	-	Sustainable practices, resources recovery & valorization	Photo bio-reactors, compost application	COD: 40 - 80%; NH_4-N: 80 - 100%; PO_4^{3-}: 30 - 80%	n.a.	n.a.
Biofiltration columns: Vegetated system filtering stormwater and	Biofilter, stormwater biofilters	Freshwater and groundwater supply and	Compost application, bioswale	n.a.	n.a.	n.a.

Name & description	Synonyms	Main challenges targeted	Combinations with other NBS	Treatment Efficiency	CAPEX	OPEX
wastewater, reducing pollutants and runoff		quality, Rainwater management & flood protection				
Photo bio reactor: Closed system cultivating photosynthetic microorganisms to treat wastewater and produce biomass	Microalgae bioreactor, Microalgal cultivation	Freshwater and groundwater supply and quality, Sustainable practices	Wetland systems, bioswale & agroforestry	n.a.	n.a.	n.a.
NBS Technological units: Bioretention systems						
Bioretention cell (rain garden): Shallow vegetated depressions capturing and treating stormwater runoff naturally	Pluvial beds; Infiltration/stormwater planters	Rainwater management & flood protection, Biodiversity & renaturalization	Mulching/ compost application, Green corridors	NH3: 84,6%; Cd: 80-90%; Cu: 80-90%; Pb: 0-90%; Zn: 80-90%; PAHs: 70-90%	100-300 €/m2	2-5 €/m2
Bioswale: Vegetated, sloped channel capturing and filtering stormwater runoff naturally	Vegetative filter, grassed swales	Rainwater management & flood protection, Air quality	Green corridors, restoring native vegetation	TSS: 63-85% ; TN:46-67% ; TP: 40-99%	13 - 122 €/m^2	1 - 5 €/m^2 y
Filter drain: Shallow gravel-filled trench storing, conveying, and filtering surface water runoff	Subsurface rainwater collector, surface sand filter	Rainwater management & flood protection, Freshwater and groundwater supply and quality	Bioretention cells (rain gardens), bioswales and riparian buffer	30-50% TSS	80 - 200 €/m^2	0.5-3 €/m^2 y
NBS Technological units: Permeable surfaces						
Porous asphalt: Permeable paving system allowing water infiltration to	Hard drainage pavements, modular	Rainwater management & flood protection,	Bioretention cells, terracing	n.a.	45-120 €/m^2	0.5-65 €/m^2 y.

Name & description	Synonyms	Main challenges targeted	Combinations with other NBS	Treatment Efficiency	CAPEX	OPEX
reduce runoff	permeable paving, grass reinforcement	Freshwater and groundwater supply and quality				
NBS Technological units: Vertical greening systems						
Wall-based green facade: Vertical greening panels supporting diverse plants on building or wall surfaces	Living wall, hydroponic green facade	Thermal regulation, Air quality	Green corridors, bioretention cells	n.a.	1000-1200 €/m^2	10-70 €/m^2 y
Vegetated pergola: Architectural structure providing shade and supporting climbing plant growth	Eco-friendly pergola; Plant-filled pergola	Biodiversity & Renaturalization, Thermal regulation, Air quality	Wall-based green facade, compost/mulching application	n.a.	n.a.	n.a.
NBS Technological units: Farming practices						
Aquaculture: Farming aquatic organisms with controlled management for food production	Recirculating Aquaculture Systems (RAS); Integrated multi trophic aquaculture (IMTA)	Biodiversity & renaturalization and Local Development & Economic Enhancement	Riparian Buffer, wetland systems and High rate algae pond	n.a.	10,000.00 - 20.00,000.00 €.	5,000.00 - 5,000,000.00 €/y
NBS Spatial units: Greenery elements						
Green corridors: Linear green spaces converting unused areas to enhance connectivity and wildlife	Cycle-pedestrian green paths; Green belt, Carbon sinks,	Biodiversity & Renaturalization, Freshwater and groundwater supply and quality, Societal benefits	Vegetated pergola, urban-microforest, riparian buffer	n.a.	n.a.	n.a.

Name & description	Synonyms	Main challenges targeted	Combinations with other NBS	Treatment Efficiency	CAPEX	OPEX
Urban micro forest: Small urban green areas mimicking natural forests with diverse vegetation	City parks, Arboreal areas around urban areas	Biodiversity & Renaturalization, Rainwater management & flood protection and Societal benefits	Bioretention cells, compost/mulching application	n.a.	n.a.	n.a.
Urban parks: City green spaces providing recreational and social opportunities for residents	Greened recreation areas/regional parks; Green resting areas	Biodiversity & Renaturalization, Rainwater management & flood protection	Vegetated pergola urban micro forest, compost/mulching application	n.a.	80 - 1000 €/m^2	3 - 45 €/m^2 y
NBS Spatial units: Farming practices						
Agroforesty: Integrated land system combining trees and crops for sustainability and biodiversity	Alley Cropping, Agroecology practices	Biodiversity & renaturalization, Local Development & Economic Enhancement	Crop rotation, riparian buffer, wetlands	n.a.	1,000.00 - 100,000.00 € ha	5,000.00 - 200,000.00 € y
NBS Biodiversity interventions: Conservation and restoration of flora and fauna						
Invasive alien species control: Management practices aimed at reducing or eradicating harmful non-native species	Management of invasive alien species; Clearing invasive alien trees	Biodiversity & Renaturalization, Societal benefits	Other NBS of biodiversity interventions, riparian buffer	n.a.	n.a.	n.a.
Restoring native vegetation: Reestablishing native plants to restore ecosystems to healthy conditions	Reforestation, planting native vegetation	Biodiversity & Renaturalization, Societal benefits, freshwater and groundwater	Other NBS of biodiversity interventions, riparian buffer	n.a.	n.a.	n.a.

Name & description	Synonyms	Main challenges targeted	Combinations with other NBS	Treatment Efficiency	CAPEX	OPEX
Techniques for fauna refuge and nesting: Structures and habitats providing shelter and nesting to support biodiversity conservation	Insect hotel, practices for enhancing wildlife	Biodiversity & renaturalization, Societal benefits	Other NBS of biodiversity interventions, riparian buffer, Agroforestry	n.a.	n.a.	n.a.
Reintroduction of native fauna: Returning native animal species to their natural habitats to restore biodiversity	Wildlife reintroduction, reintroduction of animals	Biodiversity & renaturalization, Societal benefits	Other NBS of biodiversity interventions	n.a.	n.a.	n.a.
NBS Soil interventions: Permeable surfaces						
Surface unsealing: Removing impermeable surfaces to restore soil permeability and reduce runoff	De-sealed area, demineralization	Air quality, Soil restoration & protection	Porous asphalt, bioretention cell	n.a.	10 - 30 €/m^2	n.a.
Organic soil amendments: Applying organic compost to improve soil fertility, structure, and water retention	Community composting, soil improvement and conservation	Soil restoration & protection	Green corridors, agroforestry	n.a.	n.a.	n.a.
Mulching Application: Applying a protective soil layer to conserve moisture, reduce erosion, and weeds	Weeds management, soil improvement and conservation	Biodiversity & renaturalization, Rainwater management & flood protection	Bioretention cell, agroforestry, mulching application	n.a.	0.75 - 2 €/m^2	0.15 - 0.5 €/m2 y
NBS Soil and Land use interventions: Farming practices & Land management techniques						
Cover crops: Crops planted to protect soil, improve fertility, prevent erosion, and weeds	Green manure, Soil management	Biodiversity & renaturalization and Societal benefits	Crop rotation, Agroforestry	n.a.	20 - 180 €/ha	n.a.

Name & description	Synonyms	Main challenges targeted	Combinations with other NBS	Treatment Efficiency	CAPEX	OPEX
Crop rotation: Alternating different crops on the same land to improve soil and yields	Crop diversification, conservation agriculture	Biodiversity & renaturalization, Societal benefits, Soil restoration & protection	Compost/mulching application, cover crop	n.a.	1,000 - 20,000 €	200 - 350 €/ha y
Terracing: Constructing stepped platforms on slopes to reduce erosion and retain water	Terraces	Rainwater management & flood protection, Biodiversity & renaturalization, Societal benefits	Cover crop, urban mucro-forest, porous asphalt	n.a.	n.a.	n.a.
Sustainable communal grazing: Collaborative grazing management ensuring fair, balanced, and sustainable pasture use	Sustainable grazing, communal grazing	Biodiversity & renaturalization, Societal benefits	Agroforestry, invasive alien species control	n.a.	n.a.	n.a.
NBS Aquatic interventions: Riverbank measures and rehabilitation of aquatic ecosystems						
Riparian buffer: Vegetated strip along waterways reducing runoff, sediments, and pollutant flow	Vegetative filter strips, buffer strips	Biodiversity & renaturalization, Rainwater management & flood protection	Restoring native flora & fauna, mulching application, urban micro forest	TN: 25-97%; TP: 55-94%; TSS: 75-97%	100 - 2000 €/ha	20-500 €/ha y
Diversion Channels: Artificial channels redirecting water to prevent flooding, erosion, and landslides	Redirecting channels, channelling conduits	Freshwater and groundwater supply and quality, Rainwater management & flood protection	Dams, Bioswale, Riparian Buffer	n.a.	n.a.	n.a.
Dams: Low-cost structures capturing rainwater to boost groundwater and	Stone weirs, Riverbank erosion control and	Rainwater management & flood protection,	Bioswale, Diversion channels	n.a.	n.a.	n.a.

Name & description	Synonyms	Main challenges targeted	Combinations with other NBS	Treatment Efficiency	CAPEX	OPEX
land productivity	water harvesting structures	Biodiversity & renaturalization				
Lagoon Restoration: Restoring degraded lagoon ecosystems to improve biodiversity and ecological resilience	Restoring coastal lagoon, coastal wetlands restoration	Biodiversity & renaturalization, Local Development	Restoring native flora and fauna, riparian buffer	n.a.	n.a.	n.a.

2.1 NBS Technological units

This section presents **14 factsheets** related to **NBS Technological units**, highlighting innovative technological solutions integrated into the project regarding **Advanced Ecological Treatments**, **Bioretention Systems**, **Permeable Surfaces, Vertical Greening Systems**, and **Farming Practices.**

ADVANCED ECOLOGICAL TREATMENTS

CARDIMED	1. SUBSURFACE FLOW CONSTRUCTED WETLAND

Synonyms: Vertical flow treatment wetland; horizontal flow treatment wetland; vertical subsurface flow constructed wetland; horizontal subsurface flow constructed; Constructed wetlands. **Description:** There can be various configurations of Subsurface Flow Constructed Wetlands (SSF CWs). They can be vertical or horizontal and saturated or unsaturated. Typically, saturated SSF CWs are fed continuously and no oxygenation is provided from other sources than plants' roots, while unsaturated SSF CWs are vertical so they can be fed intermittently (fill & drain). During the resting period, air flows through the pores, providing oxygenation to the filter and promoting aerobic biodegradation and nitrification processes. Nowadays CWs are proven to be a robust and reliable technology for addressing all the common parameters: COD, BOD_5, TSS, NH_4^+, NO_3^-, PO^{3-} (partially), at the same level and often with more stable performances than other conventional biological treatment technologies; they are also providing interesting results with the removal of the persistent organic pollutants and most of the CECs in general; they also contribute to disinfection although not sufficiently if the effluents are going to be reused. Properly designed combinations of CWs can operate also with very high loads of biologically treatable compounds, as in some industrial wastewater (food industry, oil sector, chemical sector, and so on). The lifespan when operated properly ranges from 10 to 50 years. Picture source: IRIDRA

Main challenges targeted	Freshwater and groundwater supply and quality, Biodiversity & renaturalization, Sustainable practices, resources recovery & valorization ,
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Improve carbon sequestration, Support pollination, Develop resilience of green spaces, Support free movement of species, Reduce harmful impacts to fauna & flora, Wetland creation and/or restoration, Improve soil fertility / biodiversity, Provide thermal regulation / cooling
Cultural Services	Facilitate education, Support environmental awareness, Health and Well-Being improvement, Promote mental health, Reconnect people with nature, Aesthetic values, Recreation and ecotourism, Social relations.
Provisioning Services	Water reuse, Preserve groundwater and surface waters supply, Nutrient recovery, Produce energy / Reduce energy demand,Provide nutrition sources for birds and insects, Provide raw material, Production of biomass
Other services	Reduced costs in comparison with other solutions, Contribute to local employment, Contribute to new or existing business, Favour green economy (reuse

	of local by-products), Reduced water footprint
Replicability	★★★
Design & planning	**Plants:** *Phragmites Australis, Typha spp., Echinochloa spp., Scirpus Lacustris, Iris Pseudacorus* and other macrophytes. **Media type:** Coarse sand and gravel. **Hydraulic conductivity:** $10^{-3} – 10^{-2}$ m/s (gravel); $10^{-5} – 10^{-4}$ m/s (sand). **Media depth:** 70 – 100 cm. **HLR:** <80 (L/m^2-d). **Type of layers:** bed is separated on gravel layers (5 – 10 mm and 16 – 32 mm) in the case of saturated systems, sand layer is also used in the case of intermittently fed vertical SSF CWs (0.5 – 4 mm).
Operation and maintenance	**Operational activities:** Inspection of intermittent loading in the tank before and after each loading, verification of pre-treatment step optimal performance so that suspended solids will not cause clogging of the constructed wetland bed. **Maintenance activities:** Annual removal of invasive plants. Verification of the proper wastewater percolation through the bed Removal of sludge from primary treatment. Occasionally Pruning plants every 2-3 years. **Others**: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	Combinations of different **Treatment Wetland types**, just making use of their different and specific processing capacities depending on the desired targets, are very common in real scale implementations of NBSs. As an example, Vertical flow constructed wetlands are inserted in the combination when there is the need of strong oxidising aerobic environments (nitrification, organics oxidation, etc), while **Free water surface constructed wetland** can be used for a final disinfection or enhanced denitrification (together with HF CWs) as also for CECs removal. **Electroactive constructed wetland** can be used when there is the need to substantially reduce the footprint, up to 5 times in comparison with passive CW types. **Sludge treatment wetlands** can be added to classic activated sludge treatment plants or even for working with primary sludge or faecal sludge, still in combination with **Subsurface flow constructed wetland** (for enhancing treatment efficiency and sustainability). These NBSs can serve as a source of biomass that can be used for **Compost application, mulching application, Agroforestry** (for enhancing sustainability of food production and improving soil quality) This NBS can provide treated water for diverse NBS such as **Agroforestry, Green corridors, urban micro forest (**for enhancing sustainability of water management) **Porous/pervious asphalt, surface unsealing, riparian buffer, bioretention cells (raingarden), bioswale** and **filter drain** (for integrated stormwater management).
Supportive units & smart tech	**Advanced water treatments** (filtration membranes, reverse osmosis, biochar or activated carbon filters and oxidation process to enhance pollutant removal). **Rainwater harvesting systems** (for enhanced rainwater management and treatment). **Remote sensing by IoT** (for real-time monitoring of water quality and

	hydraulic parameters). **Solar panels** (for reducing energy costs and enhancing overall sustainability). **Artificial intelligence** (for predictive modelling and adaptive management, coupled with remote sensing). **Septic tanks, screening, grit removal, detention vaults and tanks** (for increased treatment efficiency and capacity).
Treatment efficiency	**COD: 80-95%; BOD_5: 85-98%; TSS: 80-95%; NH_4^+: 85-99%; NO_3^-: > 80%; TP: 35-75%**
CAPEX	80-200 €/m^2. Main type of costs: Equipment and materials (grid, sedimentation tank, grit chamber, detention vaults and tanks, first flush tank, septic tank, pumps, pipes, geomembranes, filter media, lining materials and monitoring and control devices); Permits, fees and administrative (land acquisition); Labour (soil levelling and land excavation).
OPEX	2-5 €/m^2 y. Main type of costs: Utilities (electricity); Labour (operation and monitoring, sludge removal, reed harvesting, green space maintenance).
By-product(s):	Harvested reeds as biomass (for composting /agricultural uses).

CARDIMED

2. ELECTROACTIVE CONSTRUCTED WETLAND

Synonyms: Electroactive constructed wetland; Electroconductive wetlands; Electroactive biofilm-based constructed wetland (EABB-CW); Electroactive constructed wetlands; Electroactive wetland. **Description:** Electroactive constructed wetlands are bioelectrochemical systems integrated in constructed wetlands. They accommodate a diverse microbial community in which each microbe sets their own potential to further participate in electron transfer, aided by conductive filling media. In some types of electroactive wetlands artificial electron acceptors are located in the anaerobic regions of the reactor, which accommodate faster microbial metabolism for some pollutants. Further, the electron transfer from anaerobic to aerobic regions through an electrical circuit results in electricity generation, even though with very low yields. By contrast, the electroconductive coke-based CWs are just reducing the treatment volume in comparison with passive systems, making them comparable with Aerated CWs. Picture source: IRIDRA/NTUA/Hydrousa

Main challenges targeted	Freshwater and groundwater supply and quality, Biodiversity & renaturalization, Sustainable practices, resources recovery & valorization
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Improve carbon sequestration, Support pollination, Develop resilience of green spaces, Reduce harmful impacts to fauna & flora, Wetland creation and/or restoration, Provide thermal regulation / cooling, Habitat for species
Cultural Services	Facilitate education, Support environmental awareness, Health and Well-Being improvement, Promote mental health, Reconnect people with nature, Aesthetic values, Recreation and ecotourism.

Provisioning Services	Water reuse, Preserve groundwater and surface waters supply, provide nutrition sources for birds and insects, Nutrient recovery, Produce energy / Reduce energy demand, Provide raw material, Production of biomass
Other Services	Reduced costs in comparison with other solutions, Contribute to local employment, Contribute to new or existing business, Favour green economy (reuse of local by-products), Reduced water footprint.
Replicability	★☆☆
Design & planning	**Plants:** *Phragmites spp.*, *Typha spp.* and *Scirpus spp.* **Type of layer:** Electroconductive filled main layer supported by siliceous gravel on top and bottom. **Total layer:** 100 cm. **Filter media:** Top and bottom layers from siliceous gravel (3-10 mm top; 10-30 bottom). Main filter of electroconductive material (3-10 mm, unsaturated beds; 10-30 mm saturated beds)
Operation and maintenance	Regular documentation of maintenance activities, operational issues, and measurements. **Operational activities:** Inspection of intermittent loading in the tank before and after each loading, Verification of the proper wastewater percolation through the bed. verification of pre-treatment step optimal performance so that suspended solids won't cause clogging. **Maintenance activities:** Annually removal of invasive plants. Occasional pruning plants every 2-3 years. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Subsurface flow constructed wetland** (for enhancing treatment efficiency and sustainability). These NBSs can serve as a source of biomass that can be used for **Compost application, mulching application, Agroforestry** (for enhancing sustainability of food production and improving soil quality). This NBS can provide treated water for diverse NBS such as **Agroforestry, Green corridors, urban micro forest**, (for enhancing sustainability of water management).
Supportive units & smart tech	**Advanced water treatments** (filtration membranes, reverse osmosis, biochar or activated carbon filters and oxidation process to enhance pollutant removal). **Remote sensing** (for real-time monitoring of water quality and hydraulic parameters). **Solar panels** (for reducing energy costs and enhancing overall sustainability). **Artificial intelligence** (for predictive modelling and adaptive management). **Septic tanks, screening, grit removal, detention vaults and tanks** (for increased treatment efficiency and capacity).
Treatment efficiency	**COD: 80-90%; BOD_5: 85-90%; NH_4^+: > 90%**

CAPEX	930 €/m^2. Main type of costs: Equipment and materials (grid, sedimentation tank, grit chamber, detention vaults and tanks, septic tank, pumps, pipes, geomembranes, electrodes or electroconductive media, power supply systems, monitoring and control devices, geomembranes, pipes, electrode supports, filter media and lining materials); Permits, fees and administrative (land acquisition); Labour (soil levelling and land excavation).
OPEX	*not available.* Main type of costs: Utilities (electricity); Labour (operation and monitoring, sludge removal, reed harvesting, green space maintenance).
By-product(s):	Harvested reeds biomass (for composting /agricultural uses).

CARDIMED	3. FREE WATER SURFACE CONSTRUCTED WETLAND

Synonyms: Free water surface treatment wetland; surface flow constructed wetland. **Description:** A free water surface constructed wetland is a type of engineered system designed to mimic natural wetland processes for wastewater and stormwater treatment. They are considered as cost-effective, environmentally friendly, and can be tailored to fit various treatment needs, making them a popular choice for decentralised wastewater treatment applications and sustainable rainwater management. In these systems, wastewater/stormwater flows through shallow ponds or channels with a surface layer of emergent aquatic plants. As the water moves through the wetland, physical, biological, and chemical processes occur, leading to the removal of pollutants such as nutrients, organic matter, and pathogens. Picture source: IRIDRA

Main challenges targeted	Freshwater and groundwater supply and quality, Biodiversity & renaturalization and Rainwater management & flood protection
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Wetland creation and/or restoration, Create or restore habitat, Create or restore fauna, Coastal restoration & protection/ Promote resilience against natural disasters, Reduce sediment flow into drainage systems, Rehabilitate polluted soil, Provide thermal regulation / cooling, Habitat for species Climate regulation
Cultural Services	Facilitate education, Support environmental awareness, Aesthetic values, Recreation and ecotourism, Social relations
Provisioning Services	Water reuse, Preserve groundwater and surface waters supply, Nutrient recovery
Replicability	★★☆
Design & planning	**Plants:** *Phragmites Australis, Typha spp., Echinochloa spp.* and other macrophytes. **Required area:** approx. 3.2-4.5 m^2/pe depending on flow rate and quality. **Depth:** 0.5-1 m.

Operation and maintenance	**Maintenance activities:** Monthly cleaning and sampling of manholes. Annually removal of selected plants and/or replanting. Occasionally mosquito management, utilisation of integrated management practices in the event of vector outbreaks. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factors.
Combinations with other NBS	**Subsurface flow constructed wetlands , Electroactive constructed wetland, Sludge treatment wetlands, High rate algae pond** (for enhancing treatment efficiency and sustainability). These NBSs can serve as a source of biomass that can be used for **Compost application, mulching application, Agroforestry** (for enhancing sustainability of food production and improving soil quality). as also a CO_2 storage. This NBS can provide treated water for diverse NBS such as **Agroforestry, Green corridors, urban micro forest ,Agroforestry** (for enhancing sustainability of water management) **Porous asphalt, surface unsealing, Riparian buffer, Bioretention cells (rainraden), Bioswale, Filter drain** (for integrated stormwater management). **Aquaculture** (to use treated water).
Supportive units & smart tech	**Advanced water treatments** (filtration membranes, reverse osmosis, biochar or activated carbon filters and oxidation process to enhance pollutant removal). **Remote sensing** (for real-time monitoring of water quality and hydraulic parameters). **Solar panels** (for reducing energy costs and enhancing overall sustainability). **Artificial intelligence** (for predictive modelling and adaptive management). **Septic tanks, screening, grit removal, detention vaults and tanks** (for increased treatment efficiency and capacity). **Flow regulators or diversion structures** (for managing hydraulic loading and maximising treatment efficiency during peak flow events).
Treatment efficiency	**COD: 41- 90%; BOD_5: ~54%; TN: 30- 80%; NH_4-N: ~73%; TP: 27-60%.**
CAPEX	30 - 70 €/m^2. Main type of costs: Equipment and materials (grid, sedimentation tank, grit chamber, detention vaults and tanks, first flush tank, septic tank, pumps, pipes, geomembranes, filter media, lining materials and monitoring and control devices); Permits, fees and administrative (land acquisition); Labour (soil levelling and land excavation).
OPEX	0.5 - 2 €/m^2 y. Main type of costs: Utilities (electricity); Labour (operation and monitoring, sludge removal, reed harvesting, green space maintenance).
By-product(s):	Biofuels (biogas, bioethanol, bio oil, biochar, and synthesis gas)

CARDIMED	4. SLUDGE TREATMENT WETLAND

Synonyms: Sludge Drying Reed Beds; Sludge Treatment Reed Beds. **Description:** Sludge treatment wetlands, represent a relatively new approach to sludge treatment inspired by constructed wetlands functioning. Unlike traditional sludge treatment methods that often require chemical or thermal conditioning, sludge treatment wetlands operate without the need for such treatments. Sludge is either directly introduced into the basins from aeration tanks or homogenised in a buffer tank before being discharged into the wetlands. Microbial activity, facilitated breaks down and stabilises organic matter present in the sludge. Additionally, physical processes such as filtration and adsorption further contribute to pollutant removal. Over time, these processes transform the sludge into a stabilised, dewatered by-product that can be safely reused or disposed of. Picture source: Steen Nielsen/WSP

Main challenges targeted	Resources recovery & valorization, Soil restoration & protection, Local Development & Economic Enhancement
Regulation and Maintenance Services	Improve carbon sequestration, Reduce greenhouse gas emissions, Improve soil fertility / biodiversity, Reduce changes on soil characteristics, Stabilise soil / substrate.
Cultural Services	Facilitate education, Support environmental awareness
Provisioning Services	Nutrient recovery, Produce energy / Reduce energy demand, Production of biomass, Material reuse, Habitat for species
Other Services	Reduced costs in comparison with other solutions, Contribute to local employment, Contribute to new or existing business, Favour green economy (reuse of local by-products), Sustainable food production
Replicability	★★☆
Design & planning	**Plants**: *Phragmites Australis*, *Typha spp.*, *Echinochloa spp* and other macrophytes. **Filter media:** upper layer of 10-15 cm sand (0.5-1mm), intermediate layer of 20-30 cm gravel (2-10mm) and drainage layer of 15-20 cm stones (5cm). **Total depth:** 2.4 m (0.6–0.7 m of filter medium and 1.5–1.6 m for sludge accumulation). **Number of beds:** 3-18. **Bed surface:** 4.5- >1000 m^2 **. Feeding period:** 1–2 days (or even 1–2 weeks). **Resting period:** 1–2 months to 1 year. **Surface area required:** 1.5 and 4 pe/m^2.
Operation and maintenance	**Operational activities:** Monitor the performance in terms of sludge dewatering rates, pollutant removal efficiency, and vegetation health. Adjust sludge loading rates to prevent overloading. Adjust flow rates, controlling inlet and outlet structures, and managing sediment accumulation to maximise treatment efficiency and minimise the risk of clogging or overflow. **Maintenance activities:** Controlling invasive species, trimming overgrown vegetation, and periodically replanting. Maintain buffer zones around the wetland to prevent contamination from adjacent land. Periodic removal of accumulated biomass or harvesting of nutrient-rich vegetation for reuse or disposal. **Others:** Training to staff and

	volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).
Combinations with other NBS	These NBSs can serve as a source of biomass that can be used for **Compost application, mulching application, Agroforestry** (for enhancing sustainability of food production and improving soil quality)
Supportive units & smart tech	**Advanced water treatments** (oxidation process to enhance pollutant removal). **Remote sensing** (for real-time monitoring of water quality and hydraulic parameters). **Artificial intelligence** (for predictive modelling and adaptive management). **Storage tanks or dewatering facilities** (for providing temporary storage capacity during periods of high loading or maintenance activities).
Treatment efficiency	*not available*
CAPEX	100 - 200 €/m^2. Main type of costs: Equipment and materials (pumps, agitation systems, aeration systems, excavation, canal construction, reservoirs, geotextiles, pipes, support structures; Permits, fees and administrative (land acquisition); Labour (soil levelling and land excavation).
OPEX	2-5 €/m^2 y. Main type of costs: Utilities (electricity); Labour (operation and monitoring, sludge removal, reed harvesting, green space maintenance).
By-product(s):	Treated sludge (for agricultural uses)

CARDIMED	5. HIGH RATE ALGAE PONDS

Synonyms: High-Rate Algal Ponds **Description:** High-Rate Algae Ponds are engineered systems to improve wastewater treatment while concurrently cultivating microalgal biomass. In this method, microalgae absorb nutrients from the wastewater and generate O_2 essential for bacterial activity, facilitating the breakdown of organic matter. This symbiotic relationship between bacteria and microalgae results in the production of clean water suitable for reuse, alongside algal biomass with potential applications in bioproduct manufacturing. HRAPs demonstrate versatility in treating various wastewater types (industrial effluents, digester discharge, as well as wastewater from agricultural operations such as piggeries and dairy farms). Picture source: UPC/PAVITR

Main challenges targeted	Sustainable practices, resources recovery & valorization, Freshwater and groundwater supply and quality, Air quality
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Improve carbon sequestration, Reduce greenhouse gas emissions

Cultural Services	Facilitate education, Support environmental awareness, Aesthetic values
Provisioning Services	Water reuse, Preserve groundwater and surface waters supply, Production of biomass, Nutrient recovery, Material reuseFresh water, Food production
Other Services	Reduced costs in comparison with other solutions, Reduced carbon footprint, Reduced water footprint
Replicability	★★☆
Design & planning	**Area requirement:** 3 - 5 pe/m^2. **HRT:** varies seasonally (3 - 4 days in summer and 7 - 9 days in winter). **Depth:** 0.2 - 0.6 m. **Paddle wheel:** mixing (typically 0.15 - 0.30 m/s)
Operation and maintenance	**Operational activities:** Checking of inlet and outlet pumps, as well as proper paddle wheel operation. Measuring the turbidity of the settled effluent. **Maintenance activities:** Checking and maintenance of the probes (weekly cleaning and calibration). **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Photo bio reactors** (for enhancing microalgae cultivation). These NBSs can serve as a source of biomass that can be used for **Compost application, Agroforestry** (for enhancing sustainability and food security). **Free water surface constructed wetland** (for enhancing treatment efficiency and sustainability). **Riparian buffer** (for integrated stormwater management). **Aquaculture** (to use treated water). This NBS can provide treated water for diverse NBS such as **Agroforestry, Green corridors, urban micro forest** ,**Agroforestry** (for enhancing sustainability of water management)
Supportive units & smartech	**Smart sensors** and **remote sensing** (to monitor biomass density, nutrient concentrations and pH for optimising algae growth conditions). **Harvesting systems** (centrifugation, flocculation, or membrane filtration for increasing harvesting efficiency and reducing energy consumption). **Settling tanks or clarifiers** (for optimising algae growth conditions). **Advanced water treatments** (membrane filtration or UV disinfection for polishing treated effluent, making it suitable for reuse in non-potable applications). **Solar panels** (for reducing energy costs and enhancing overall sustainability).
Treatment efficiency	**COD: 40 - 80%; NH_4-N: 80 - 100%; PO_4^{3-}: 30 - 80%**
CAPEX	*not available.* Main type of costs: Equipment and materials (agitators, algae harvesters, control and monitoring devices, building access roads, electrical facilities to power equipment, lighting systems, pumps, pipelines, filtration systems, concrete, geomembranes); Permits, fees and administrative (land acquisition); Labour (soil levelling and land excavation).

OPEX	*not available.* Main type of costs: Utilities (electricity); Labour (replacing parts, repairing leaks, monitoring algae growth, maintaining equipment, cleaning and harvesting algae); Materials and supplies (nutrients supplied for algae); Transportation and delivery (processing facilities).
By-product(s)	Harvested microalgal biomass (for biofuel, animal feed, fertiliser, cosmetics, pharmaceuticals, bioplastics).

CARDIMED 6. BIOFILTRATION COLUMNS

Picture not available. **Synonyms:** Biofilter; Biofilter column; Stormwater biofilters; Biofiltration systems; Bioretention systems; Biofilter urban stormwater. **Description:** Biofilters provide the combined effects of improving water quality as well as reducing the volume and rate of runoff from impervious surfaces. It can also be used for treating wastewaters. They consist of a vegetated column filled with a filter media and a drainage pipe on the bottom. Stormwater runoff infiltrates, is filtered by the vegetation and filter media, and the treated water is collected in the drainage pipe. Their filter media and vegetation properties enhance pollutant removal efficiency and increase their span life compared to traditional sand or gravel filters.

Main challenges targeted	Freshwater and groundwater supply and quality, Rainwater management & flood protection, Sustainable practices, resources recovery & valorization,
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Reduce flood risk, Reduce sediment flow into drainage systems, Reduce urban runoff, Stormwater source control, Habitat for species
Cultural Services	Facilitate education, Support environmental awareness, Aesthetic values
Provisioning Services	Water reuse, Preserve groundwater and surface waters supply, Harvest, store and treat rainwater, Produce energy / Reduce energy demand Fresh water
Other Services	Reduced costs in comparison with other solutions, Reduced water footprint
Replicability	★★☆
Design & planning	**Plants:** Species with thick roots. **Filter media:** Some examples are sand, activated carbon, gravel, peat moss, pumice, expanded clay aggregate, coconut shell, zeolite etc.) upper layer of 300-700 mm sandy-loam; intermediate layer of 70 mm of coarse sand and 70 mm of fine sand; drainage layer of 90 mm of gravel. **Diameter:** 375mm. **Drainage pipe:** 50 mm diameter.
Operation and maintenance	**Operational activities:** Regular monitoring performance of the biofilter system (hydraulics, water quality, plants health). Monitor nutrient levels to maintain optimal conditions for microbial colonisation. This may involve adding supplemental nutrients or adjusting feed rates (in case wastewater is used as water source) to achieve desired nutrient ratios.Maintain appropriate flow rates through the biofilter to ensure adequate contact time. Ensure adequate oxygenation within the biofilter system to support aerobic microbial activity

	(forced aeration or by maintaining proper flow rates and passive aeration). Avoid disturbances or sudden changes in operating conditions that may disrupt biofilm development. **Maintenance activities:** Regularly inspect the filter media, and replace it if necessary, to prevent clogging. Control pests such as insects, rodents, or algae from colonising the biofilter system. Repair or replace damaged components promptly to prevent water loss and maintain system integrity. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Stay informed about emerging technologies and best practices in biofiltration to continually improve system performance.
Combinations with other NBS	These NBSs can serve as a source of biomass that can be used for **Compost application, mulching application, Agroforestry** (for enhancing sustainability of food production and improving soil quality) **. Bioswale** and **bioretention cell (rain garden)** (to enhance and holistic rainwater management). This NBS can provide treated water for diverse NBS such as **Agroforestry, Green corridors, urban micro forest** ,**Agroforestry** (for enhancing sustainability of water management)
Supportive units & smartech	**Smart sensors and remote sensing** (to monitor pH, DO, and pollutant concentrations for enabling automatic system control and optimization). **Flow regulators or diversion structures** (for managing hydraulic loading and maximising treatment efficiency during peak flow events). **Advanced water treatments** (ultrafiltration or nanofiltration to achieve higher water quality standards for reuse; oxidation processes as pre-treatment to enhance the breakdown of recalcitrant pollutants and improves overall treatment performance). **Solar panels** (for reducing energy costs and enhancing overall sustainability).
Treatment efficiency	*not available*
CAPEX	*not available.* Main type of costs: Equipment and materials (concrete, steel, composite materials, gravel, sand, activated carbon, pipes, valves, fittings, distribution systems, pumps, blowers, control and monitoring devices); Permits, fees and administrative (land acquisition); Labour (soil levelling and land excavation).
OPEX	*not available.* Main type of costs: Utilities (electricity); Labour (monitoring systems inspections, cleaning, servicing equipment, media replacement, repairing of pumps/valves/piping and replacing parts).
By-product(s):	*Not applicable*

CARDIMED	7. PHOTO BIO REACTOR

Picture not available. **Synonyms:** Microalgae bioreactor; Algae bioreactor; Microalgal photobioreactor; Microalgal cultivation. **Description:** A Photo Bio Reactor (PBR) is a closed or semi-closed system designed to cultivate photosynthetic microorganisms, such as algae or cyanobacteria, under controlled environmental conditions. These reactors utilise light, typically from artificial sources such as LEDs or natural sunlight, to facilitate photosynthesis,

wherein microorganisms convert CO_2 and nutrients into biomass and O_2. PBRs are commonly used in various applications, including wastewater treatment, biofuel production, carbon capture, and bioremediation. In wastewater treatment applications, microalgae or other photosynthetic microorganisms cultivated within the PBR utilise nutrients, including nitrogen and phosphorus, as well as CO_2, present in the wastewater as sources for growth.

Main challenges targeted	Freshwater and groundwater supply and quality, Sustainable practices, resources recovery & valorization, Air quality,
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Improve carbon sequestration, reduce greenhouse gas emissions.
Cultural Services	Facilitate education, Support environmental awareness.
Provisioning Services	Water reuse, Preserve groundwater and surface waters supply, Production of biomass, Nutrient recovery, Material reuse Fresh water, Food production
Other Services	Contribute to local employment, Reduced costs in comparison with other solutions, Reduced water footprint, Reduced carbon footprint
Replicability	★★☆
Design & planning	**Species:** Microalgae and cyanobacteria. **Requirements conditions: pH:** 7 - 8, **DO:** 0.2 - 0.5 mgO_2/L, **COD:** 5, **TN:** 0.3, **Bacterial product:** Maximum 2.5 at **OLR** of 5 g/L/d COD biomass. For outdoor Photobioreactor the implementation of a buffered medium or installation of a pHstat system in conjunction with PBRs is recommended to mitigate the inhibition of cell growth rates caused by seasonal variations, T fluctuations, and light intensity.
Operation and maintenance	**Operational activities:** Monitoring key parameters such as T, pH, DO, nutrient concentrations (e.g., nitrogen and phosphorus), biomass density, and light intensity (to ensure optimal growth conditions and early detection of any deviations or issues). **Maintenance activities:** Regular biomass harvesting (to prevent biomass accumulation and maintain optimal growth conditions). Repair or replace damaged components promptly to prevent water loss, contamination, or operational disruptions **Others**: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Subsurface flow constructed wetlands, electroactive wetlands, biofiltration columns, free water surface constructed wetlands** and **high rate algae ponds** (for synergistic approach for wastewater treatment). **Bioretention cells (rain gardens) and bioswale** (for the treatment of captured stormwater) and **Aquaculture**

	(Microalgae biomass harvested can serve as a nutritious feed source for species such as fish, shrimp, or shellfish).This NBS can provide treated water for diverse NBS such as **Agroforestry, Green corridors, urban micro forest**, **Agroforestry** (for enhancing sustainability of water management)
Supportive units & smartech	**Smart sensors** and **remote sensing** (to monitor pH, DO and pollutant concentrations, enabling automatic system control and optimization). **Artificial intelligence** (for predictive modelling and adaptive management). **Solar panels** (for reducing energy costs and enhancing overall sustainability). **Anaerobic digesters or microbial fuel cells** (for integrated bioprocesses for wastewater treatment, bioenergy production, and resource recovery). **Advanced water treatments** (membrane filtration, UV disinfection, or electrocoagulation to enhance effluent quality and pathogen removal for potable water production or wastewater reuse).
Treatment efficiency	*not available.*
CAPEX	*not available.* Main type of costs: Equipment and materials (pumps, pipes, sensors, lighting systems, valves, fittings, distribution systems photobioreactor modules, glass, acrylic, polyethylene, LEDs/fluorescent lamps, lighting fixtures, control and monitoring devices, mixing systems, aeration devices, nutrient dosing systems, harvesting equipment); Permits, fees and administrative (land acquisition); Labour (soil levelling and land excavation).
OPEX	*not available.* Main type of costs: Utilities (electricity); Labour (replacing parts, repairing leaks, monitoring algae growth, maintaining equipment, harvesting algae and cleaning); Materials and supplies (nutrients supplied for algae); Transportation and delivery (processing facilities).
By-product(s):	Harvested biomass can be processed for various applications such as biofuel production, animal feed supplements, nutritional supplements, or bioplastics. Microalgae produce a wide range of bioactive compounds, pigments, antioxidants, and other high-value chemicals with pharmaceutical, nutraceutical, or cosmetic applications.

BIORETENTION SYSTEMS

CARDIMED	1. BIORETENTION CELL (RAIN GARDEN)

Synonyms: rain garden, Bioretention facility; Bioretention cell; Pluvial beds; Infiltration/stormwater planters; Biofilter; Infiltration garden; Rainfall garden; Water control garden; Floodable garden; Bioretention filter; Bioretention area. **Description:** Bioretention cells (rain gardens), are shallow, vegetated depressions designed to capture, store, filter, and treat stormwater runoff from impervious surfaces like driveways. By reducing the volume

and speed of runoff, they minimise erosion and flood risks. While often associated with urban areas, rain gardens can be adapted to various environments, including rural settings. In rural areas, they can be strategically placed along drainage ditches, field edges, or at the base of slopes to capture sediment, nutrients, and pollutants from agricultural runoff, thereby enhancing water quality and safeguarding downstream ecosystems. Furthermore, rain gardens are integral components of innovative design approaches that enable the onsite reuse of treated water, promoting sustainability and resource efficiency. Picture source: Fondation Engie France

Main challenges targeted	Rainwater management & flood protection, Biodiversity & renaturalization, Freshwater and groundwater supply and quality
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Reduce flood risk, Reduce sediment flow into drainage systems, Reduce combined sewer overflows, Reduce urban/agricultural runoff, Stormwater source control, Permeability restoration, Mitigate desertification, Create or restore flora, Support pollination, Develop resilience of green spaces, Coastal restoration & protection/ Promote resilience against natural disasters, Enhance and stabilise water retention, Reduce CO_2 emissions, Provide thermal regulation / cooling, Habitat for species
Cultural Services	Health and Well-Being improvement, Increase aesthetic and patrimonial or cultural value,Facilitate education, Support environmental awareness Increase stakeholder engagement, Aesthetic values, Social relations
Provisioning Services	Water reuse, Preserve groundwater and surface waters supply, Harvest, store and treat rainwater, Provide nutrition sources for birds and insects,Production of biomass
Other Services	Contribute to local employment, Increase land/property monetary value, Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Reduced water footprint, Sustainable food production
Replicability	★★★
Design & planning	Native **plant** species are chosen for their resilience to occasional flooding, serving not only to enhance biodiversity but also to aid in water filtration and erosion control. This selection ensures the bio retention cell's ability to thrive within its environment. Additionally, the versatility of these cells makes them suitable for **small-scale installations**, whether in private gardens or public spaces, offering an effective solution for stormwater management in various urban settings. Incorporating a gentle **slope** into the design further enhances its performance by facilitating water infiltration and retention. This slope promotes efficient drainage and groundwater recharge, minimising runoff and reducing the risk of flooding and soil erosion. Ensuring easy **access** for maintenance and management activities is essential for the sustained effectiveness of the bio retention cell.

Operation and maintenance	**Operational activities:** Watering is essential, particularly during dry periods, to sustain the health of the native plant species. In this sense, periodic reviews of the irrigation system are crucial to identify and address any issues promptly, ensuring efficient water distribution. **Maintenance activities:** Pruning and pollarding help manage plant growth and promote a tidy appearance, while also encouraging healthy root development. Substituting mulching as needed aids in moisture retention and weed suppression, contributing to overall plant vitality and ecosystem balance. Weed control and fertilisation are carried out as necessary to maintain plant health and minimise competition for resources. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Mulching application, Compost application, Surface unsealing** (for improving soil quality, reduction of erosion, water and moisture retention, and suppressing weeds). **Green corridors, Urban micro forest, Terracing, Restoring native vegetation, Riparian buffer, Bioswales and Filter drains** (for an integrated rainwater management with a positive impact on biodiversity)
Supportive units & smart tech	**Rainwater harvesting systems** (for using collected rainwater for irrigation). **Smart irrigation systems** (for optimising water usage). **Smart sensors** (to monitor humidity, T and air quality, rainfall measurements for assessing the impact of environmental conditions, detecting anomalies and optimising maintenance).
Treatment efficiency	**NH_3: 84,6%; Cd: 80-90%; Cu: 80-90%; Pb: 80-90%; Zn: 80-90%; PAHs: 70-90%.**
CAPEX	100-300 €/m^2 Main types of costs: Equipment and materials (containers or sealed and unsealed surfaces, rainwater barrels, fibreglass pots along with wooden lamellas, bench and hydrophytic plants), Labour (irrigation and monitoring system installation, information board installation).
OPEX	2-5 €/m^2 y Main types of costs: Labour (removing litter, maintaining vegetation, weeding, removing sediment, clearing inlets and outlets, inspections, flushing out drainage, minor repairs and infiltration test).
By-product(s)	Pruned plant material or harvested plants can be used for onsite and production of organic fertilisers (for agricultural uses), Edible goods and pharmaceuticals (for local consumption or sales).

CARDIMED	2. BIOSWALE

Synonyms: Swale; Green drainage corridor; Vegetative filter; Vegetated bioswale, grassed swales, vegetated swale.
Description: A bioswale is a vegetated, linear, and gently sloped pit commonly established in urban areas near or between roads to reduce flood risk during heavy rain events. They absorb, store, and convey surface water runoff, removing pollutants and sediments as water filters through the vegetation and soil layer. While typically found in

urban settings, bioswales can also be effective in rural areas. In both settings, they capture and treat stormwater runoff from roads, agricultural fields, and other surfaces. Some bioswales include dams or similar structures to support water infiltration. Picture source: SIARE naturalwalkingcities

Main challenges targeted	Rainwater management & flood protection, Air quality
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Reduce flood risk, Reduce sediment flow into drainage systems, Stormwater source control, Permeability restoration, Create or restore habitat, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Develop resilience of green spaces, Coastal restoration & protection/ Promote resilience against natural disasters,Reduce sediment flow in the river, Reduce sediments deposition in river beds, Enhance and stabilise water retention, Improve carbon sequestration, Reduce CO2 emissions, Provide thermal regulation / cooling ,Reduce risk of pest and diseases, Habitat for species
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Facilitate education, Support environmental awareness, Increase stakeholder engagement, Aesthetic values
Provisioning Services	Water reuse, Preserve groundwater and surface waters supply Not applicable, Harvest, store and treat rainwater, Production of biomass, Nutrient recovery, Produce energy / Reduce energy demand, Material reuse
Other Services	Contribute to local employment, Increase land/property monetary value Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced carbon footprint, Reduced water footprint, Sustainable food production
Replicability	★★☆
Design & planning	The native deep-rooted **plants** are selected to withstand occasional flooding (often grass, + other plants for esthetic reasons). The **slope** typically ranges from 1% to 4%, facilitating efficient drainage and erosion prevention. Bioswales vary in **length** from 10 to 30 m and may include **elements** like forebays, berms and internal water storage for enhanced performance in capturing sediment and reducing flow velocities. Integrating these elements ensures bioswales effectively manage stormwater runoff, promoting improved water quality and sustainable urban development.

Operation and maintenance	**Operational activities:** Inspection and correction of erosion, vegetation damage, sediment, and debris accumulation. It is essential to ensure uniformity in cross-section and longitudinal slope, as well as monitor vegetation on side slopes to prevent erosion and the formation of rills or gullies. Identify any pools of standing water, which should be promptly dewatered and discharged into a sanitary sewer. Swale inlets and outlets, such as curb cuts and pipes, are also inspected for signs of erosion or blockage to ensure continued functionality. **Maintenance activities:** Regular mowing and trimming of vegetation are conducted to maintain safety, aesthetics, and proper swale operation, as well as to suppress weeds and invasive species. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Green corridors, Urban micro forest, Terracing, Restoring native vegetation, Bioretention cells (rain gardens), Riparian buffer, Filter drains** and **permeable surfaces** (for an integrated rainwater management with a positive impact on biodiversity). **Cover crop** (to improve soil quality, control erosion, increase biodiversity, and suppress weeds)
Supportive units & smart tech	**Rainwater harvesting systems** (for using collected rainwater for irrigation). **Smart irrigation systems** (for optimising water usage). **Smart sensors** (to monitor humidity, T and air quality, rainfall measurements for assessing the impact of environmental conditions, detecting anomalies and optimising maintenance).
Treatment efficiency	**TSS: 63-85% ; TN:46-67% ; TP: 40-99%**
CAPEX	13 - 122 €/m^2. Main types of cost: Design and development infrastructure; Equipment and materials (salvaged topsoil, seed and mulch and sod); Labour (clearing, grubbing, excavation, level and till).
OPEX	1 - 5 €/m^2 y. Main types of cost: Labour (grass mowing, general grass care, swale debris and litter, removal grass, reseeding with mulch and fertiliser and swale inspection)
By-product(s)	Pruned plant material or harvested plants can be used for onsite and production of organic fertilisers (for agricultural uses)

CARDIMED	3. FILTER DRAIN

Synonyms: Filter trench; Surface sand filter; Customised drain, Subsurface rainwater collector, Gravel filter drain; Runoff collection filter drain; Rainwater filter drain. **Description:** Filter drains are shallow excavations filled with stone or gravel, designed to provide temporary subsurface storage for attenuating, conveying, and filtering surface water runoff, including rainwater. These drains play a crucial role in managing stormwater in various environments,

including urban, peri-urban, and rural areas. By capturing and temporarily storing runoff, filter drains help reduce the volume and velocity of water entering downstream water bodies, minimising the risk of erosion and flooding. Additionally, the bottom of filter drains can be also impermeable/permeable allowing for controlled drainage while retaining captured water. This design feature enhances their effectiveness in treating runoff and facilitates onsite reuse for purposes such as irrigation for agricultural lands, landscaping, or other non-potable water uses, contributing to water conservation efforts and promoting sustainable water management practices. Picture source: Travauxbricolage.fr

Main challenges targeted	Rainwater management & flood protection, Freshwater and groundwater supply and quality, Sustainable practices, resources recovery & valorization
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Improve quality of groundwater and surface waters, Reduce flood risk, Reduce sediment flow into drainage systems, Reduce agricultural runoff, Stormwater source control, Permeability restoration, Mitigate desertification, Create or restore fauna, Connect blue and green spaces, Develop resilience of green spaces Coastal restoration & protection/ Promote resilience against natural disasters, Improve carbon sequestration, Reduce greenhouse emissions, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Health and Well-Being improvement, Facilitate education, Support environmental awareness, Increase stakeholder engagement.
Provisioning Services	Water reuse, Preserve groundwater and surface waters supply, Harvest, store and treat rainwater, Nutrient recovery, Produce energy / Reduce energy demand, Material reuse Fresh water
Other Services	Contribute to local employment, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced carbon footprint, Reduced water footprint.
Replicability	★★☆
Design & planning	The main types of **filter media** include gravel, washed gravel, and stones. It is designed with a minimum **length** of 5 m and a minimum **depth** of 1 m to effectively filter water and manage drainage. The **width** of the filter drain should be triple the diameter of the incoming pipe, including bedding and surround, ensuring proper installation and functionality. Additionally, to maintain optimal performance, there should be a minimum distance of 500 mm between any pipework and the bed of the filter trench, preventing interference with the drainage system
Operation and maintenance	**Operational activities:** Regular inspections are conducted to detect signs of clogging, which may impede the drain's function. **Maintenance activities:** Sediment accumulated in the pre-treatment system is removed to prevent

	blockages and maintain efficient water flow. Additionally, the surface layer of gravel is intermittently cleaned or replaced, typically every five to ten years, to optimise filtration performance. Cleaning and replacing gravel are preferred over disposal, as it is a more sustainable option, contributing to the long-term viability and environmental friendliness of the filter drain system. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Bioretention cells (rain gardens), bioswales and riparian buffer** (for an integrated rainwater management).
Supportive units & smart tech	**Rainwater harvesting systems** (for using collected rainwater for irrigation), **Smart sensors** (to monitor humidity, T and air quality for assessing the impact of environmental conditions, detecting anomalies and optimising maintenance).
Treatment efficiency	**30-50 % TSS**
CAPEX	80 - 200 €/m^2. Main types of costs: Equipment and materials: pipes, gravel, stones, geotextiles, excavators and trucks); Labour (excavation, placement of materials, soil compaction, and other related tasks).
OPEX	0.5-3 €/m^2 y. Main types of costs: Labour (cleaning, repairs and replacement of parts, inspections, monitoring and controlling the operation of the filter drain).
By-product(s):	*Not applicable*

PERMEABLE SURFACES

CARDIMED	1. POROUS ASPHALT

Synonyms: Hard drainage pavements, pervious asphalt, pervious pavement, porous pavement, permeable pavements; modular permeable paving, grass reinforcement, resin bound gravel, porous concrete. **Description:** Porous asphalt is a permeable paving system designed to absorb stormwater, thereby reducing surface water runoff. Similar to permeable or pervious concrete, porous asphalt allows water to pass through its surface. Unlike regular asphalt, porous asphalt is composed of larger stones and different asphalt binders, facilitating water permeability. Beneath the porous asphalt layer lies an open-graded stone bed, which further aids in water drainage. Common application areas for porous asphalt include parking lots, streets, driveways, and other surfaces where stormwater management is essential.

Picture source: Veronique Masotti

Main challenges targeted	Rainwater management & flood protection, Freshwater and groundwater supply and quality
Regulation and Maintenance Services	Improve quality of groundwater and surface waters, Reduce flood risk, Reduce sediment flow into drainage systems, Reduce combined sewer overflows, Reduce urban runoff, Stormwater source control, Permeability restoration, Stabilise soil / substrate, Enhance and stabilise water retention Provide thermal regulation / cooling
Cultural Services	Facilitate education, Support environmental awareness
Supporting Services	Erosion regulation, Enhance and stabilise water retention
Provisioning Services	Preserve groundwater supply
Replicability	★★★
Design & planning	The porous/previous asphalt incorporates various **materials** and equipment for construction. Materials typically include larger stones, asphalt binders such as epoxy resin, grass, gravel-grass, plastic grass slabs, concrete grass slabs, gravel and geotextiles. The **equipment** required for installation is standard, similar to that used for building regular asphalt roads. One key aspect of the design is the **depth** of the stone bed, which typically ranges from 0.5 to 1 m. This depth is crucial for proper water filtration and drainage through the porous asphalt surface.
Operation and maintenance	**Operational activities:** Annual inspections are conducted to assess the surface for signs of deterioration. Additionally, the exfiltration capability of the pavement is evaluated at least once a year. **Maintenance activities:** Surface cleaning is performed using a power washer to dislodge trapped particles, followed by vacuum sweeping to remove debris. **Others:** Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations.
Combinations with other NBS	**Bioretention cell (rain garden), Bioswale and filter drain** (for reducing the runoff going to these systems, improving stormwater source control and enhancing overall biodiversity of the approach - an integrated rainwater management strategy). **Terracing** (for enhancing slope stability and maximising the available land for water infiltration).
Supportive units & smart tech	**Smart sensors** (to monitor water flow, T, and pavement condition for assessing the impact of environmental conditions, detecting anomalies, and optimising maintenance). **Subsurface drainage systems** (for channelling the water captured for a proper disposal).
CAPEX	45-120 €/m^2. Main type of costs: Equipment and materials (porous concrete, gravel and geotextiles); Labour (excavation, soil levelling, pervious pavement installation, pouring and laying porous concrete)

OPEX	0.5-65 €/m^2 y. Main type of costs: Labour (removing litter, surface vacuum, restriping, replacing pavers, cleaning out pipes, replacing joint and rehabilitation).
By-product(s):	*Not applicable*

VERTICAL GREENING SYSTEMS

CARDIMED	1. WALL-BASED GREEN FACADE

Synonyms: Hydroponic green facade; Facadebound greening; Facade bound green, wall; living wall; Continuous green, wall; Plant wall system; Green façade with vertical panels; Greening vertical panel; Vertical greening pane, Planter green wall; Planter green facade; Planter boxes; Planter pots; Planter-based green wall; **Description:** This NBS is a greening vertical panel that is fixed onto walls (in building facade or other types of walls). The panels allow the placement of plants and substrate on the entire surface. In contrast to green façades, this NBS can support a wider variety of plant species (e.g. shrubs, grasses and several perennials). The panels can be continuous or modular. Continuous panels are lightweight and permeable screens in which plants are inserted individually. A frame is fixed to the wall to support the panel, normally leaving a gap between the system and the surface. Modular panels can have several elements with specific dimensions (e.g.trays, vessels, pots, planter tiles, flexible bags). These elements can include the growing media or be soilless/hydroponics. These elements together can create modular sections that are supported by a complementary structure or fixed directly on the vertical surface. Some systems allow the removal of panels during wintertime (adapted from Castellar et al., 2021) IRIDRA Srl (Courtesy prof. Prof. Yaser Abunnasr)

Main challenges targeted	Thermal regulation, Air quality, Biodiversity & renaturalization,
Regulation and Maintenance Services	Reduce water withdrawals and Efficient water treatment (only in the case this NBS is used to treat and reuse wastewater) ,Create or restore habitat Mitigate desertification, Create or restore flora, Support pollination, Develop resilience of green spaces, Provide nesting and breeding habitat, Improve carbon sequestration, Reduce greenhouse emissions, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling, Provide thermal isolation
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Facilitate education, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Enhance acoustic comfort, Promote physical and mental health, Reconnect people with nature
Provisioning Services	Water reuse, Provide nutrition sources for birds and insects, Production of biomass, Nutrient recoveryFood production, Biochemical, natural medicines and pharmaceuticals,
Other Services	Contribute to local employment, Increase land/property monetary value, Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced water

	footprint
Replicability	★☆☆
Design & planning	The most common **plants** used are shrubs, herbs, and grasses, but edible plants can also be used. They are selected based on local climate conditions such as sunlight exposure and rainfall. It's advisable to incorporate a diverse range of 10-15 plant species to bolster resilience against pests, diseases, and environmental factors, while also ensuring visual appeal. **Panel sizes** typically fall within the range of 0.5 to 1.0 m2. The materials used for the panels should be resistant to the elements and also comply with local safety regulations (for example: resistance to fire, etc.). **Automatic irrigation systems** with perforated pipes or drippers are commonly employed, although drippers may not be suitable for wastewater treatment due to potential clogging issues. The **substrate** used is usually lightweight and mineral-based, such as perlite or expanded clay pellets, occasionally supplemented with organic materials like coconut fibre or peat moss. However, soilless systems/hydroponics can also be implemented.
Operation and maintenance	**Operation activities:** Regular inspection of irrigation systems to ensure proper functioning in line with plants needs, monitoring plant health and addressing any signs of pests or diseases promptly, adjusting irrigation schedules based on seasonal changes in environmental conditions, regular inspection of structural integrity to ensure stability and safety. **Maintenance activitie**s: pruning and trimming of plants to maintain desired aesthetics and prevent overgrowth, monitoring nutrients demand, periodic cleaning of modular components to remove dust, debris, or algae buildup. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.
Combinations with other NBS	**Green corridors** as an element (for maximising thermal regulation and biodiversity enhancement), **Bioretention cells (rain gardens)** and **Bioswales** (for reducing the runoff going to these systems).
Supportive units and smart tech	**Rainwater harvesting systems** (for using collected rainwater for irrigation). **Solar panels** (for reducing energy costs and enhancing overall sustainability). **Smart irrigation systems** (for optimising water usage). **Smart sensors** (to monitor humidity, T and air quality for assessing the impact of environmental conditions, detecting anomalies and optimising maintenance) and pretreatment, advanced water treatments and storage tanks (for treating wastewater).
CAPEX	1000-1200 €/m^2 Main type of costs: Site preparation; Equipment and materials (panels, irrigation systems, growing medium, plant-, structural support - frames, brackets, fasteners -, tools and machinery); Labour (irrigation system installation and other tasks); Transportation and delivery; Permits, fees and administrative; Design and development infrastructure (engineering services); Unforeseen expenses or project contingencies.
OPEX	10-70 €/m^2 y Main type of costs: Utilities (water and electricity); Permits, fees and administrative (municipal water fees, periodic inspections, water treatment if using recycled water, fertilisers, nutrients, or soil amendment, documentation and reporting for compliance or regulatory purposes);

	Labour (cleaning and aesthetic upkeep, record-keeping, pruning, pest control, prevent or treat plant diseases and infestations, replacement plants, periodic inspections, training staff, cleaning and aesthetic upkeep and record-keeping); Materials and supplies (pest management or treat plant diseases and infestations products); Other (Water quality analytics for compliance with current local regulations for water reuse are essential).
By-product(s):	Organic biomass from trimming, pruning, clippings and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel). Edible goods and pharmaceuticals (for local consumption or sales).

CARDIMED	2. VEGETATED PERGOLA

Synonyms: Green pergola; Greened pergola; Green mattresses; Green shady structures; Green shade, Eco-friendly pergola; Plant-filled pergola; Living pergola. **Description:** It is an architectural structure crafted to offer shade while supporting climbing plants, enhancing outdoor living spaces with a blend of functionality and visual appeal. Typically, they utilise pillars, beams, stretched textile structures, and lattices made of various materials to provide a framework for vegetation growth and shaded areas. These structures may incorporate inert substrates onto which seeds can be spread. Vegetated pergolas can be installed fixed to building facades, along streets, or supported by posts anchored to sidewalks. Picture source: NATURE4CITIES

Main challenges targeted	Biodiversity & Renaturalization, Thermal regulation, Air quality
Regulation and Maintenance Services	Habitat for species, Create or restore habitat, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Promote resilience against natural disasters, Enhance and stabilise water retention, Improve carbon sequestration, Reduce greenhouse emissions, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Preserve cultural and historic heritage, Facilitate education, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Enhance acoustic comfort, Increase physical and mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Provide nutrition sources for birds and insects, Production of biomass, food production
Other g Services	Contribute to local employment, Increase land/property monetary value, Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced carbon footprint Sustainable food production

Replicability	★★★
Design & planning	**Plants:** Usual plants are climbing vines, creepers, but also edible species can be used**.** Consider factors such as climate suitability, growth habits, maintenance requirements, aesthetics, and desired functions (e.g., shade, privacy). **Support systems:** Prioritise durability, aesthetics, plant support, functionality, maintenance ease, cost-effectiveness, environmental friendliness, and adaptability.
Operation and maintenance	**Operational activities:** Structural integrity checks, safety measures. **Maintenance activities:** Regular pruning to maintain structure and health, and timely harvesting for fruit-bearing plants. Additionally, consider fertilisation, pest and disease management. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.
Combinations with other NBS	**Wall-based green facade** (for enhancing aesthetics appeal and providing additional habitat for pollinators and other wildlife). **Compost application, Mulching application** (for optimising the maintenance or as end for produced biomass).
Supportive units & smart tech	**Rainwater harvesting systems** (for using collected rainwater for irrigation). **Smart irrigation systems** (for optimising water usage). **Smart sensors** (to monitor humidity, T and air quality for assessing the impact of environmental conditions, detecting anomalies and optimising maintenance). **Additional features or amenities** (chairs, tables, bicycle racks to create inviting spaces). **Solar panels** (for reducing energy costs and enhancing overall sustainability).
CAPEX	*not available.* Main types of costs: Equipment and materials (pergola structure, climbing vines, creepers or other suitable plants, irrigation systems, trellises, wire mesh, netting, lighting fixtures, pathways, seating areas, seating, benches, tables and decorative elements); Labour (construction, installation, and landscaping work and irrigation system installation); Permits, fees and administrative (architectural and engineering fees, and permit acquisition).
OPEX	*not available.* Main types of costs: Utilities (water and electricity); Permits, fees and administrative (insurance); Labour (pruning, trimming, weeding, and replacing vegetation, removing debris, sweeping pathways, washing surfaces, repairing and replacing damaged or worn-out components of the pergola structure, pest control and training staff); Materials and supplies (fertilisers, compost, mulch, or other soil amendments.
By-product(s):	Harvested edible plants (for local consumption or sale). Organic biomass from trimming, pruning, clippings and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel). Harvested flowers and ornamentals (for decorative purposes). Woody biomass (for biofuel).

FARMING PRACTICES

CARDIMED	1. AQUACULTURE

Synonyms: Mariculture; Aquafarming; Flow-through fish farm; Recirculating Aquaculture Systems (RAS); Integrated multi trophic aquaculture (IMTA); Open-net pens or cages. **Description:** Aquaculture is the farming of aquatic organisms, including fish, molluscs (like mussels), crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. Aquaculture includes flow-through fish farms as well as recirculating aquaculture systems (RAS). Aquaculture has potential for providing lower priced fish, enhancing nutritional security and contributing to local employment. Urban aquaculture can decrease the distance between farm and plate, generate income, use less resources, and serve as a community-building tool. Picture source: Wikimedia Commons

Main challenges targeted	Biodiversity & renaturalization and Local Development & Economic Enhancement
Regulation and Maintenance Services	Create or restore fauna, Connect blue and green spaces, Refuge for farm and wild animals, Restore aquatic habitats, Improve carbon sequestration, Provide thermal regulation / cooling
Cultural Services	Facilitate education, Support environmental awareness, Recreation and ecotourism
Provisioning Services	Provide nutrition sources for birds and insects, Sustainable food production
Other services	Contribute to local employment, Increase land/property monetary value
Replicability	★☆☆

Design & planning	**Objective setting**: Define the specific goals of the aquaculture operation, including the type of species to be farmed, production goals, and market targets. **Species selection:** Fish: salmon, tilapia, catfish, carp, trout, barramundi; Crustaceans: shrimp, prawns, crayfish; Mollusks: oysters, mussels, clams; Seaweeds: kelp, nori; Other aquatic plants: spirulina. **Site selection**: Choose a suitable location based on water source availability, environmental conditions, accessibility, and regulatory constraints. **Environmental impact assessment**: Conduct an assessment to evaluate the potential impacts of the aquaculture system on the local environment and comply with all regulatory requirements. **System design**: Choose the appropriate aquaculture system (e.g., open ponds, RAS, cage systems) based on the species, scale, environmental factors, and economic considerations. **Water source and quality analysis**: Analyse the quality of the available water sources and design water treatment systems if necessary to ensure optimal water conditions for aquaculture. I**nfrastructure planning**: Plan and design the necessary infrastructure, including tanks, cages, water supply systems, feed systems, waste management, and other facilities. **Biosecurity measures**: Design biosecurity measures to prevent the introduction and spread of diseases within the farm. **Technology and equipment selection**: Select appropriate technology and equipment for feeding, monitoring, and managing the aquatic environment. **Financial planning**: Develop a detailed business and financial plan including budgeting, expected revenue, and profitability analysis. **Operational planning**: Establish protocols for daily operations, including feeding, monitoring, harvesting, and staff management. **Marketing strategy**: Develop a marketing strategy to position and sell the aquaculture products effectively in the targeted markets.
Operation and maintenance	**Operational activities:** Monitor water quality regularly, manage feeding carefully to avoid overfeeding, ensure proper water exchange for filtration, implement biosecurity measures, maintain appropriate stocking densities, regular health checks for stock, monitor weather conditions to mitigate potential stressors, develop emergency response plans, energy efficiency measures **Maintenance activities:**Clean and maintain equipment routinely, algae control, predator control, and waste management. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Riparian Buffer, Subsurface flow constructed wetland, Electrowetland , Free water surface constructed wetland** and **High rate algae pond** (for improving the influent and effluent of the system).
Supportive units & smart tech	**Smart sensors** (to monitor water quality, T and feeding regimes for optimising production processes and maintenance, detecting anomalies and managing feeding). **Artificial intelligence, computer vision** and **machine learning** (for predictive modelling and adaptive management).

[3]CAPEX	10,000.00 - 20.00,000.00 €. Main type of costs: Equipment and materials (aquatic species, hatchery and broodstock and other construction equipment and materials); Permits, fees and administrative (land acquisition and other permits); Labour (hatchery and broodstock installation); Unforeseen expenses or project contingencies.
[4]OPEX	5,000.00 - 5,000,000.00 €/y. Main type of costs: Utilities (water and electricity); Materials and supplies (feed and nutrition); Labour (water and waste management, veterinary care, maintenance and repairs); Permits, fees and administrative (insurance); Marketing and sales.
By-product(s):	Fishmeal and fish oil (for livestock feed), Organic Fertilizer from sludge (for agriculture), biogas from organic waste (for heating, electricity, vehicle fuel), Shellfish Shells (for agriculture), Fish Skin and Scales (for cosmetics, pharmaceuticals, or dietary supplements)

2.2 NBS Spatial units

This section presents **3 factsheets** related to **NBS Spatial units**, focusing on spatial planning through the integration of **Greenery Elements** and **farming practices.**

GREENERY ELEMENTS

CARDIMED	1. GREEN CORRIDORS

Synonyms: Green way; Cycle-pedestrian green paths; Green bypass; Green belt, Carbon sinks, Ecological corridors, Green infrastructure networks. **Description:** Green corridors repurpose derelict infrastructure areas, such as old railway lines or waterways, into linear parks, revitalising diverse landscapes. These corridors serve as transitional zones enhancing ecological connectivity and facilitating wildlife movement across diverse landscapes. They play a vital role in green infrastructure networks, offering refuge, food, and protection for wildlife, while also serving recreational, ecological, and transportation-related functions. Picture source: Natural Walking Cities.

Main challenges targeted	Biodiversity & Renaturalization, Freshwater and groundwater supply and quality, Societal benefits
Regulation and Maintenance Services	Air quality regulation, Climate regulation, Water regulation, Improve quality of groundwater, Improve quality of surface water, Efficient water treatment (rainwater), Reduce flood risk, Reduce landslides, River flood protection, Coastal flood protection, Permeability restoration, Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Forest creation and/or restoration, Connect green spaces,Connect blue and green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and

[3] The total costs depend on several factors such as the scale of operation, type of aquaculture system, species cultivated, geographic location and market conditions

[4] The total costs depend on several factors such as the scale of operation, type of aquaculture system, species cultivated, geographic location and market conditions

	breeding habitat, Refuge for farm and wild animals, Restore natural forest fire regime, Reduce changes on soil characteristics, Stabilise soil / substrate, Improve soil fertility / biodiversity, Improve carbon sequestration, Provide thermal regulation / cooling, Reduction of greenhouses gases emissions, Enhance dry deposition of aerosol particles, Reduce risk of pest and diseases, Increase green areas around urban rivers, Coastal restoration & protection/ Promote resilience against natural disasters
Cultural Services	Recreation and ecotourism, Social relations, Facilitate education, Support environmental awareness, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Health and Well-Being improvement, Ensure accessibility to green spaces, Reduce undesired behaviours, activities and vandalism, Support social cohesion and justice, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits, Reduce risk of pest and diseases
Provisioning Services	Fuel, Promote natural aquifer recharge / preserve groundwater supply, Promote natural surface water recharge / preserve surface water supply, Provide nutrition sources for birds and insects, Production of biomass, Nutrient recovery, Material reuse
Other Services	Contribute to local employment, Increase land/property monetary value, Sustainable food production, Reduced carbon footprint, Increase tourism, Reduced costs in comparison with other solutions, Reduced carbon footprint
Replicability	★★☆
Design & planning	**Plants:** Tree species with large canopies or species optimised for carbon capture, heat reduction, and providing habitat or food for wildlife. **Area:** Small (<5 ha), medium (5-10 ha), and large (>10 ha). **Tree pit:** Minimum depth of 1.5 m and minimum space between street curb or building of 1.8 m.
Operation and maintenance	**Operational activities:** Watering needs vary based on plant type, soil, and climate. Young trees typically require regular watering until their root systems are established. **Maintenance activities:** Regular removal of sediment, leaves, or debris that obstruct water flow, as well as pest control and pruning. In high-traffic areas, trees should be pruned to a minimum height of 2.5-3.0 m above ground level to prevent obstruction of car and pedestrian passage. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations). Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factors.
Combinations with other NBS	**Vegetated pergola, Urban micro forest, Urban parks, Agroforestry,** and **Wall-based green facade** as elements of green corridors (for maximising thermal regulation and biodiversity enhancement). **Bioretention cells (rain gardens), Bioswales** and **permeable surfaces** (for reducing the runoff going to these systems). **Compost application** and **Mulching application** (for optimising the

	maintenance or as end for produced biomass). Existing blue infrastructure such as urban rivers, waterfronts, and lakes for increasing ecological connectivity between green and blue spaces). **Riparian buffer**, **Restoring native vegetation**, **Invasive alien species control** and **Techniques for fauna refuge and nesting** (for providing habitats for local wildlife, improving structure, composition and function of the ecosystem).
Supportive units & smart tech	**Rainwater harvesting systems** (for using collected rainwater for irrigation). **Smart irrigation systems** (for optimising water usage). **Smart sensors** (to monitor humidity, T and air quality for assessing the impact of environmental conditions, detecting anomalies and optimising maintenance).
CAPEX	*not available.* Main types of costs: Design and development infrastructure, Permits, fees and administrative (land acquisition, environmental impact assessment and other permits); Equipment and materials (planting and landscaping materials, irrigation and drainage system, signage and wayfinding infrastructure); Labour (irrigation system installation, pathway construction, lighting installation, soil preparation and amendment, and drainage system installation).
OPEX	*not available.* Main types of costs: Utilities (water and electricity -if applicable-); Labour (pruning, watering, fertilisation, irrigation system maintenance, pest and disease management for plants, cleaning of pathways and surrounding areas, inspection and repair of infrastructure, landscape design updates or enhancements); Permits, fees and administrative (insurance premiums for liability coverage); Community engagement and educational programs (if applicable).
By-product(s):	Organic biomass from trimming, pruning, clippings and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel). Potential generation of carbon credits.

CARDIMED	**2.** URBAN MICRO FOREST

Synonyms: Urban/City forestry; Urban vegetation; Urban woodland; Arboreal areas around urban areas; Arboreal urban parks; Arboretum; Urban tree cover; Urban greenery. **Description:** Urban micro forests are green spaces designed to replicate the appearance and structure of natural forests within urban environments. They encompass various elements such as woodlands, tree clusters, individual trees, street trees, park trees. Typically, urban forests are actively managed and provide opportunities for foraging. Picture source: Regreen project

Main challenges targeted	Biodiversity & Renaturalization, Rainwater management & flood protection and Societal benefits
Regulation and Maintenance Services	Air quality regulation, Climate regulation, Water regulation, Create or restore habitat, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Forest creation and/or restoration, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Stabilise soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilise water

	retention, Improve carbon sequestration, Reduction of greenhouses gases emissions, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling, Provide thermal isolation
Cultural Services	Recreation and ecotourism, Social relations, Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Facilitate education, Support environmental awareness, Increase stakeholder engagement, Enhance acoustic comfort, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Fuel, Production of biomass, Provide raw material, aromatic plants, biochemical, natural medicines, pharmaceuticals, Promote natural aquifer recharge / preserve groundwater supply, Harvest, store and treat rainwater, Provide nutrition sources for birds and insects, Nutrient recovery, Sustainable food production
Other Services	Contribute to local employment, Increase land/property monetary value, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced carbon footprint
Replicability	★★☆
Design & planning	**Plants:** trees, bush and shrub species. The species are chosen in accordance with local characteristics (climate, soil conditions, pollution levels, spatial needs and management capability). **Area:** <0.5 ha
Operation and maintenance	**Operational activities:** Depending on the local weather, plantation watering will be necessary. **Maintenance activities:** Occasionally, depending on the species, it will be necessary to apply pruning or cleaning treatments. It might also be necessary to apply treatments to fight against pests and weeds. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations). Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factors.
Combinations with other NBS	**Vegetated pergola** and **Urban parks** as an element of urban micro forests (for maximising shading effect, thermoregulation and biodiversity enhancement. **Wall-based green facade** (for enhancing aesthetic appeal and additional habitats for flora and fauna). **Green corridors** (for increasing ecological connectivity). **Bioretention cells (rain gardens), bioswales** and permeable surfaces (for reducing the runoff going to these systems). **Compost application** and **Mulching application** (for optimising the maintenance or as end for produced biomass). Existing blue infrastructure such as urban rivers, waterfronts, and lakes for increasing ecological connectivity between green and blue spaces).
Supportive units & smart tech	**Rainwater harvesting systems** (for using collected rainwater for irrigation). **Smart irrigation systems** (for optimising water usage). **Smart sensors** (to monitor humidity, T and air quality for assessing the impact of environmental conditions,

	detecting anomalies and optimising maintenance).
CAPEX	50 - 400 €/m^2. Main types of costs: Permits, fees and administrative (land acquisition, environmental impact assessment and other permits); Equipment and materials (tree saplings/planting stock and tree shelter); Labour (soil preparation and amendment, planting, irrigation system installation, pathway construction, fencing or boundary establishment and tree shelter installation); Design and development infrastructure (engineering services).
OPEX	20 - 50 €/m^2 y. Main types of costs: Labour (watering, irrigation, soil enrichment, pruning, trimming, pest and disease control, soil fertility management, pathway maintenance and fence repair); Community engagement and educational programs (if applicable).
By-product(s)	Organic biomass from trimming, pruning, clippings and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel).

CARDIMED	3. URBAN PARKS

Synonyms: Large urban park; Pocket park; Public park; Park; Residential park; City park; Large urban public park; Green park; Greened recreation areas/regional parks; Green resting areas. **Description:** Urban parks refer to green areas within a city with a variety of active and passive recreational facilities that meet the recreational and social needs of the residents and of visitors to the city. They are open to wide-range communities. Urban parks can serve all the city or part of the city, and they are open to a wide range of communities. Picture source: Urbinat

Main challenges targeted	Biodiversity & Renaturalization, Rainwater management & flood protection and Societal benefits
Regulation and Maintenance Services	Improve quality of groundwater, Efficient water treatment (urban runoff), Reduce flood risk, Reduce combined sewer overflows, Reduce urban runoff, Reduce agricultural runoff, Coastal flood protection, Stormwater source control, Permeability restoration, Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Wetland creation and/or restoration, Forest creation and/or restoration, Connect green spaces, Connect blue and green spaces, Develop resilience of green spaces, Support free movement of species, Refuge for farm and wild animals, Restore natural forest fire regime, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Improve carbon sequestration, Reduce greenhouses gases emissions, Reduce particles (PM10), Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green

	spaces, Preserve cultural and historic heritage, Facilitate education, Support environmental awareness, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Promote natural aquifer recharge / preserve groundwater supply, Harvest, store and treat rainwater, Provide nutrition sources for birds and insects, Production of biomass, Provide raw material, Nutrient recovery, Sustainable food production
Other Services	Reduced carbon footprint, Contribute to local employment, Increase land/property monetary value, Increase tourism, Reduced costs in comparison with other solutions
Replicability	★★☆
Design & planning	**Plants:** trees, bush and shrub species. The species are chosen in accordance with local characteristics (climate, soil conditions, pollution levels, spatial needs and management capability). **Area:** <0.5 ha (pocket urban park) or >0.5 (large urban park).
Operation and maintenance	**Maintenance of vegetation and landscape:** Landscaping, mowing, flower and tree planting, grooming, pesticide and herbicide applications, weeding, hoe work, irrigation, raising of saplings, pruning, cutting branches, removing trees and shrubs, processing fallen and dehydrated trees, removing leaf litter, suppressing invasive plants, automatic irrigation systems. **Maintenance of recreational facilities:** Establishment, maintenance or removal of playgrounds, benches, sport courts, fountains, drinking fountains, etc. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations). Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor.
Combinations with other NBS	**Vegetated pergola**, **Urban micro forest** and **Green corridor** (for maximising shading effect, thermoregulation and biodiversity enhancement and increasing ecological connectivity). **Wall-based green facade** (for enhancing aesthetic appeal and additional habitats for flora and fauna). **Bioretention cells (rain gardens), bioswales** and permeable surfaces (for reducing the runoff going to these systems). **Compost application** and **Mulching application** (for optimising the maintenance or as end for produced biomass).
Supportive units & smart tech	**Rainwater harvesting systems** (for using collected rainwater for irrigation). **Smart irrigation systems** (for optimising water usage). **Smart sensors** (to monitor humidity, T and air quality for assessing the impact of environmental conditions, detecting anomalies and optimising maintenance).
CAPEX	80 - 1000 €/m^2. Main types of costs: Permits, fees and administrative (land acquisition, environmental impact assessment and other permits); Equipment and materials (tree saplings/planting stock and tree shelter, landscaping materials and wayfinding infrastructure); Labour (soil preparation and amendment, planting,lighting installation, irrigation system installation, pathway

	construction and fencing or boundary establishment); Design and development infrastructure (engineering services).
OPEX	3 - 45 €/m^2 y. Main types of costs: Utilities (water and electricity -if applicable-); Labour (pruning, watering, fertilisation, irrigation system maintenance, pest and disease management for plants, cleaning of pathways and surrounding areas, inspection and repair of infrastructure, landscape design updates or enhancements); Permits, fees and administrative (insurance premiums for liability coverage); Community engagement and educational programs (if applicable).
By-product(s)	Organic biomass from trimming, pruning, clippings and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel).

FARMING PRACTICES

CARDIMED

1. AGROFORESTRY

Synonyms: Alley Cropping; Agroecology practices; Ecoagriculture; Permaculture; Forest farming; Food forests; Forest gardens; Integrated farming; Sustainable farming practices; Conservation and sustainable use of forests.

Description: Agroforestry is the combination of trees and crops cultivation. Agroforestry provides a different land use option, compared with separated traditional arable and forestry systems and optimises the benefits from the biological interactions created when trees and crops are combined. The complementarity between trees and crops allows a more effective exploitation of the available resources. Agroforestry helps to better control soil erosion and increases the sustainability and resilience of agriculture. Additionally, agroforestry contributes to biodiversity by providing diverse habitats and supports a wider range of wildlife. Trees modify the microclimate, which can reduce T extremes and stress on crops during extreme weather, enhancing crop growth. By capturing CO_2, agroforestry also plays a role in climate change mitigation and supports water management by improving water infiltration and reducing irrigation needs. Socio-economically, agroforestry can stabilise farm income through the production of non-timber forest products like fruits, nuts, and medicines, alongside traditional crop yields. Furthermore, by enhancing floral diversity, agroforestry systems support pollinators crucial for the pollination of many crops. Over time, agroforestry farms can become less dependent on crop subsidies, and less susceptible to crop price variations, as timber and non-timber forest products generate a significant part of their income. Picture source: Wikimedia Commons

Main challenges targeted	Biodiversity & renaturalization, Societal benefits, Local Development & Economic Enhancement
Regulation and Maintenance Services	Air quality regulation, Climate regulation, Water regulation, Improve quality of groundwater, Avoid / reduce salinity in groundwater, Reduce flood risk, Reduce landslides, Reduce urban runoff, Reduce agricultural runoff, Stormwater source control, Create or restore habitat, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Forest creation and/or restoration, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Increase green areas around urban rivers, Reduce changes on soil characteristics, Stabilise soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilise water

	retention, Improve carbon sequestration, Reduction of greenhouses gases emissions, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Recreation and ecotourism, Supporting traditional knowledge, Spiritual and ritualistic uses, Sense of place and identity, Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Enhance acoustic comfort, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Timber, Fuel (e.g., firewood), Forage & fodder, other products for the bioeconomy like essential oils, resins, fibres, colours, compound materials, etc. Promote natural aquifer recharge / preserve groundwater supply, Promote artificial aquifer recharge / preserve groundwater supply, Provide nutrition sources for birds and insects, Provide raw material, Nutrient recovery, Produce energy / Reduce energy demand, Material reuse, Sustainable food production
Other Services	Contribute to local employment, Increase land/property monetary value, Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products)
Replicability	★★☆

Design & planning	**Clearly define your goals and objectives:** What do you hope to achieve with your agroforestry system? Increased food production? Improved soil health? Habitat creation for wildlife? Once you know your goals, you can start to make informed decisions about the specific types of plants to include in your system. **Assess your site characteristics:** Carefully evaluate your land's characteristics, including soil type, drainage, sunlight availability, and slope. This information will help you choose appropriate plant species that will thrive in your specific conditions. **Select appropriate plant species:** Incorporate a minimum of ten distinct species to create a diverse and resilient agroforestry system. Common plant choices include acacia species, eucalyptus species, pine species (for specific climates), coffee plants, cocoa trees, various fruit trees (like mango, avocado, citrus, apple), nut trees (walnut, almond), leguminous trees (leucaena, calliandra), timber trees (depending on your goals, teak, mahogany could be options), medicinal plants (neem, moringa), and aromatics (sage, oregano, lavender). Remember, selection should be based on compatibility with crops, soil preferences, climate suitability, and your specific objectives. **Design the layout of your system:** Consider the spatial arrangement of trees, crops, and other elements in your agroforestry system. Factors like light availability, root competition, and access for management should all be taken into account. **Establish the system:** This involves planting trees, crops, and other vegetation according to your design plan. Consider installing a drip irrigation system to increase irrigation efficiency, especially in drier climates or for high-value crops. **Long-term management:** Agroforestry systems require ongoing care and management to ensure their success. This may include pruning trees, controlling weeds, and monitoring for pests and diseases. The highest yields are expected only after 15 years, if planted as a new system.
Operation and maintenance	**Operational activities:** (**Irrigation)** Manage irrigation effectively, especially during dry periods. Consider installing a drip irrigation system to increase irrigation efficiency, especially in drier climates or for high-value crops. Regularly inspect irrigation systems (pumps, tanks, piping, soil moisture sensors, etc.) and perform necessary maintenance to ensure proper functioning. (**Fertilisation)** Provide nutrients to your plants to promote healthy growth and productivity. Whenever possible, prioritise organic fertilisers and nutrient sources derived from within the system, such as compost or composted manure. (**Harvesting)** Harvest crops, fruits, nuts, timber, or other products according to your system's design and maturity of the plants. Implement sustainable harvesting practices to ensure the long-term health and productivity of the system. (**Monitoring)** Regularly monitor the health and productivity of your agroforestry system. **Maintenance activities: (Pruning)**Regularly prune trees to maintain desired size and shape, improve light penetration for understory crops, and promote healthy growth. (**Weed control)** Implement strategies to manage weeds, which can compete with crops for water and nutrients. This could involve manual weeding, mulching, or using cover crops. (**Pest and disease management)** Monitor your agroforestry system for pests and diseases, and implement control measures using Integrated Pest Management (IPM) techniques whenever possible. This emphasises preventive methods and minimises reliance on chemical controls. **(Infrastructure)** Maintain any fences, trellises, or other infrastructure associated with your agroforestry system to ensure

	its functionality and protect your plants. Pruning, Weed control, Irrigation, Pest and disease management. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Crop rotation, Mulching application, Compost application, Cover crop** (to improve soil quality), **Advanced ecological treatments** (for treating and reusing wastewater for irrigation). **Riparian buffers** (to filter runoff and provide habitat). **Urban micro forest** (to cool and improve air quality). **Subsurface flow constructed wetland**, **Electroactive constructed wetland** and **Sludge treatment wetland** (for irrigation of treated water).
Supportive units and smart tech	**Building levees, floodwalls, or floodgates** (to protect agricultural land from flooding events). **Smart irrigation systems** (supply and optimization of irrigation). **Advanced water treatments** (to ensure safe reuse of treated wastewater). **Remote sensing** (to assess crop health, monitor vegetation dynamics, and identify areas of stress or water deficiency). **Decision support systems (DSS)** (to integrate various data sources and provide informed recommendations for managing the agroforestry system). **Unmanned aerial vehicles (UAVs) or drones** (for high-resolution aerial imagery and data collection on crop health, soil conditions, and other parameters). Drones can provide valuable data for monitoring large areas of land quickly and efficiently. **Precision agriculture techniques** (for targeted application of fertilisers, pesticides, and irrigation water). **Internet of Things (IoT) sensors** (for monitoring a wide range of environmental parameters, such as T, humidity, light intensity, and soil moisture). **Blockchain technology** (for secure record-keeping and traceability of products from agroforestry systems).
CAPEX	1,000.00 - 100,000.00 € ha. Main types of costs: Permits, fees and administrative (land acquisition); Site preparation; Equipment and materials (seedlings and planting materials, fencing, irrigation infrastructure, shelterbelts and windbreaks); Labour (planting and other tasks).
OPEX	5,000.00 - 200,000.00 € y. Main types of costs: Utilities (water); Labour (water management, fertilisers and soil amendments application, pest and disease management, pruning and maintenance, harvesting and processing); Permits, fees and administrative (insurance and taxes); Community engagement and educational programs.
Revenues	5,000 - 50,000 € ha y. Revenue depends on product types (fruits, nuts, timber, etc.); Market prices and management practices; Intensive systems with high-value products can generate more income; Research local markets and choose profitable species for your system).
By-product(s):	Mulch and woody biomass (for energy production, biofuel, soil amendments, composting and organic fertiliser). Forage and fodder (for livestock or other animals). Wood pellets or charcoal (for biofuel). Potential generation for carbon credits. Honey from beekeeping (for blooming trees and shrubs). Mushrooms from mushroom cultivation (certain types of mushrooms can be cultivated in the shaded areas created by trees). Medicinal plants for herbal products (processable into

	herbal teas, tinctures, and other products). Nitrogen fixation from legumes for improved soil fertility (after fixation, the nitrogen is then released into the soil, making it available for other plants to use).

2.3 NBS Biodiversity interventions

This section presents **4 factsheets** devoted to **NBS Biodiversity Interventions**, shedding light on strategies for **conservation and restoration of fauna & flora.**

CONSERVATION AND RESTORATION OF FLORA

CARDIMED	1. INVASIVE ALIEN SPECIES CONTROL

Picture not available. **Synonyms:** management of invasive alien species; Clearing invasive alien trees. **Description:** Invasive alien species control involves the strategic management and mitigation efforts aimed at reducing or eradicating invasive species within an ecosystem or habitat. These invasive species, comprising non-native organisms such as plants, animals, or microorganisms, pose significant threats upon introduction to new environments. They can outcompete native species, disrupt ecological balance, and adversely affect the environment, economy, or human health. Removal of invasive species is a crucial conservation and environmental management practice, essential for maintaining the health and resilience of natural ecosystems while safeguarding native species from the impacts of invasive organisms. Such efforts are typically coordinated by governmental agencies, conservation organisations, and community groups.

Main challenges targeted	Biodiversity & Renaturalization, Societal benefits
Regulation and Maintenance Services	Improve quality of surface water, Improve quality of groundwater, Efficient water treatment (effluent of WWTP), Reduce flood risk, Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Wetland creation and/or restoration, Forest creation and/or restoration, Connect green spaces, Connect blue and green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Restore natural forest fire regime, Coastal restoration & protection/ Promote resilience against natural disasters, Restore aquatic habitats, Stabilise soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilise water retention, Improve carbon sequestration, Reduction of greenhouses gases emissions, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Nature appreciation, Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Facilitate education, Reduce undesired behaviours, activities and vandalism, Support environmental awareness, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits

Provisioning Services	Improve soil fertility / biodiversity; Produce biochemicals, natural medicines and pharmaceuticals; Production of biomass; Provide raw material, Provide nutrition sources for birds and insects, Promote natural aquifer recharge / preserve groundwater supply, Promote natural surface water recharge / preserve surface water supply, Material reuse
Other Services	Contribute to local employment, Increase land/property monetary value, Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products)
Replicability	★★☆
Design & planning	The design for controlling invasive species encompasses various **methodologies**: **Biological control**: This involves the application of natural enemies (biocontrol agents) by humans to manage pests or plants (target hosts), thereby reducing their populations by targeting invasive species. An example is the use of insects or pathogens to decrease or eradicate non-native invasive plants. **Cultural control**: This approach involves adopting practices to increase the mortality of invasives or reduce their rate of damage. Examples include selecting pest-resistant crops, utilising winter cover crops, and adjusting planting dates. **Mechanical control:** This method encompasses activities such as mowing, hoeing, tilling, girdling, chopping, and constructing barriers using tools or machinery to "harvest" invasive plants. This involves removing and collecting them, transporting them elsewhere, and allowing them to decompose. **Physical or manual control:** This strategy entails physical interventions such as hand-pulling, digging, flooding, drawdowns (de-watering), dredging, mulching, manual destruction or removal of nests, egg masses, or other life stages, as well as shading to manage invasive plants.
Operation and maintenance	**Operational activities:** Monitoring of the area where control measures have been applied to detect the presence of invasive species. This includes assessing the effectiveness of control measures, identifying any new invasive species, and adjusting control strategies in response to the effectiveness of implemented measures and changes in invasive species populations. **Maintenance activities:** Upkeep the infrastructure or interventions used for Invasive alien species control, such as replacing physical barriers, maintaining biocontrol agents, etc. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Restoring native vegetation, Reintroduction of native fauna, Green corridors** and **Riparian buffer** (for reducing the pressure from invasive alien species, improving structure, composition and function of the ecosystem). **Techniques for fauna refuge and nesting** (woody debris or vegetation can be used to create habitat structures for wildlife or provide nesting sites for native species). Leaves, grass clippings, straw, or wood chips can be used for **mulching application.**

Supportive units & smart tech	**GIS, computer vision** and **remote sensing** (for detecting invasive species outbreaks in agricultural fields or natural habitats).
[5]CAPEX	*not available.* Main types of costs: Equipment and materials (trapping devices, drones, monitoring sensors, fencing, barriers, exclusion nets) Labour (clearing vegetation, establishing access roads and installing monitoring stations).
OPEX	*not available.* Main types of costs: Labour; Materials and supplies (traps, bait, protective gear, and monitoring equipment), Permits, fees and administrative (coordinating invasive alien species control programs, managing permits, regulatory compliance, administering outreach and public awareness campaigns); Research and development (Innovative approaches to invasive species control, develop new technologies or improve existing management techniques).
By-product(s):	Harvested organic biomass (for composting, organic fertilisers, biofuel production).

CARDIMED	2. RESTORING NATIVE VEGETATION

Picture not available. **Synonyms:** Reforestation; Afforestation; Planting Native Vegetation. **Description:** The restoration of native vegetation involves promoting natural regeneration and planting native plant species characteristics of the habitat to be restored,thus bringing the ecosystem back towards a good condition.

Main challenges targeted	Biodiversity & Renaturalization, Societal benefits, freshwater and groundwater
Regulation and Maintenance Services	Air quality regulation, Climate regulation, Water regulation, Improve quality of surface water, Improve quality of groundwater, Avoid / reduce salinity in groundwater, Efficient water treatment (effluent of WWTP), Reduce flood risk, Reduce landslides, Permeability restoration, Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Wetland creation and/or restoration, Forest creation and/or restoration, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Increase green areas around urban rivers, Reduce sediment flow in the river, Restore natural forest fire regime, Coastal restoration & protection/ Promote resilience against natural disasters, Restore aquatic habitats, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Reduction of greenhouses gases emissions, Improve carbon sequestration, Provide thermal regulation / cooling, Reduce risk of pest and diseases, Provide genetic resources

[5] The researchers used a filtered version of the database, to assess costs incurred globally between 1960 and 2020. They report that over this period the total cost of damages from invasive alien species was €1,055.82 billion. The researchers highlight that the expenditure on management action for invasive species is 10 times lower than the cost of the damage they cause, and that the expenditure on preventive action is 25 times lower than on reactive measures. (European commission, 2022)

Cultural Services	Recreation and ecotourism, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Preserve cultural and historic heritage, Facilitate education, Support environmental awareness, Health and Well-Being improvement, Ensure accessibility to green spaces, Increase stakeholder engagement, Enhance acoustic comfort, Promote mental health, Reconnect people with nature
Provisioning Services	Biochemical, natural medicines, pharmaceuticals, Fuel, Production of biomass, Provide raw material, Provide nutrition sources for birds and insects, Promote natural aquifer recharge / preserve groundwater supply, Promote natural surface water recharge / preserve surface water supply
Other Services	Contribute to local employment, Increase land/property monetary value, Increase tourism, Reduced costs in comparison with other solutions, Reduced carbon footprint
Replicability	★★☆
Design & planning	Select variety of **species** and genetic variability. Seeds or cuttings are often collected from various sources within the local region to ensure genetic diversity, a crucial factor in fostering resilient ecosystems. **Planting** with seeds or seedlings. Planting methods may involve the direct sowing of seeds or the transplantation of seedlings, both aimed at re-establishing diverse and thriving native plant communities. Developing an irrigation plan in the early stages of planting to ensure the survival of seedlings. Planting in suitable environmental conditions (i.e., avoiding planting during drought months in Mediterranean climates). Considering **ecological succession**, initially planting pioneer species and, once established, introducing late successional species. Placing **protective structures** around planted seedlings to improve their chances of survival and natural **perches** to promote the dispersion of planted species.
Operation and maintenance	**Operational activities:** Installation of fencing, If soil preparation and soil moisture during planting were adequate, monitoring irrigation should not be necessary. Annual monitoring is essential to evaluate and identify the success of native vegetation restoration or determine if modifications are needed. In this sense a monitoring management plan should include specific measures aligned with the SMART principles (Specific, Measurable, Achievable, Realistic and Time-bound). **Maintenance activities:** Control of competing plants, and management of herbivores or other animals that may damage the plantations. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Invasive alien species control, Reintroduction of native fauna, Techniques for fauna refuge and nesting** (for reducing the pressure from invasive species, improving structure, composition and function of the ecosystem). **Riparian buffer** and **Green corridors** (enabling native species to establish and adapt to their

	environment, improving structure, composition and function of the ecosystem). Leaves, grass clippings, straw, or wood chips can be used for **Mulching applications.** Properly composted organic biomass can also be used for **Compost application.**
Supportive units & smart tech	**Remote sensing, computer vision and GIS** (for prioritising intervention areas and monitoring the success of native species restoration practices).
CAPEX	*not available.* Main type of costs: Equipment and materials (seeds, seedlings or saplings, fencing, tree shelter, irrigation system, seed drills, planting machinery and irrigation equipment); Labour (land clearing, soil preparation, and erosion control measures construction, fencing and irrigation system installation and access roads construction).
OPEX	*not available.* Main type of costs: Labour (training staff, maintenance of seeds, seedlings, or saplings, watering, fertilising, pest control measures, weed control, invasive alien species management, data collection, analysis and reporting); Research and development (innovative approaches to invasive alien species control, develop new technologies or improve existing management techniques).
By-product(s):	Woody biomass and organic biomass from trimming, pruning, clippings and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel). Potential generation for carbon credits.

CONSERVATION AND RESTORATION OF FAUNA

CARDIMED	1. TECHNIQUES FOR FAUNA REFUGE AND NESTING

Picture not available. **Synonyms:** Insect Hotel; Practices for enhancing wildlife habitat; Habitat structures for animal conservation. **Description:** Techniques for Fauna Refuge and nesting aim to bolster biodiversity and support habitat restoration efforts. This involves constructing hedgehog houses and rock piles to offer cosy shelters for small mammals and reptiles, while also creating insect hotels to attract and shelter various beneficial insects crucial for ecosystem health. Additionally, brush piles and artificial roosts provide cover and nesting sites for a variety of wildlife, while wildflower meadows attract insects and serve as habitat for a diverse array of plant species. Together, these interventions form a comprehensive strategy for promoting ecological balance and preserving biodiversity in our environment.

Main challenges targeted	Biodiversity & renaturalization, Societal benefits
Regulation and Maintenance Services	Create or restore fauna, Support pollination, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals
Cultural Services	Recreation and ecotourism, Health and Well-Being improvement, Increase recreational and socialisation value, Facilitate education, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Provide nutrition sources for birds and insects

Other Services	Not available
Replicability	★★
Design & planning	Understanding the natural structures preferred by the target species involves either conducting well-designed experiments to assess the interaction between the target species and the proposed structures, or collaborating with experts in ecology and biology. It also requires closely observing the behavioural patterns and habitat preferences of the target species, including nesting preferences and shelter requirements. Additionally, it's crucial to evaluate whether the desired outcomes are achieved and make necessary adjustments accordingly. This ensures alignment with ecological principles and best practices.
Operation and maintenance	**Operational activities:** Monitoring and measuring durability and effectiveness of the structures. Detect possible negative outcomes (such as facilitating invasive insect species). Assessment and distribution of findings to more effectively inform conservation managers. Furthermore, regular monitoring and adaptive management are essential for ongoing success, allowing for adjustments based on observed outcomes and feedback from the target species. Following these guidelines ensures the creation of effective and sustainable habitat enhancements that contribute to biodiversity conservation and ecosystem preservation. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Restoring native vegetation, Invasive alien species control, Reintroduction of native fauna, Lagoon restoration, Agroforestry, Green corridors, Riparian buffer** and **Urban micro forest** for providing a holistic approach to ensure safe habitats for wildlife reproduction and nesting, maintain and promote healthy populations of native species, and increase wildlife's ability to adapt to environmental and climate changes. Leftover wood scraps and sawdust generated during the fabrication of structures can be used for **Mulching / Compost application.**
Supportive units & smart tech	**Smart sensors** and **computer vision** incorporated into nesting boxes (for tracking occupancy, environmental conditions, and animal behaviour). **Remote sensing** and **GIS** (for prioritising intervention areas).
CAPEX	*not available.* Main type of costs: Equipment and materials (nesting boxes, bat boxes, hedgehog houses, rock piles, insect hotels, brush piles, artificial roosts, purchase of sensors, cameras, data loggers, and other monitoring devices); Technology and software (GIS and other software applications); Permits, fees and administrative; Labour.
OPEX	*not available.* Main type of costs: Labour (maintaining and repairing habitat structures, equipment and infrastructure); Permits, fees and administrative; Community engagement and educational programs.

By-product(s):	Leftover wood scraps and sawdust generated during the fabrication of structures for nesting and refuge (for mulching or composting). Soil may be displaced to create suitable habitats. This soil can be repurposed for landscaping or gardening.

CARDIMED	2. REINTRODUCTION OF NATIVE FAUNA

Picture not available. **Synonyms:** Species reintroduction; Wildlife reintroduction; Rewilding; Wildlife restoration; Species reintroduction; Reintroduction of wildlife; Reintroductions of fauna; Reintroductions of animals. **Description:** The reintroduction of native fauna is a deliberate process focused on returning animal species to their native habitats following extirpation or extinction in the wild. It often involves releasing individuals bred in captivity or captured from the wild, with the primary goal of revitalising wild populations and reinstating biodiversity in areas where species have vanished.

Main challenges targeted	Biodiversity & renaturalization, Societal benefits
Regulation and Maintenance Services	Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Increase green areas around urban rivers, Restore natural forest fire regime, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Improve carbon sequestration, Reduce risk of pest and diseases
Cultural Services	Aesthetic values, Recreation and ecotourism
Provisioning Services	Provide nutrition sources for birds and insects, Nutrient recovery, Sustainable food production
Other Services	Contribute to local employment, Increase land/property monetary value, Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products)
Replicability	★★☆
Design & planning	Ensuring that **habitat** suitability and availability align with the requirements of selected species is essential for determining feasibility. Comprehensive understanding of any species for translocation must encompass its **biotic and abiotic habitat requirements**, its interspecific relationships, critical dependencies, and fundamental biological traits. The **climate** at the destination site should remain suitable for the future. In some instances, the original species or subspecies may have become extinct, both in the wild and in captivity. In such cases, a similar, related species or subspecies can serve as an ecological replacement, provided that the substitution is grounded in objective criteria such as **phylogenetic closeness**, resemblance in appearance, ecology, and behaviour to the extinct form.

	Conservation translocations should strive to adhere to internationally accepted **standards for welfare**. They must also comply with the legislation, regulations, and policies in both the source and release areas. **Managing disease and preventing pathogen** transfer is crucial. It aims to optimise the health of translocated organisms while minimising the risk of introducing new pathogens to the destination area.
Operation and maintenance	**Operational activities:** Monitoring and evaluation are crucial for identifying new threats to the translocated population that were not initially anticipated in the translocation design. The intensity and duration of monitoring for both the source and translocated populations should be tailored to each specific situation. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Techniques for fauna refuge and nesting, Lagoon restoration, Restoring native vegetation, Invasive alien species control** (for promoting the restoration and conservation of natural habitats for native species, encouraging the reproduction and establishment of native species, and controlling populations of invasive species)
Supportive units & smart tech	**GPS** (to monitor the movements and behaviours of reintroduced animals in their natural habitats). **Remote sensing** (satellite imagery and aerial drones) and **computer vision** (to assess habitat suitability, monitor vegetation dynamics and identify potential threats to reintroduced species). **Artificial intelligence** and **machine learning** (to identify patterns, predict population trends, and optimise management strategies for better conservation outcomes).
CAPEX	*Not available.* Main type of costs: Equipment and materials (vehicles and equipment for transporting animals, tracking devices, GPS collars, cameras, and other monitoring systems and breeding and raising animals facilities); Research and development (feasibility studies and planning activities prior to reintroduction); Transportation and delivery; Labour (restoring or enhancing habitats and other tasks).
OPEX	*Not available.* Main type of costs: Labour (monitoring, data collection and veterinary care); Research and development.
By-product(s):	*Not applicable*

2.4 NBS soil interventions

This section presents **6 factsheets dedicated** to **NBS Soil Interventions**, detailing Permeable surfaces, organic soil amendment farming practices and land management techniques.

PERMEABLE SURFACES

CARDIMED	1. SURFACE UNSEALING

Picture not available. **Synonyms:** De-sealing; De-sealed area; Deculvering; unsealing surfaces, demineralization. **Description:** Surface unsealing encompasses a variety of techniques aimed at removing impermeable surfaces to enhance water infiltration and reduce runoff. It involves the removal of impervious layers, such as asphalt or concrete, to restore natural permeability of soil or replace them with permeable surfaces. By creating pathways for water to penetrate into the soil below, these techniques mitigate stormwater issues and contribute to environmental sustainability. Furthermore, desilting surfaces can improve soil health, stimulate vegetation growth, and bolster overall ecosystem resilience.

Main challenges targeted	Air quality, Soil restoration & protection, Societal benefits
Regulation and Maintenance Services	Permeability restoration, Create or restore habitat, Restore degraded areas Mitigate desertification, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Rehabilitate polluted soil, Improve carbon sequestration, Reduction of greenhouses gases emissions, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling
Cultural Services	Aesthetic value, Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Facilitate education, Reduce undesired behaviours, activities and vandalism, Support social cohesion and justice, Support environmental awareness,, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Promote artificial aquifer recharge / preserve groundwater supply
Other Services	*Not applicable*
Replicability	★★★
Design & planning	Standard **equipment** typically used in road construction for regular asphalt can also be utilised for surface unsealing projects. This includes machinery and tools necessary for excavation, levelling, and laying materials.
Operation and maintenance	*Not applicable*
Combinations with other NBS	**Porous/Pervious asphalt** (for an integrated management of stormwater runoff). **Bioretention cell (rain garden), Bioswale and Filter drain** (for reducing the runoff going to these systems, improving stormwater source control and enhancing overall biodiversity of the approach - an integrated rainwater management strategy). **Terracing** (for enhancing slope stability and maximising the available land for water infiltration).
Supportive units & smart tech	*Not applicable*

CAPEX	10 - 30 €/m^2. Main type of costs: Equipment and materials (demolition machinery, hand tools and other) Labour (replacement materials of the paved surface, demolition and removal of the sealants).
OPEX	*Not applicable*
By-product(s):	*Not applicable*

ORGANIC SOIL AMENDMENTS

CARDIMED	1. COMPOST APPLICATION

Picture not available. **Synonyms:** Community composting; Compost heap; Compost application facility; Soil improvement and conservation; Soil enhancement; Soil amendment; Gentle remediation options; Soil management; Improved soil; Xeriscaping. **Description:** There are various techniques to produce organic compost, and numerous sources contribute to its production, including urban allotments, livestock, restaurants, markets, fruit stores, and industrial processes. However, the true transformation occurs when it's applied to the soil. Compost application is a game-changer for soil health and fertility. Through compost application, the soil's microbiota is enriched, and its physical characteristics are improved, such as its ability to retain water, which is crucial for plant growth. When spread onto the land, compost enriches soil structure, infuses it with essential nutrients, and nurtures robust plant growth.

Main challenges targeted	Soil restoration & protection, Societal benefits
Regulation and Maintenance Services	Erosion regulation, Reduce flood risk, Permeability restoration, Create or restore fauna, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention
Cultural Services	Social relations (related to recycling activity of organic waste and its valorization), Facilitate education, Support social cohesion and justice, Support environmental awareness, Reconnect people with nature
Provisioning Services	Nutrient cycling , Soil formation, Promote natural aquifer recharge / preserve groundwater supply, Promote artificial aquifer recharge / preserve groundwater supply, Provide nutrition sources for birds and insects, Production of biomass, Nutrient recovery, Sustainable food production
Other Services	Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products)
Replicability	★★★
Design & planning	**Assess soil needs:** soil quality analysis to determine nutrient deficiencies and ph levels. **Calculate application rates:** based on size of the area, soil's requirements and composition of the compost. **Application timing**: typically during the growing season or before planting. avoid applying compost during heavy rain or when the ground is frozen. **Proper application method**: The method chosen depends on factors like soil structure,

	plant type, and etc. Some methods are: topdressing, incorporation into the soil, or as a mulch. If incorporating compost into the soil, ensure thorough mixing to distribute nutrients evenly and prevent clumping. **Consider local context:** slope, proximity to water bodies, and regulations regarding compost application to minimise potential runoff and environmental hazard.
Operation and maintenance	**Operational activities: (Monitor moisture Levels)** Water the area if necessary to help activate microbial activity and facilitate nutrient uptake by plants. **(Rotate application areas)** Rotate compost application areas to ensure all proper distribution and resting time between applications. (**Follow best practices)** local agricultural extension services or composting organisations to maximise effectiveness and minimise risks. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Green corridors**, **vegetated pergolas** and **agroforestry** (for maintaining the soil quality and sustainability). **Sludge treatment wetland** (to obtain compost).
Supportive units & smart tech	**Advanced soil health monitoring**, (for assessing impact and optimising compost management practices).
[6]**CAPEX**	*Not available*. Main type of costs: Equipment and materials (compost material, storage facilities, equipment for spreading compost or manual labour and vehicles); Permits, fees and administrative (regulatory compliance and consulting fees); Transportation and delivery; Labour.
OPEX	*Not available*. Main type of costs: Permits, fees and administrative.
By-product(s):	*Not applicable*

[6] It depends on the type of crop, the amount of compost required (depth and size of area), and the application method.

CARDIMED	2. MULCHING APPLICATION

Picture not available. **Synonyms:** weeds management; Mulch; Soil improvement and conservation; Soil enhancement; Soil amendment; Gentle remediation options; Soil management; Improved soil; Soil moisture management, Retaining stubble and green manuring; Xeriscaping. **Description:** Mulching application is a technique that involves placing a layer of material (mulch) over the soil around plants, which can be organic (such as straw, compost, or bark) or inorganic (such as plastic or fabric). This material acts as a protective cover that offers various benefits, such as soil moisture conservation, erosion reduction, weed control, soil T regulation, and soil health improvement. Mulch serves the dual purpose of retaining moisture and suppressing weed growth in dry, hot conditions, but it must be managed carefully to avoid waterlogging and rot in wet, cold climates. Mulching is commonly used in agriculture, gardening, and horticulture to maintain a more conducive environment for plant growth and to reduce the need for irrigation and the use of herbicides.

Main challenges targeted	Biodiversity & renaturalization, Rainwater management & flood protection, Soil restoration & protection
Regulation and Maintenance Services	Erosion regulation, Reduce flood risk, Reduce combined sewer overflows Reduce landslides, Reduce urban runoff, Stormwater source control, Permeability restoration, Create or restore habitat, Create or restore fauna Create or restore flora, Reduce harmful impacts to fauna & flora, Forest creation and/or restoration, Develop resilience of green spaces, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Improve carbon sequestration
Cultural Services	Facilitate education, Support environmental awareness
Provisioning Services	Promote natural aquifer recharge / preserve groundwater supply, Provide nutrition sources for birds and insects, Nutrient recovery
Other Services	Contribute to local employment, Increase land/property monetary value, Reduced costs in comparison with other solutions, Reduced carbon footprint
Replicability	★★★
Design & planning	**Materials** used for mulching vary depending on the type of mulch. For mineral mulch, options include sand, pozzolana, gravel, and slate. Raw organic mulch includes flax flakes, hay, and hemp glitter. Wood mulch encompasses maritime pine bark, wood chips, wood pellets, bagasse, fragmented rameal wood, and non-composted wood mulch. **Depth of application** varies depending on the mulch material, ranging from 5-18 cm. The most common **type of mulch to be anchored** is hay or straw. The primary **anchoring methods** include mulch tiller, netting, manual anchoring with spade or peg and twine.
Operation and maintenance	**Operational activities:** Inspect mulched areas, monitor weeds and pest, assess the effectiveness of the mulch (application, coverage, durability, etc.) and adapt management or mulch type accordingly. **Maintenance activities:** Remove or integrate mulch materials as required. Appropriately gather and dispose of synthetic mulch

	material after its intended use. Manage undesirable weeds and pests. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Bioretention cell (rain garden)** (for promoting moisture retention and weed suppression, reducing the need for frequent watering, which is especially relevant for young rain gardens). **Agroforestry** and **Urban micro forest** (for maintaining the soil quality and sustainability). These NBS can also act as a source of organic material for **Mulching application**. **Permeable surfaces** (for moisture regulation, weed control, enhanced water infiltration).
Supportive units & Smart tech	**Smart irrigation systems** (supply and optimization of irrigation). **Remote sensing, computer vision** and **advanced precision agriculture equipment** (for supporting informed decisions and optimising mulch distribution and coverage). **Biodegradable mulch films** (for weed suppression and moisture retention benefits while degrading naturally over time). **Solar panels** (for reducing energy costs and enhancing overall sustainability). **Advanced soil health monitoring** (for assessing impact and optimising mulch management practices).
[7]CAPEX	0.75 - 2 €/m^2. Main type of costs: Equipment and materials (mulch material, equipment for spreading mulch or manual labour, wheelbarrows and rakes); Labour (clearing and levelling the area); Transportation and delivery.
OPEX	0.15 - 0.5 €/m^2 y. Main type of costs: Labour (mulch replacement, weed control, inspections and repairing damaged areas).
By-product(s):	*Not applicable*

[7] The cost varies depending on the type of mulching chosen, the size of the covered area, encompassing both material costs and installation expenses

FARMING PRACTICES

CARDIMED	1. COVER CROPS

Synonyms: Green manure, Soil enhancement; Soil amendment; Gentle remediation options; Soil management; Improved soil; Soil moisture management, Conservation agriculture; Agroecology practices; Sustainable farming practices; Climate-smart agricultural techniques (CSA,). **Description:** Cover crops are crops planted primarily to cover and protect the soil, rather than for harvesting and sale. These crops are typically planted between main crop seasons or alongside cash crops. The primary purpose of cover crops is to improve soil health and fertility, prevent erosion, and suppress weeds. Indeed, cover crops are an important part of sustainable and regenerative agricultural practices aimed at maintaining and enhancing the long-term health and productivity of the land. Picture source: Ledda

Main challenges targeted	Biodiversity & renaturalization and Societal benefits
Regulation and Maintenance Services	Erosion regulation, Improve quality of surface water, Improve quality of groundwater, Reduce flood risk, Reduce sediment flow into drainage systems, Reduce combined sewer overflows, Reduce landslides, Reduce urban runoff, Stormwater source control, Permeability restoration, Create or restore habitat, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Forest creation and/or restoration, Connect green spaces; Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Improve carbon sequestration, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Facilitate education, Support environmental awareness;Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits

Provisioning Services	Nutrient cycling , Soil formation, Production of biomass, Nutrient recovery, Promote natural aquifer recharge / preserve groundwater supply, Harvest, store and treat rainwater, Provide nutrition sources for birds and insects, Sustainable food production
Other services	Contribute to local employment, Increase land/property monetary value, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced carbon footprint
Replicability	★★★
Design & planning	**Plants selection:** consider factors such as climate, soil type, cropping sequence, and desired benefits such as nitrogen fixation, weed suppression, erosion control. **Main categories of plants:** grasses, including grains such as oats, barley, or wheat, as well as warm-season grasses like millets, sorghums, and sudangrass; brassicas, this group consists of leafy broadleaf plants with a large taproot, such as radishes, turnips, and other related species; legumes, any species capable of forming nodules on its roots and fixing excess soil nitrogen, such as clovers, peas, and vetches. **Residue removal and weed control**, creates optimal conditions for cover crop germination and growth.**Seeding depth** from 0.5-2.5 cm. When species with different seeding depths are mixed together, there are several strategies that can be used to aid in the successful establishment of each species. It is recommended to sow cover crops at a **seeding rate** ranging from 265-290 Kg per ha depending on the species.
Operation and maintenance	To properly define the termination time of the cover crops e.g biomass quantity and quality (in terms of C/N ratio). Optimised plants density and species selection or mixing. Different species for different agro-ecological objectives. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	Crop rotation and Agroforestry (for improving soil quality, reduction of erosion, water and moisture retention, and suppressing weeds)
Supportive units & Smart tech	**Advanced precision agriculture equipment** (for precise planting and management in line with field variability). **Advanced soil health monitoring** (for assessing impact and optimising cover crop management practices).
CAPEX	20 - 180 €/ha. Main types of costs: Equipment and materials (cover crop seed); Labour (preparing the soil and seeding the cover crops)
OPEX	*not available*. Main types of costs: Labour (soil management, fertilisation and weed control).
By-product(s):	*not applicable*

CARDIMED	2. CROP ROTATION

Picture not available. **Synonyms:** Crop Diversification; Soil enhancement; Soil amendment; Gentle remediation options; Soil management; Improved soil;Conservation agriculture; Agroecology practices; Sustainable farming practices; Climate-smart agricultural techniques (CSA). **Description:** Crop rotation is an agricultural practice involving the systematic alternation of different crops on the same land over time to enhance soil health, increase yields, and manage pests and diseases sustainably. It's based on varying crop types planted in successive seasons, contributing to improved crop and soil health, and overall agricultural sustainability. Rotation patterns may vary based on local conditions and crops grown, but the core principle remains consistent: alternating crops to maintain and improve land health while maximising productivity.

Main challenges targeted	Biodiversity & renaturalization, Societal benefits, Soil restoration & protection
Regulation and Maintenance Services	Reduce water withdrawals, Improve quality of surface water, Improve quality of groundwater, Avoid / reduce salinity in groundwater, Efficient water treatment (effluent of WWTP), Efficient water treatment (agricultural runoff), Reduce flood risk, Reduce agricultural runoff, Permeability restoration, Mitigate desertification, Coastal restoration & protection/ Promote resilience against natural disasters, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Rehabilitate polluted soil, Improve carbon sequestration, Reduction of greenhouses gases emissions
Cultural Services	Aesthetic values, Facilitate education, Support environmental awareness
Provisioning Services	Production of biomass, Provide raw material, Nutrient recovery, Sustainable food production
Other Services	Increase land/property monetary value, Contribute to new or existing business, Reduced costs in comparison with other solutions, Reduced carbon footprint, Reduced water footprint
Replicability	★★★
Design & planning	**Plants** with similar pest and disease susceptibilities must be separated by an appropriate time interval. Rotate crops from different plant families, such as brassicas (cabbage, broccoli, cauliflower, etc.), solanaceae (tomato, potato, eggplant, etc.), cucurbits (cucumber, squash, melon, etc.), alliaceae (onion, garlic, leek, etc.), and leguminous (peas, lentils, beans, etc.), etc. Rotate heavy nitrogen-consuming crops with nitrogen-fixing crops or cover crops. Rotate crops with different root systems, such as taproots (carrot, beet, radish, etc.), fibrous roots (lettuce, spinach, celery, etc.), and tubers (potato, sweet potato, yam, etc.). **Plan cover crop planting** strategically to avoid leaving soil bare or periods where nutrients are released without active plant growth **Harvesting time** determines the sequence of crops in a rotation. For instance, autumn-sown crops require a clear area in summer and/or autumn for necessary cultivation, limiting them to succeeding crops harvested by summer's end. Conversely, summer-sown crops like winter brassicas typically follow vegetables or green manures that were cultivated

	over winter, freeing up the land earlier than spring-sown crops. Segment the **crop allotment** into equal-sized sections, with an additional area designated for perennial crops.
Operation and maintenance	**Operational activities:** Maintain healthy soil (including chemical balance, drainage, vitality, biological health, fertility, nutrient cycling, tilth, organic matter, and soil cover to prevent erosion). The frequency and amount of watering are adjusted according to rainfall and evaporation rates, crucial for maintaining soil and plant health. Adjusting the timing of harvest, either earlier or later, based on the ripeness and quality of the crops. **Maintenance activities:** Control and management of weeds, diseases and pests. Adding or removing mulch as necessary, based on the T and moisture levels of the soil. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Compost application, Mulching application and Cover crop** (for improving soil quality, reduction of erosion, water and moisture retention, and suppressing weeds)
Supportive units & smart tech	**Weather stations data** (for optimising planting and harvesting schedules to maximise rotation benefits). **Remote sensing** (satellite imagery and aerial drones for assessing rotation success, identifying areas for improvement and thus supporting informed decisions and optimising crop rotation management). **Advanced precision agriculture equipment** (for optimising planting, fertilisation, rotation and crop yields). **Solar panels** (for reducing energy costs and enhancing overall sustainability). **Advanced soil health monitoring** (for assessing impact and optimising crop rotation management practices). **Decision support systems** (for enabling data-driven decision-making and optimise rotation planning).
CAPEX	1,000 - 20,000 €. Main type of costs: Equipment and materials (seeds and planting materials, machinery and fertilisation); Labour (land preparation and other tasks).
OPEX	200 - 350 €/ha y. Main type of costs: Labour (seeding, fertilisation, soil management, harvesting and weed control).
By-product(s):	Organic biomass from trimming, pruning, clippings, straw and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel). Forage and fodder (for livestock or other animals).

LAND MANAGEMENT TECHNIQUES

CARDIMED	1. TERRACING

Picture not available. **Synonyms:** Terraces; Crescent terraces. **Description:** Terracing involves constructing a series of

horizontal platforms or steps on sloping or hilly terrain (such as crescent terraces). These platforms, often created with retaining walls or embankments, provide flat surfaces at different elevations. Terracing is primarily used in agriculture to reduce soil erosion by slowing down the flow of water down slopes. It creates level planting areas for crops, making it easier to manage irrigation, prevent soil loss, and enhance crop productivity, soil erosion and improve water retention.

Main challenges targeted	Rainwater management & flood protection, Biodiversity & renaturalization, Societal benefits
Regulation and Maintenance Services	Reduce flood risk, Reduce sediment flow into drainage systems, Reduce combined sewer overflows, Reduce landslides, Reduce urban runoff, Stormwater source control, Permeability restoration, Create or restore habitat, Support pollination, Forest creation and/or restoration, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Improve carbon sequestration, Provide thermal regulation / cooling
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Facilitate education, Reduce undesired behaviours, activities and vandalism, Support environmental awareness, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature
Provisioning Services	Promote natural aquifer recharge / preserve groundwater supply, Material reuse
Other Services	Contribute to local employment, Increase land/property monetary value, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products)
Replicability	★★★
Design & planning	When constructing terraces, several factors must be considered. The **slope**, typically less than 50%, though it's feasible to manage steeper slopes up to 100%, requires gradual and consistent construction. Careful balance between soil cut and fill is crucial. The **size** of the terrace depends on drainage needs and agricultural methods employed. Similarly, terrace **length** varies based on the lot's size and shape. The **width** of non mechanised crops, terrace ranges from 2.5 to 5 m, while mechanised crops require wider terraces, typically spanning 3.5 to 8 m.
Operation and maintenance	Monitoring and maintenance are essential, especially after severe storms and harvests, particularly during the initial two to three years following construction. It's important to conduct inspections and promptly repair any damage to the structure. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor

Combinations with other NBS	**Cover crop, Crop rotation, Compost application, Mulching application, Urban micro forest** and **Agroforestry** (for improving soil quality, reduction of erosion, water and moisture retention, and suppressing weeds). **Porous asphalt** (to enhance erosion control, water management, and water quality improvement).
Supportive units & smart tech	**GPS** and **GIS** (for identifying erosion hotspots, for mapping terraced landscapes and guiding earth-moving equipment).
CAPEX	*not available.* Main type of costs: Equipment and materials (irrigation systems, planting materials, plants, stones, tractor, wire and staking poles); Labour (land levelling, ploughing/harrowing, destoning, terrace wall construction, irrigation system installation, planting and staking/wiring).
OPEX	*not available.* Main type of costs: Labour (ploughing/harrowing, fertilisation, plant protection, weed control, irrigation, pruning, topping/thinning and harvesting).
By-product(s):	Surplus soil, rocks, or other materials excavated from the site (for landscaping, construction projects, or filling in other areas prone to erosion)

2.5 NBS aquatic interventions

This section presents **4 fact sheets** delving into **NBS aquatic Interventions,** elucidating approaches employed for **River Management Techniques**, **riverbank measures, rehabilitation of aquatic systems.**

RIVERBANK MEASURES

CARDIMED	1. RIPARIAN BUFFER

Picture not available. **Synonyms:** Riparian buffer strip; Vegetative filter strips; Buffer strips, Riparian area, riparian forest. **Description:** A riparian buffer involves the purposeful establishment and management of a vegetated or naturally preserved strip of land along the banks of rivers, streams, or other water bodies. Riparian buffers reduce surface runoff and detain sediments and sediment-bound pollutants, primarily from agricultural areas. Situated between agricultural catchments and streams/rivers, they act as filters for pollutants and sediment transportation into the river, slowing down the flow.

Main challenges targeted	Biodiversity & renaturalization, Freshwater and groundwater supply and quality, Rainwater management & flood protection
Regulation and Maintenance Services	Improve quality of surface water, Improve quality of groundwater, Avoid / reduce salinity in groundwater, Efficient water treatment (effluent of WWTP), Efficient water treatment (agricultural runoff), Efficient water treatment (urban runoff), Efficient water treatment (rainwater), Reduce flood risk, Reduce sediment flow into drainage systems, River flood protection, Reduce landslides, Reduce urban runoff, Reduce agricultural runoff, Coastal flood protection, Stormwater source control, Permeability restoration, Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Connect blue and green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Increase green areas around urban rivers, Restore natural forest fire regime, Coastal restoration & protection/ Promote resilience against natural disasters, Re-establish hydrologic connection,

	Improvement of the hydromorphological functioning, Restore aquatic habitats, Reduce sediment flow in the river, Reduce sediments deposition in river beds, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Improve carbon sequestration, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Facilitate education, Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Reduce undesired behaviours, activities and vandalism, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Promote natural aquifer recharge / preserve groundwater supply, Promote natural surface water recharge / preserve surface water supply, Provide nutrition sources for birds and insects, Production of biomass, Nutrient recovery
Other Services	Contribute to local employment, Increase land/property monetary value Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favor green economy (reuse of local by-products)
Replicability	★★☆
Design & planning	The design consists of a **three-zone system**: **Zone 1:** This zone begins at the top of the bank and **plants** will contain trees and shrubs needed to provide aquatic shade, bank stability, detritus, large woody debris, and retain nutrients bound to soils. Large woody debris and tree roots in the water create habitat complexity and niches for invertebrates and aquatic organisms. Detritus such as leaves, twigs and fruit seeds entering the water and held by woody debris provide a base to the aquatic food chain. The minimum **width** for this zone is 4.5 m from the top of the bank. **Zone 2**: This zone is landward of Zone 1 and **plants** will contain the trees and shrubs and other vegetation needed to filter runoff and provide uptake of nutrients and pollutants. Together, Zone 1 and 2 will provide a travel corridor and habitat for wildlife in addition to providing shade and a source of woody debris. The minimum **width** for this zone for all purposes is 6 m. **Zone 3:** This zone, the **plants** are a strip of grass or herbaceous cover to spread, slow and filter runoff which may be transporting sediment, nutrients, and pesticides off cropland or other erosive areas. The minimum **width** for this zone is 4.5 m. Factors that improve effectiveness include: **Slopes** less than 5 percent, groundwater close to the surface. **Planting** during the growing season. **Buffer widths** greater than 7.5 m, entry **stormwater velocity** less than 0.5 m/s.
Operation and maintenance	Monitoring vegetation to ensure survival, removing invasive species, replanting areas with low vegetation survival may be necessary. Others: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be

	prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Restoring native vegetation** and **Techniques for fauna refuge and nesting** (for providing habitats for local wildlife, stabilising soils, reducing erosion, and improving water quality), **Invasive alien species control** (for preventing competition with native plants, preserving biodiversity and functions of the riparian ecosystem), **Mulching application** (for promoting healthy vegetation growth, stabilising soils, reducing erosion, suppressing weed growth and facilitating establishment of native plants). **Green corridor, Urban micro forest, Bioretention cells (rain gardens), Bioswales, Terracing** and **Filter drains** (for an integrated rainwater management). terracing, green corridor and urban micro
Supportive units & smart tech	**Remote sensing** (to evaluate riparian form, function, and change over time, as it allows for the continuous collection of geospatial data over large areas); **GIS Mapping** (geographical Information Systems (GIS) can be used for detailed mapping of riparian zones, analysing spatial relationships and changes over time to help in planning and conservation efforts; **Unmanned Aerial Vehicles (UAVs) or drones** (equipped with cameras and sensors can provide high-resolution imagery and are useful for monitoring changes in vegetation, erosion, and other ecological factors in riparian areas); **Water quality sensors** (automated sensors placed in streams or rivers can continuously monitor water quality parameters such as pH, temperature, turbidity, and contaminant levels, providing real-time data critical for assessing the effectiveness of riparian buffers in filtering runoff); **Automated weather stations** (can collect data on local climate conditions (e.g., rainfall, humidity, temperature) for understanding weather-related impacts and planning adaptive management strategies); **Soil moisture sensors** (can help monitor soil moisture levels, providing data that can be used to assess the health of the vegetation and its effectiveness in stabilising the soil and filtering pollutants).
Treatment efficiency	**TN: 25-97%; TP: 55-94% ; TSS: 75-97%**
CAPEX	100 - 2000 €/ha. Main type of costs: Equipment and materials (seeds, shrubs, trees and tree shelters) Labour (planting and tree shelters installation).
OPEX	20-500 €/ha y. Main type of costs: Labour (maintenance and mowing)
By-product(s)	Woody biomass (for biofuel) and organic biomass from trimming, pruning, clippings and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel).

RIVER MANAGEMENT TECHNIQUES

CARDIMED	**1. DIVERSION CHANNELS**

Picture not available. **Synonyms:** Redirecting channels, Canal diversions, Channelling conduits, Diversion conduits, , Flow redirection channels. **Description:** Diversion channels are primarily artificial waterways crafted to redirect water flow, serving to mitigate flooding, erosion, and landslides, while also facilitating water recharge and supply to other areas or bodies of water. These channels can be constructed or utilised to divert either all or a portion of river flow away from the base of slopes or landslide-prone areas. Typically, diversion channels are stabilised with a covering of vegetation, predominantly comprising grasses. Their lifespan may vary, ranging from temporary to permanent, depending on project goals. Importantly, the design of diversion channels should prioritise biodiversity benefits and strive to have a positive impact on nature in both the short and long term, contributing not only to water management but also to biodiversity conservation and protection efforts.

Main challenges targeted	Freshwater and groundwater supply and quality, Rainwater management & flood protection, Biodiversity & renaturalization
Regulation and Maintenance Services	Water regulation, Efficient water treatment (effluent of WWTP), Efficient water treatment (agricultural runoff), Efficient water treatment (urban runoff), Efficient water treatment (rainwater), Reduce flood risk, River flood protection, Reduce urban runoff, Reduce agricultural runoff, Coastal flood protection, Stormwater source control, Create or restore habitat, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Connect green spaces, Connect blue and green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Increase green areas around urban rivers, Restore natural forest fire regime, Coastal restoration & protection/ Promote resilience against natural disasters, Re-establish hydrologic connection, Improvement of the hydromorphological functioning, Restore aquatic habitats, Enhance and stabilize water flow (Sustain river flow), Enhance and stabilize water retention, Provide thermal regulation / cooling
Cultural Services	Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Reconnect people with nature
Provisioning Services	Promote natural aquifer recharge / preserve groundwater supply, Promote natural surface water recharge / preserve surface water supply, Water reuse, Provide nutrition sources for birds and insects, Nutrient recovery
Other Services	Contribute to local employment, Increase land/property monetary value Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced water footprint
Replicability	★★☆
Design & planning	The main **plants** are grass or herbaceous species, to stabilise their banks and reduce erosion. A minimum **depth** of 3 m, these channels effectively manage water flow and hydraulic forces. To prevent overtopping, a **freeboard** equal to 10% of the channel depth is recommended, ensuring safety during high-flow periods. Embankments should feature a **crest width** of at least 600 mm and a down-slope bank gradient of 2:1 for stability and accessibility. A minimum **berm width** of 1.5 m along the channel enhances stability and supports vegetation.

Operation and maintenance	**Operational activities:** Inspect weekly inspections of the diversion channel and inspect after any increase in flow within the channel. Verify that fill material or sediment is not obstructing the channel in any way **Maintenance activities:** Repair any slumps or loss of freeboard promptly.. Properly dispose of any collected sediment or fill to prevent erosion or pollution hazards. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Dams, Bioswale** and **Riparian buffer** (for flood prevention, erosion control and landslide mitigation)
Supportive units & smartech	**Retaining walls** (structural support along channel edges, for resisting lateral soil pressure and minimising erosion risks). **Smart sensors** (to monitor water flow, level, water quality and T for assessing the impact of environmental conditions, detecting anomalies, and optimising maintenance).
CAPEX	*not available*. Main type of costs: Permits, Fees and administrative (engineer fees and land acquisition); Equipment and materials (concrete, stone or other material, monitoring systems); Labour (excavation, levelling, construction of the channel, gates or flow control structures).
OPEX	*not available*. Main type of costs: Labour (inspection, cleaning, and repairing damaged equipment).
By-product(s):	*Not applicable*

CARDIMED — 2. DAMS

Picture not available. **Synonyms:** Stone weirs; Sand dams; Embankment; Earth dams; Subsurface dam; Riverbank erosion control and water harvesting structures. **Description:** Dams are a sustainable, low-cost rainwater harvesting technique and highly effective. A dam is a reinforced stone masonry wall built across a seasonal river. They raise groundwater levels, enabling vegetation regrowth, reducing soil erosion, reversing land degradation and increasing the productivity of the land. Also, they reduce runoff, increase infiltration and prevent the formation of gullies (such as earth dams).

Main challenges targeted	Rainwater management & flood protection, Biodiversity & renaturalization, Societal Benefits
Regulation and Maintenance Services	Improve quality of groundwater, Avoid / reduce salinity in groundwater, Reduce flood risk, River flood protection, Mitigate desertification, Create or restore fauna, Create or restore flora, Provide nesting and breeding habitat, Coastal restoration & protection/ Promote resilience against natural disasters, Improvement of the hydromorphological functioning, Reduce sediment flow in the river, Enhance and stabilize water flow (Sustain river flow)

Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Preserve cultural and historic heritage, Facilitate education, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Reconnect people with nature
Provisioning Services	Promote natural aquifer recharge / preserve groundwater supply, Promote natural surface water recharge / preserve surface water supply, Water reuse , Provide nutrition sources for birds and insects, Material reuse, Sustainable food production
Other Services	Contribute to local employment, Reduced costs in comparison with other solutions, Reduced water footprint
Replicability	★★☆
Design & planning	**Materials** are blocks or stones, alluvial soil, coarse sand, reinforced concrete wall. Typical **heights** ranging from 2.5 to 5 m and lengths varying based on river width. To prevent overtopping, a freeboard equal to 10% of the channel depth is recommended, ensuring safety during high-flow periods. A **freeboard**, the vertical distance between the water level and the top of the dam structure, should always be maintained at a minimum of 0.5 m. However, for optimal safety and effectiveness, it is recommended to aim for a range between 0.75-1.0 m. The embankment **crest width** should be designed to allow the safe passage of plant and equipment to be used in the dam construction and should be no less than 2 m wide. The **embankment** constitutes the core structure of the dam, and adherence to specific design and construction guidelines is imperative. Side slopes should not exceed a ratio of 1:2 on the upstream side and 1:1.75 on the downstream side.
Operation and maintenance	Inspections and repairs to ensure structural integrity and effectiveness in water management and erosion control. Others: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Bioswale**, **Diversion channels** (for flood prevention, erosion control and landslide mitigation)
Supportive units & smartech	**Remote sensing** and **GIS** (for identifying suitable dam sites, monitoring environmental impacts, and optimising dam functionality. They enable effective water resource management, erosion control, and flood risk assessment).
CAPEX	*not available*. Main type of costs: Permits, fees and administrative (engineer fees); Equipment and materials; Labour (clearing site, excavating cutoff, backfilling, embankment work, spillway construction and trimming/tidying); Research and development
OPEX	*not available*. Main type of costs: Labour (inspection, cleaning, replacement and repairing of infrastructure).

By-product(s)	*Not applicable*

REHABILITATION OF AQUATIC ECOSYSTEMS

CARDIMED	1. LAGOON RESTORATION

Picture not available. **Synonyms:** Restoring coastal lagoon; Restore coastal lagoons; Coastal wetlands restoration. **Description:** Lagoon restoration involves restoring the ecological status of degraded lagoon ecosystems due to human activities or natural factors. Main threats include changes in water conditions, pollution, fishing, habitat destruction from infrastructure development, dredging, and hydrodynamic regulation. Measures to address these threats include hydrological modifications, Invasive alien species control, infrastructure removal, habitat creation, and native vegetation replanting. The overarching goal is to enhance ecological resilience, promote biodiversity, and improve the ecological status of lagoon ecosystems.

Main challenges targeted	Biodiversity & renaturalization, Societal benefits, Local Development & Economic Enhancement
Regulation and Maintenance Services	Efficient water treatment (rainwater), Reduce flood risk, Reduce urban runoff, Reduce agricultural runoff, Coastal flood protection, Stormwater source control, Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Reduce harmful impacts to fauna & flora, Connect blue and green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Coastal restoration & protection/ Promote resilience against natural disasters, Improvement of the hydromorphological functioning, Restore aquatic habitats, Improve carbon sequestration, Reduction of greenhouses gases emissions, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Recreation and ecotourism, Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Reduce undesired behaviours, activities and vandalism, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Promote natural surface water recharge / preserve surface water supply, Water reuse , Provide nutrition sources for birds and insects, Production of biomass, Nutrient recovery, Produce energy / Reduce energy demand, Material reuse, Sustainable food production
Other Services	Contribute to local employment, Increase land/property monetary value Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced carbon footprint, Reduced water footprint
Replicability	★☆☆

Design & planning	**Environmental context** is information and data collected through monitoring activities prior to project implementation establish the baseline condition of the site at the onset of the restoration process. The information on biotic and abiotic elements of the site, along with the assessment of pressures, threats, and impacts, forms an initial step in determining the desired and feasible restoration targets. **Desired state to be achieved:** identification of a reference state involves referencing sites that are comparable in structure and function to the proposed restoration site before it was degraded. Restoration projects require clearly defined goals and objectives to achieve success. Directly implementing these goals and objectives establishes standards for measuring success; they must be tied to anticipated outcomes that are measurable through specific indicators. **Policies and socio-economic context:** Recognizing the expectations and interests of stakeholders, involving them directly to identify provisions for site maintenance after project completion, is crucial for ensuring that both nature and society benefit mutually, thus ensuring the long-term viability of a restored area by minimising the need for continuous maintenance. **Typology and actions** involved in the recovery and/or improvement of habitats and ecosystems. **Methods for monitoring** the impact of the project.
Operation and maintenance	**Operational activities:** Monitoring and evaluation involves quarterly site visits to assess habitat health, the presence or lack of invasive weeds, and documenting wildlife within the habitat, etc. These assessments are used to inform maintenance needs. **Maintenance activities:** Additional plantings, weed control, erosion control, trash removal, etc. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	**Invasive alien species control, Restoring native vegetation; Reintroduction of native fauna, Riparian buffer** (for reducing competition between invasive species and newly native plants planted, enabling native species to establish and adapt to their environment, improving structure, composition and function of the ecosystem).
Supportive units & smart tech	**Remote sensing** (satellite imagery and aerial drones) and **computer vision** (to monitor lagoon conditions, identify areas of degradation, and track changes in water quality and habitat composition over time). **GIS** (to assess habitat connectivity, and identify suitable locations for restoration).
CAPEX	*not available.* Main type of costs: Equipment and materials (levees, berms, monitoring system and drainage systems); Permits, fees and administrative (environmental assessments, regulatory compliance and engineering fees); Research and development (design restoration plans, feasibility studies, data analysis and technical expertise); Labour (planting vegetation, creating marshes, and constructing fish habitats, removing invasive species, reintroducing native fauna, drainage system installation, levees and berms construction).
OPEX	*not available.* Main type of costs: Labour (monitoring, habitat maintenance, replacement and repairing of infrastructure, invasive alien species control, vegetation maintenance, replanting efforts,

	water quality testing and nutrient management); Permits, fees and administrative (insurance coverage).
By-product(s):	Mulch and woody biomass (for energy production, biofuel, soil amendments, composting and organic fertiliser). Potential generation for carbon credits.

2.6 NBS land use interventions

This section included 1 factsheet diving into details of farming practices such as sustainable communal grazing

FARMING PRACTICES

CARDIMED	1. SUSTAINABLE COMMUNAL GRAZING
Picture not available. **Synonyms:** Sustainable grazing; Community-based grazing; Communal grazing. **Description:** Sustainable communal grazing is a collaborative approach to utilising communal pastures by multiple users, including sheep, goats, and cattle, for livestock grazing. It embodies principles of fairness, equity, and environmental stewardship within a community setting. Pastoralists work together to plan and implement rotational grazing systems, ensuring responsible and balanced use of pastures while allowing for adequate regeneration. It represents a holistic and integrated approach to land use management that promotes the well-being of both people and the environment.	
Main challenges targeted	Biodiversity & renaturalization, Societal benefits
Regulation and Maintenance Services	Reduce water withdrawals , Permeability restoration, Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Restore natural forest fire regime, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Improve carbon sequestration, Reduce risk of pest and diseases, Provide genetic resources
Cultural Services	Social relations, Health and Well-Being improvement, Increase aesthetic and patrimonial or cultural value, Preserve cultural and historic heritage, Reduce undesired behaviours, activities and vandalism, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Promote mental health, Reconnect people with nature
Provisioning Services	Promote natural aquifer recharge / preserve groundwater supply, Promote natural surface water recharge / preserve surface water supply, Provide nutrition sources for birds and insects, Production of biomass, Produce energy / Reduce energy demand, Sustainable food production
Other Services	Contribute to local employment, Increase land/property monetary value, Contribute to new or existing business, Reduced costs in comparison with other

	solutions, Reduced water footprint
Replicability	★★☆
Design & planning	This farming system utilises **communal pasture land** for cattle and small livestock (sheep and goats) grazing. A borehole for drinking by livestock is shared with other farmers. Increasingly, however, collective (community) action is recognized as a viable and promising method of managing natural resources. For **effective management** of community natural resources, it's imperative that both management and usage rights are entrusted to the community. Furthermore, the community needs to establish clear usage regulations and ensure strict enforcement of these rules.
Operation and maintenance	**Operational activities:** Planning and coordination among pasture users to ensure proper and equitable grazing rotation. Regular monitoring of pasture health, including soil quality and native vegetation, to identify any deterioration or need for intervention. Implementation of soil management practices, such as erosion prevention and soil compaction avoidance, to maintain pasture health. Surveillance and control of livestock diseases and parasites through preventive measures and veterinary treatments when necessary. **Maintenance activities:** repair of fences and livestock handling structures to ensure safety and proper livestock movement control. **Others:** Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements.Safety protocols and training (to prevent accidents and ensure compliance with safety regulations).Track legal and regulatory compliance.Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	Agroforestry (for promoting integrated and sustainable management of natural resources, enhancing the resilience of agricultural systems). Invasive alien species control (for grazing).
Supportive units & smart tech	**GPS** and **GIS** (to map pasture boundaries, track animal movements, and analyse grazing patterns, for optimising rotational grazing plans and monitoring pasture health). **Remote sensing** (satellite imagery and drones to assess vegetation cover, monitor pasture condition and identify areas vulnerable to degradation). **Smart sensors and automation** (to control species movement, create grazing zones, and safeguard sensitive areas, improving pasture management and conservation).
CAPEX	*Not available.* Main type of costs: Equipment and materials (fencing, yards, pens, loading ramps, GPS trackers, remote sensing devices and monitoring systems); Permits, fees and administrative (environmental assessments, regulatory compliance and engineering fees); Research and development (design restoration plans, feasibility studies, data analysis and technical expertise); Labour (construction of fencing, water sources, access roads, yards, pens, and loading ramps, and reseeding, erosion control, and riparian zone restoration).
OPEX	*Not available.* Main type of costs: Labour (veterinary care, monitoring, tracking animal movements, collecting data on grazing patterns and habitat health, regular maintenance and repair of fencing); Permits, fees and administrative (insurance coverage); Community engagement and

	educational programs (training programs and capacity-building initiatives for pastoralists and community members).
By-product(s):	Organic fertilisers (for agricultural uses)

3. CARDIMED - NBS systems factsheets

The CARDIMED project introduces an innovative approach: **NBS systems.** These systems encompass a diverse range of NBS, including technological and spatial units, aquatic, soil, land use and biodiversity interventions, along with supportive units. The project adopts a holistic approach to tackle various challenges, with each component of the NBS systems playing a pivotal role in ensuring effectiveness and sustainability. By capitalising synergies between NBS and supportive units, the project provides a holistic and sustainable approach to environmental stewardship and climate resilience. Diverse types and applications of NBS systems are showcased through 9 DEMOs distributed across diverse mediterranean climates (see figure 4 and 5).

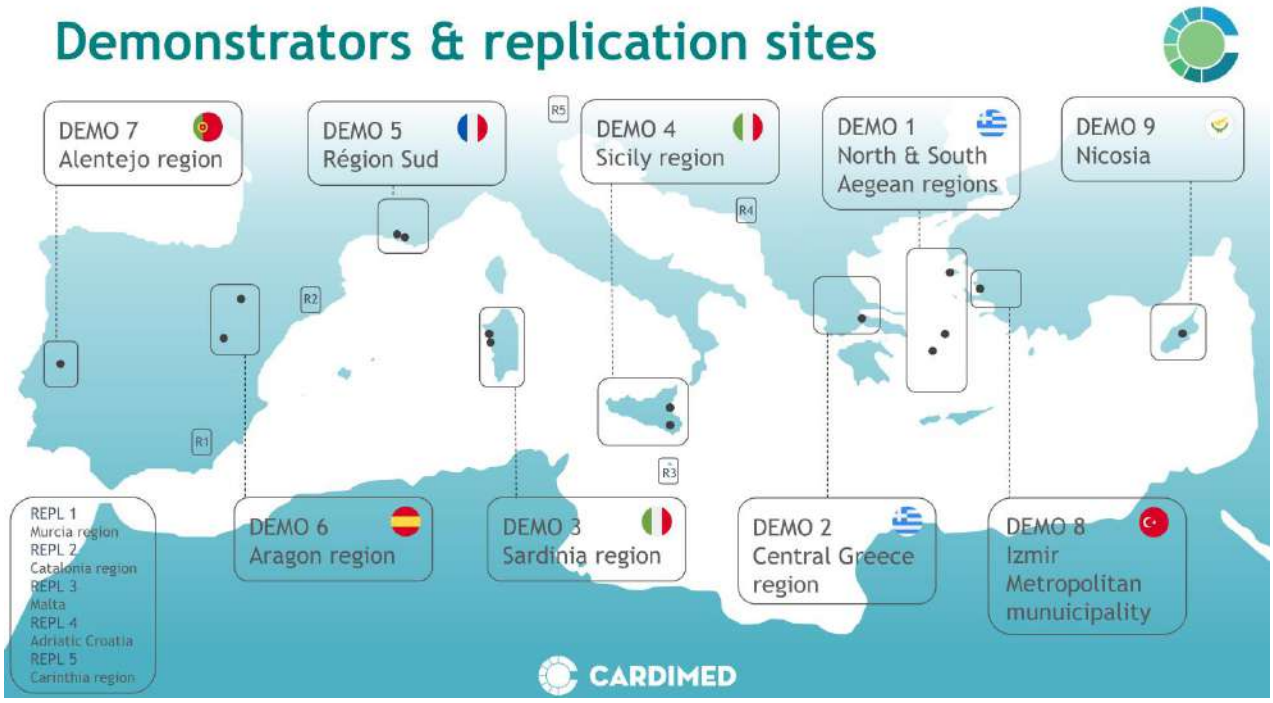


Figure 4. List of CARDIMED DEMOs and replicators.

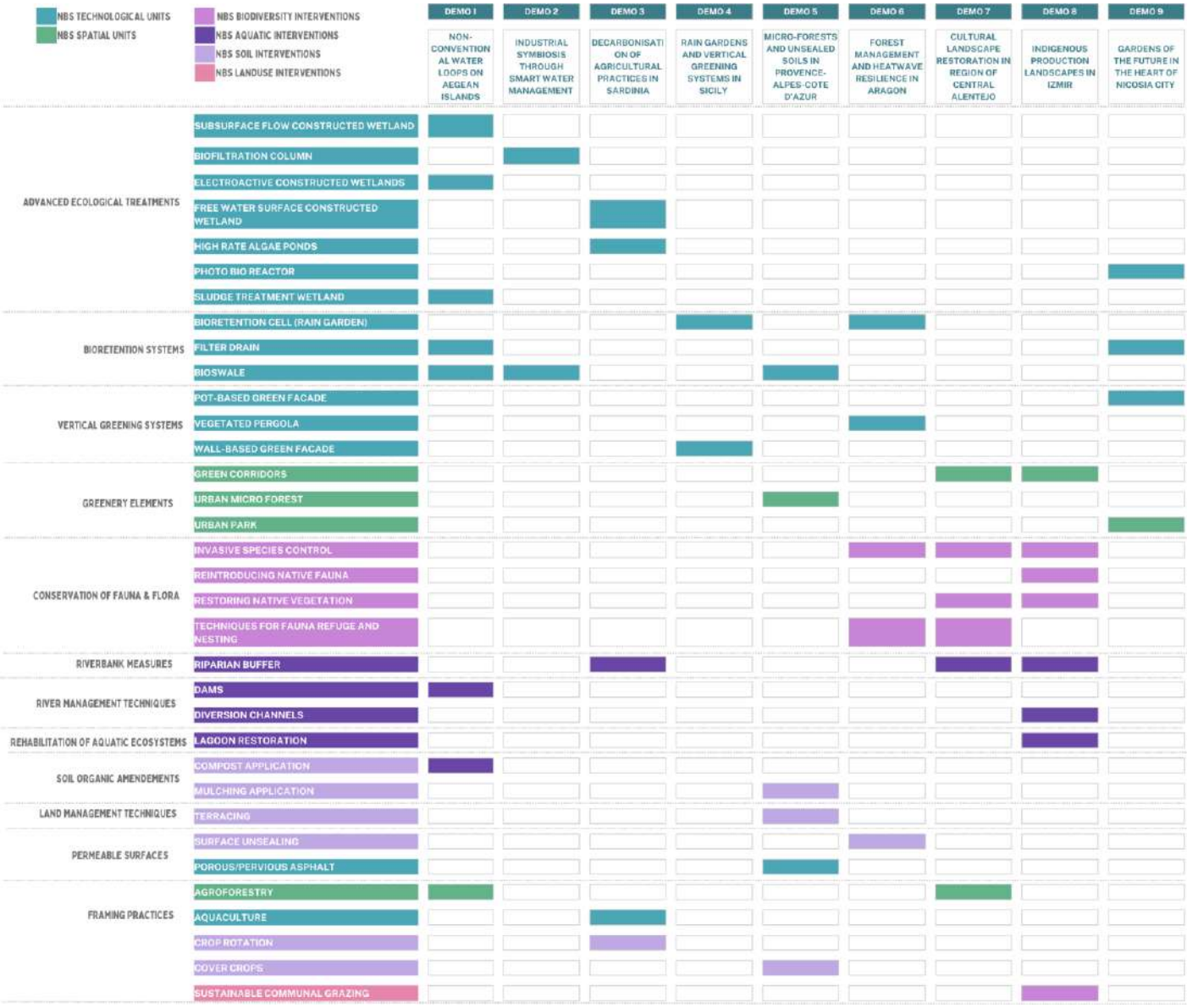


Figure 5. Types of NBS applied across the 9 DEMOs.

3.1 DEMO1 - Non-conventional water loops on Aegean islands

Located across the Greek islands, DEMO1 represents a pioneering approach to holistic water management and sustainability. This DEMO serves as a model for integrated resource management, showcasing the synergy between energy generation, waste recycling, and water reuse (Sub-DEMO1.1). Meanwhile, cutting-edge rainwater harvesting systems ensure efficient irrigation practices, conserving precious freshwater resources and replenishing aquifers (Sub-DEMO1.2a and 1.2b). Additionally, traditional stone weirs networks exemplify the fusion of traditional wisdom with modern conservation practices, safeguarding natural ecosystems and providing essential water resources for agricultural activities (Sub-DEMO1.3). Thus, DEMO1 embodies a harmonious blend of innovation, sustainability, and ecological stewardship, offering scalable solutions to address the complex challenges of water management in the unique context of the Greek islands.

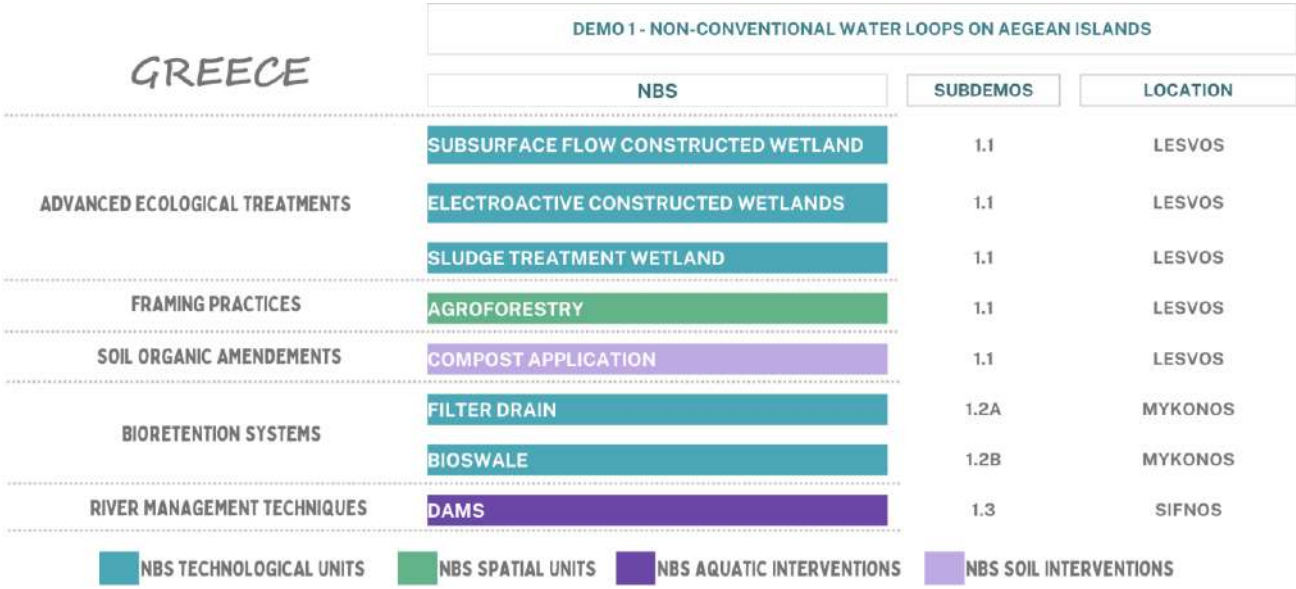
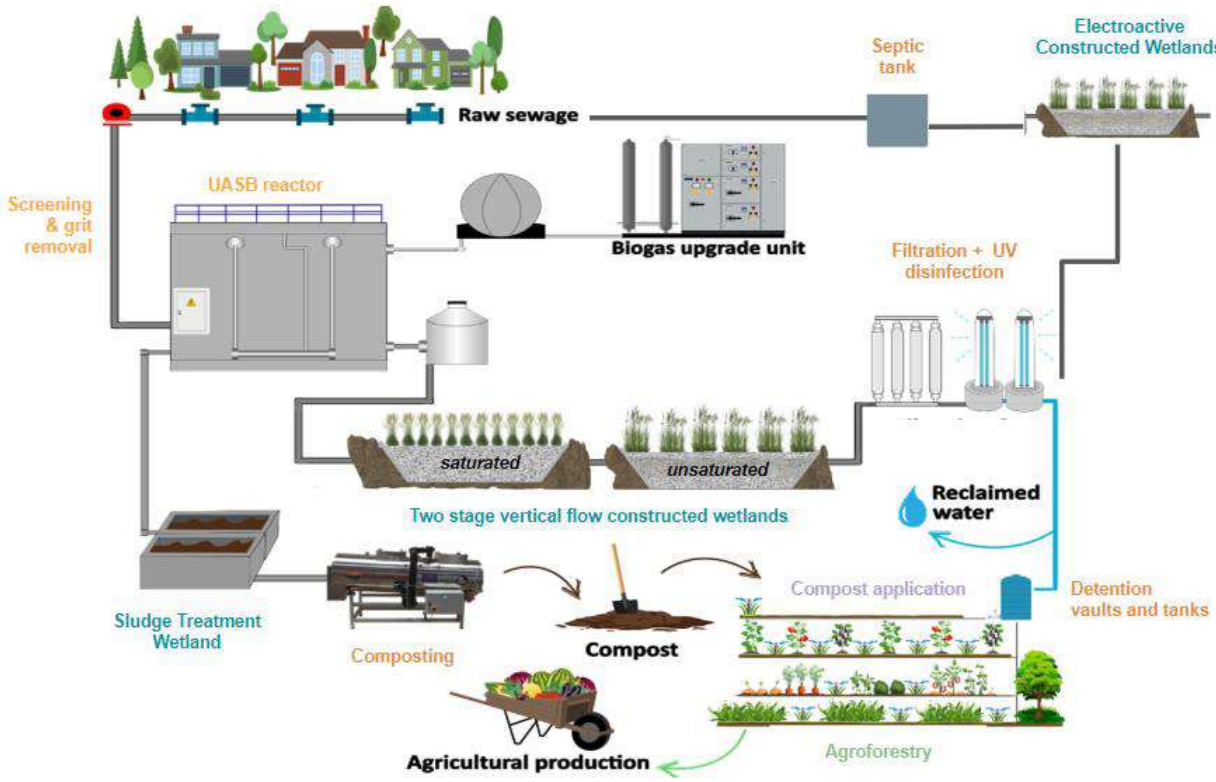


Figure 6. DEMO1 overview of the 3 sub-DEMOs and respective NBS.

CARDIMED	Sub-DEMO1.1 - A Sustainable Circular System Promoting Wastewater Valorization Through NBS

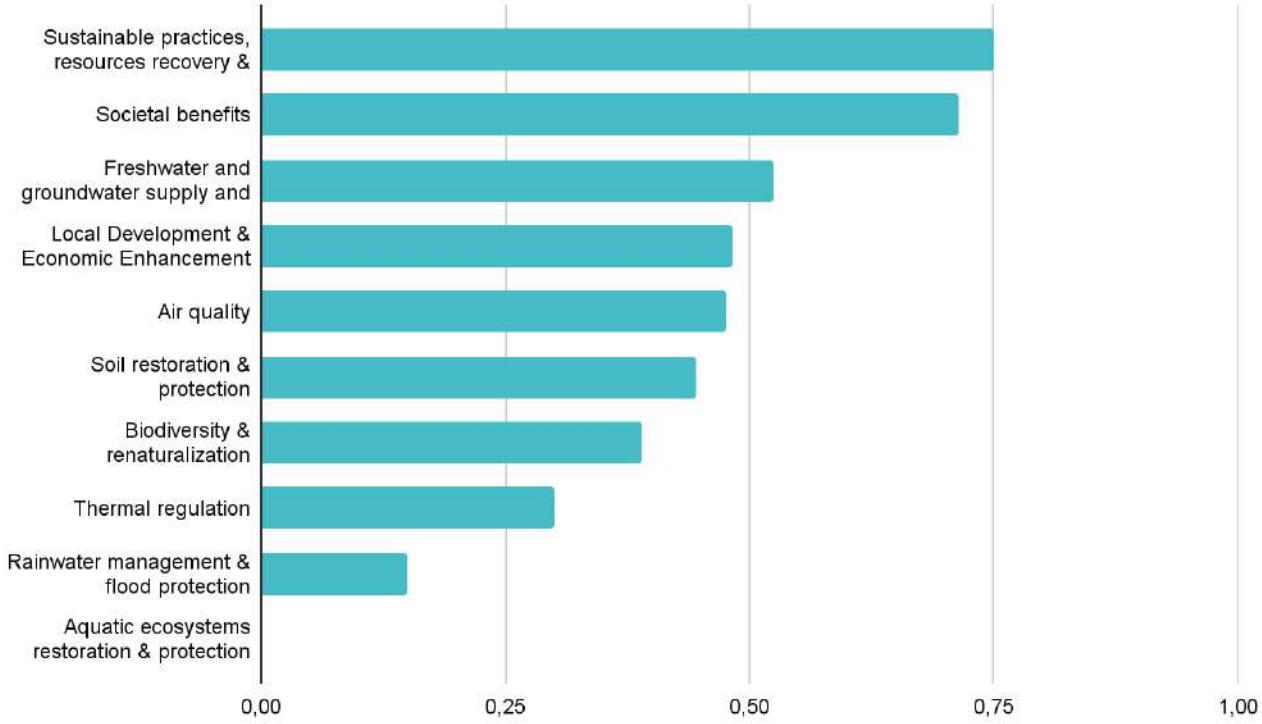
Description: A circular system is implemented where energy is generated (biogas from anaerobic processes) and **sludge** is recycled as **compost.** Reclaimed water is reused, and nutrients are recycled on a nearby 1 ha agroforestry field (without pesticides, chemicals, or additional fertilisers). This process involves passing through a system that combines **two-stage subsurface vertical flow constructed wetlands, an electroactive constructed wetland**, **UV disinfection and an optional ultrafiltration.**

Location: Lesvos, Greece. **TRL:** 5 to 7. **SRL:** 5. **Sub-DEMO area (m^2):** 11000 m^2. **Scale**: rural (public land). **Stakeholders**: Water utility company (DEYAL), Regional government (North Aegean). **CAPEX:** 276000 €. **OPEX:** 18000 €/m^2.



NBS_{tu}: Two-stage subsurface vertical flow constructed wetlands (850 m^2; TRL *not available*) ; Electroactive constructed wetland (4 m^2; TRL *not available*); Sludge treatment wetland (12 m^2; TRL *not available*). **NBS_{su}:** Agroforestry (10000 m^2; TRL *not available*). **NBS_{si}:** Compost application (TRL *not available*). **Supportive units:** Screening & grit removal, septic tank, UASB reactor + biogas unit, optional filtration, UV disinfection, detention vaults and tanks, biogas upgrade unit. **Water source(s):** Raw sewage. **Water applications:** For irrigation of agricultural land. **By-product(s):** Treated sludge (for composting), harvested organic biomass (for animal feed). **Smart tech:** Water is monitored with online pH, T, Conductivity, Turbidity, DO, COD, NH_4-N, NO_3-N, ORP. Weather station (rainfall, humidity, T, solar power, etc.). **Supportive actions:** Community engagement and educational visits, research and innovation initiatives, capacity building and training for local stakeholders and collaboration with indigenous and local communities.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION TO SDGs

Regulation and Maintenance Services	Efficient water treatment, Reduce water withdrawals, Improve quality of groundwater; Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Connect blue and green spaces, Stabilise soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilise water retention, Improve carbon sequestration, Reduce CO_2 emissions, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces; Facilitate education, Support environmental awareness, Promote mental health, Reconnect people with nature, Increase physical and mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Water reuse, Provide nutrition sources for birds and insects, Produce biochemicals, natural medicines and pharmaceuticals, Production of biomass, Provide raw material Nutrient recovery, Produce energy / Reduce energy demand, Material reuse
OtherServices	Contribute to local employment, Increase land/property monetary value, Increase tourism,

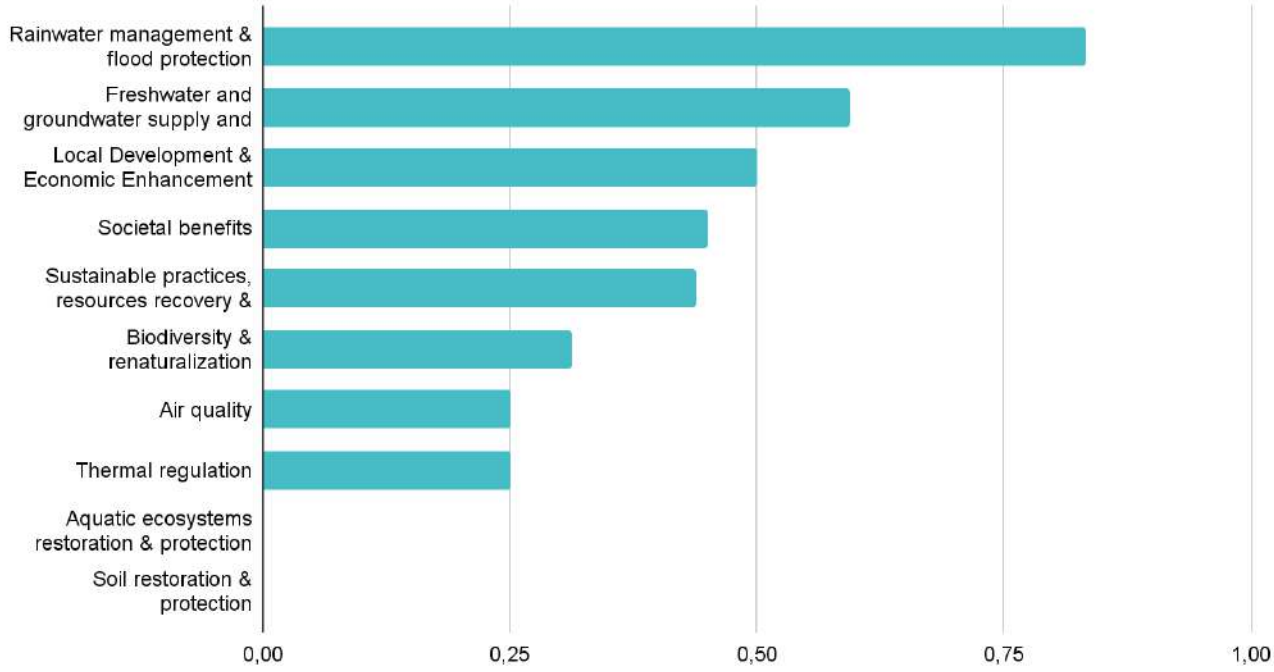
	Contribute to new or existing business, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced carbon footprint, Reduced water footprint, Sustainable food production.
Limiting factors	Lack of supportive policies & conflicting legal frameworks, Treatment efficiency is directly influenced by the concentrations of pollutants in the inlet, Biomass harvesting is an essential requirement, It requires meticulous design considerations and expert input, Functional & performance uncertainties, High land footprint / Competition for space, Limited acceptability and tolerance among end users

CARDIMED Sub-DEMO1.2a - The Rainwater Harvesting when Nature Inspires: A novel rainwater harvesting NBS in remote, water scarce areas

Description: In Mykonos, an innovative **filter drain** introduces adaptations to accommodate the collection, treatment, and storage of rainwater for agricultural reuse. This innovative system is situated in the village of Ano Mera on the island of Mykonos (Ampelokipoi). A shallow, sub-surface, rainwater collection system is used to directly catch rainwater and by draining transport into two storage tanks. Rainwater is used to irrigate 0.4 ha of oregano. Precision irrigation and online monitoring are also implemented. **Location:** Mykonos island, Greece. **TRL** 7. **SRL:** 7. **Sub-DEMO area (m^2):** 4500 **Scale**: rural (private land). **Stakeholders**: Owners and co-owners of land and property, Ecological engineering and consultancy companies (Hydrapsis), Municipality (MYKONOS), Water utility company (DEYAL), Farmers, Public body for water management (Azienda Servizi Ambientali, Integrated Water Service and gas distributor in the Tuscan region, Italy), Schools. **CAPEX:** 32.000,00 € **OPEX:** 4.000,00 €/y

NBS_{tu}: Filter drain (280m² TRL 7). **Supportive units:** Detention vaults and tanks. **Water resource:** rainwater (311 mm/y). **Water applications:** irrigation of agricultural land (oregano cultivation) and natural aquifer recharge**. By-product(s):** *not applicable.* **Smart tech:** weather station (T, humidity, rainfall, wind speed /direction, atmospheric pressure), hydraulic sensors (water tank(s) level measurements, water storage quantity), water quality sensors (ph, conductivity, T), soil moisture sensors and smart irrigation. **Supportive action:** Community engagement and educational visits - tech tours, research and innovation initiatives, capacity building and training for local stakeholders, collaboration with indigenous and local communities.

MAIN CHALLENGES TARGETED



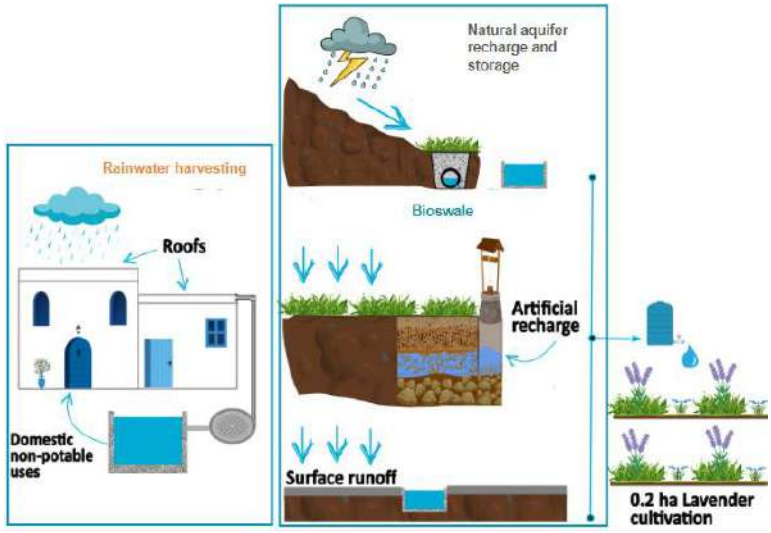
POTENTIAL CONTRIBUTION TO SDGs

Regulation and Maintenance Services	Stormwater source control, Reduce water withdrawals ,Efficient water treatment , Reduce agricultural runoff
Cultural Services	Support environmental awareness
Provisioning Services	Harvest, store and treat rainwater; Water reuse
Other Services	Reduced costs in comparison with other solutions, Reduced carbon footprint
Limiting factors	Lack of supportive policies & conflicting legal frameworks

CARDIMED Sub-DEMO1.2b - From Rain to Resilience: A Decentralised Combination of Residential Rainwater Harvesting, flood protection Bioswale system and Subsurface Rainwater Storage and Recovery for Arid Communities

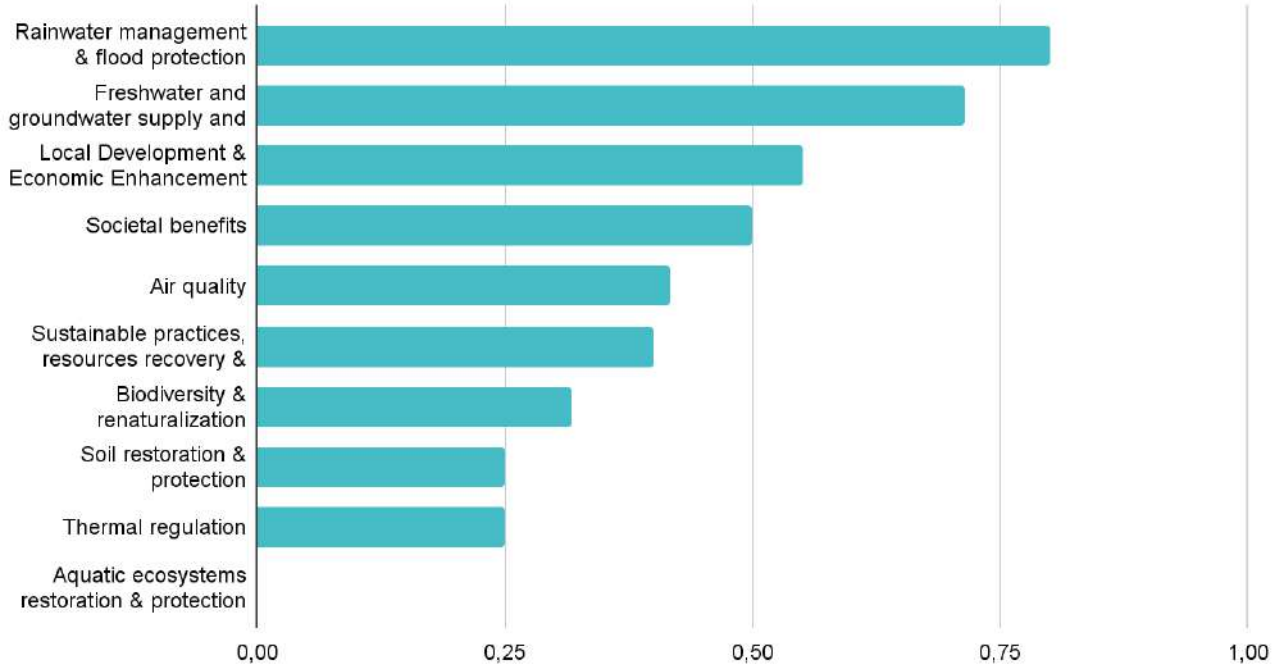
Description: A smart residential water management system, incorporating a **bioswale**, operates in the village of Ano Mera on Mykonos Island. The hybrid bioswale efficiently captures stormwater, along with rainwater from 400 m^2 of rooftops and surface runoff from 350 m^2 of residential yards, directing them to buffer tanks for storage. The majority of this water is allocated for non-potable domestic uses, with a portion dedicated to precision irrigation for a 0.2 ha lavender field, monitored online for efficiency.

Additionally, this stored water serves to replenish the aquifer during wet seasons and provides a water source for dry seasons. **Location:** Mykonos island, Greece. **TRL:** 6. **SRL:** 6. **Sub-DEMO area (m^2):** 8000.. **Scale**: rural (private land). **Stakeholders**: Owners and co-owners of land and property, Ecological engineering and consultancy companies (Hydrapsis), Municipality (MYKONOS), Water utility company (DEYAL), Farmers, Public body for water management (Azienda Servizi Ambientali/Italy), Schools. **CAPEX:** 20.000,00 €. **OPEX:** 3.000,00 €/y



NBS$_{tu}$: Bioswale (30.5m^2; TRL *not available*). **Supportive units:** Rainwater harvesting, detention vaults and tanks. **Water source(s)** rainwater and stormwater. **Water applications:** Natural aquifer recharge and storage, artificial aquifer recharge and toilet flush. **By-product(s)(s):** Harvested weeds (for composting). **Smart tech:** weather station (T, humidity, rainfall, wind speed /direction, atmospheric pressure), hydraulic sensors (water tank(s) level measurements, water storage quantity), water quality sensors (pH, conductivity, T), soil moisture sensors and smart irrigation. **Supportive actions:** Community engagement and educational visits - tech tours, research and innovation initiatives, capacity building and training for local stakeholders, collaboration with indigenous and local communities.

MAIN CHALLENGES TARGETED

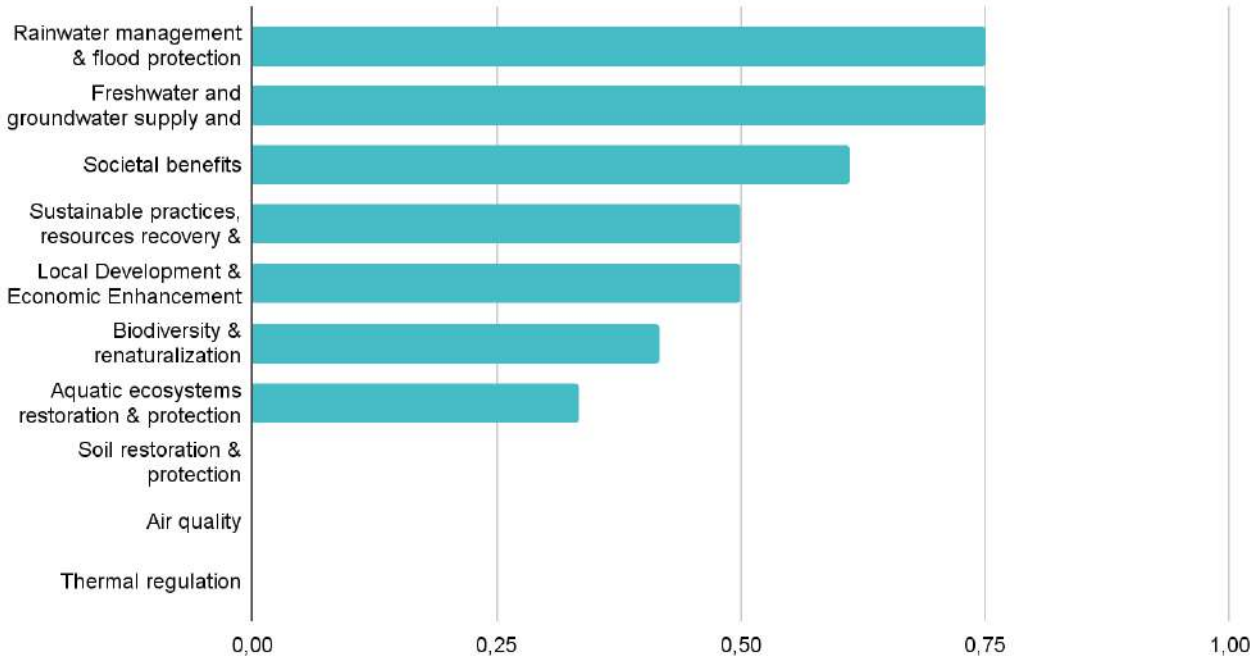


POTENTIAL CONTRIBUTION TO SDGS	
	
Regulation and Maintenance Services	Stormwater source control; Efficient water treatment
Cultural Services	Facilitate education, Support environmental awareness
Provisioning Services	Preserve groundwater supply, Water reuse, Harvest, store and treat rainwater
Other Services	Reduced costs in comparison with other solutions, Reduced carbon footprint
Limiting factors	*not available*

CARDIMED — Sub-DEMO1.3 - Revitalising Island Streams: Stone Dams For Flood Mitigation and Surface Water Valorisation

Description: A network of about 150 traditionally built stone-weirs (dry stone check dams) will be constructed by MedINA on Sifnos' streams, to reduce the flood risk, recharge the aquifer, improve the conditions for biodiversity, and provide water for agricultural use. **Location:** Sifnos Island, Cyclades, Aegean Sea. **TRL:** 7 **SRL:** 6 **Surface (m^2):** 10.000 m^2 (approx.). **Scale**: Natural/Rural zone (public land). **Stakeholders**: Permitting and controlling authorities, Municipality (Sifnos). **CAPEX:** 100.000 (approx.). **OPEX:** *not available*. **NBS_{ri}: Dams** 0.75-2 m^2; TRL 7. **Water source(s):** Rainwater. **Water applications:** Aquifer recharge. **By-product(s):** *not applicable*. **Smart tech:** water level sensors, Arduino-based camera that will detect floods, Drone-derived orthophoto mosaics for monitoring the effect of stone-weirs. **Supportive actions:** Community engagement through workshops, educational tours, and eco-tourism activities, Collaboration with local communities, Policy advocacy and stakeholder coordination, Adaptive management and planning processes.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION TO SDGs	
	
Regulation and Maintenance Services	Reduce flood risk, River flood protection
Cultural Services	Preserve cultural and historic heritage; Support environmental awareness
Provisioning Services	Water reuse, preserve groundwater and surface water supply
Other Services	*not applicable*
Limiting factors	Success depends on local, environmental and climate conditions

3.2 DEMO2 - Industrial symbiosis through smart water management

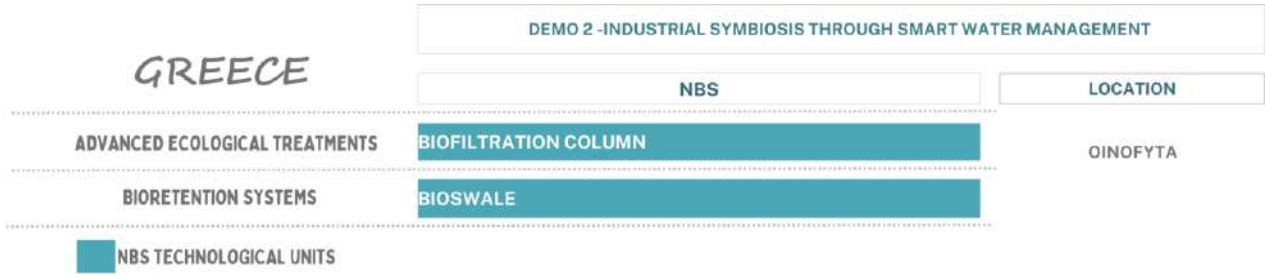
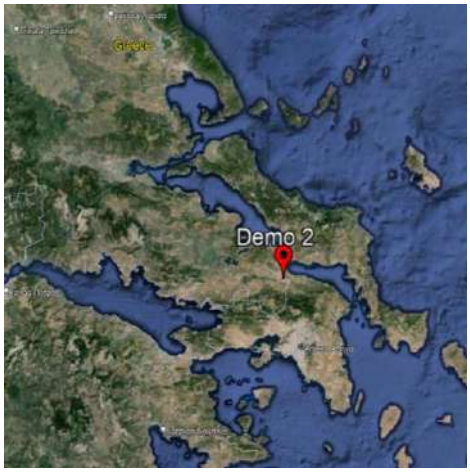


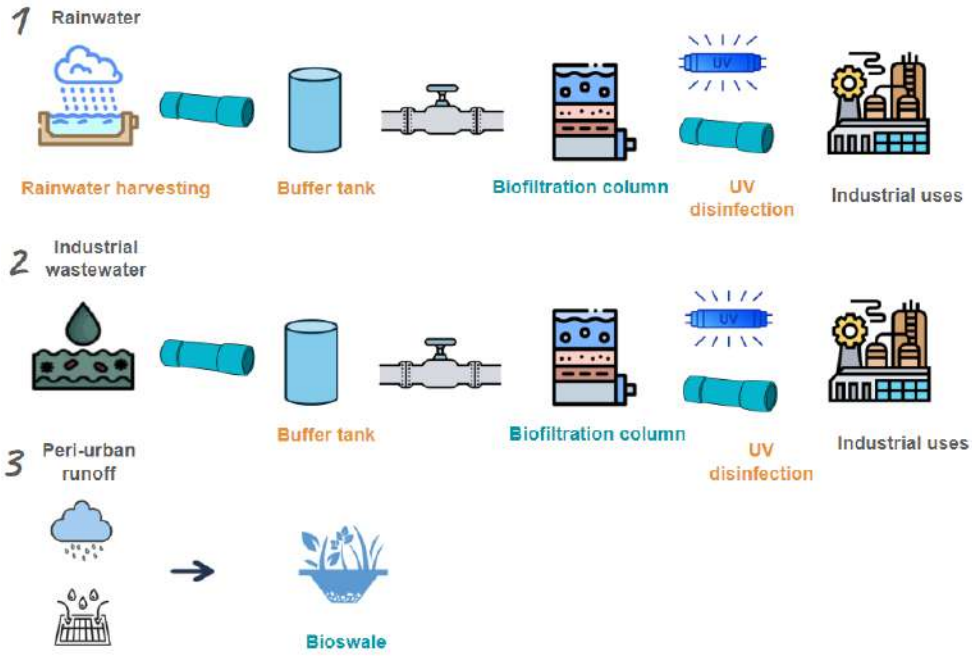
Figure 7. DEMO2 overview of NBS.

CARDIMED — DEMO2 - Industrial symbiosis through smart water management



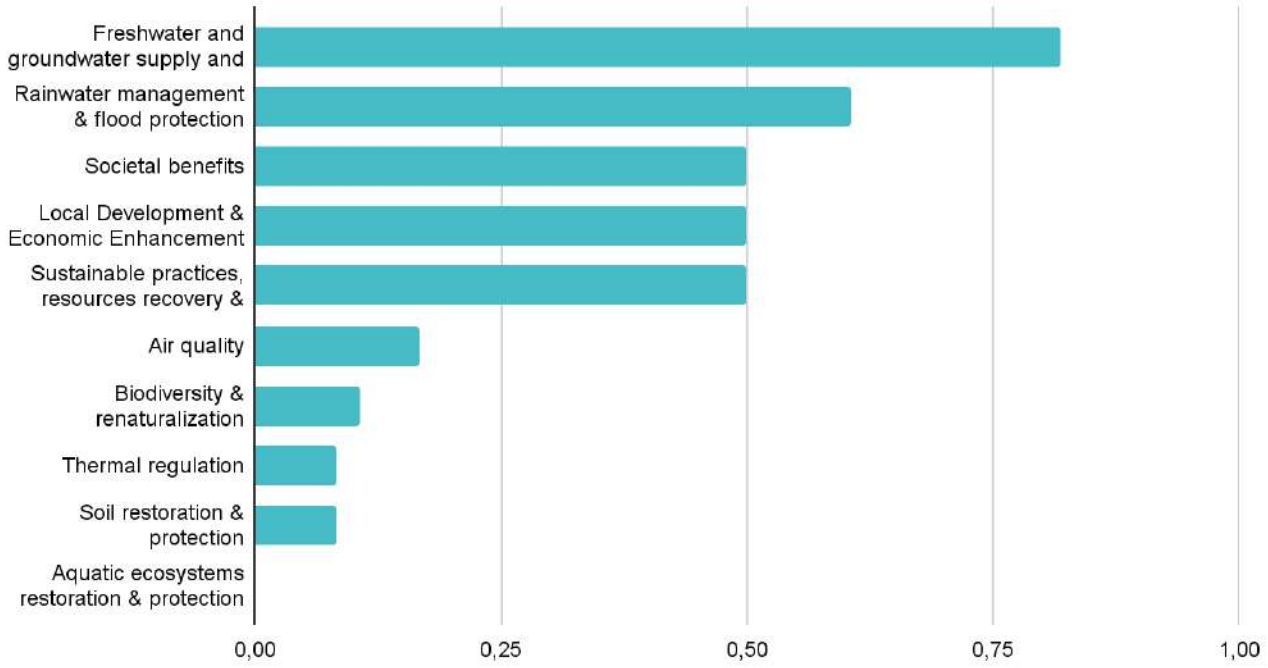
Description: DEMO2 introduces a smart water management system focused on 3 systems running in parallel to recovery treat and reuse of rainwater, peri-urban runoff and wastewater. These resources are then repurposed for the industry's water needs in different production stages such as cooling, etc.. The main novelty of DEMO2 relies on integrating **bioswale** and **biofiltration columns** with advanced digital technologies and engineered systems within a sophisticated interface (Demand-Driven Industrial Water Symbiosis System). The overarching goal is to ascertain the feasibility of achieving net-zero water usage, potentially sourcing over 70% of water demand when scaled up.

Location: Oinofyta, Greece. **TRL:** 2. **SRL:** 2. **DEMO area (m^2)**: *not available.* **Scale**: Peri-urban (Industrial facilities) **Stakeholders:** Ecological engineering and consultancy companies (IRIDRA and HYDRAPSIS), Regional government, Industry companies (HALCOR`s Foundry and Brass Bars and Tubes Extrusion Plant). National Technical University of Athens (NTUA). **CAPEX** and **OPEX:** *not available*.



NBStu: Bioswale (*not available* m^2; TRL 2 *not available*), biofiltration column (*not available* m^2; TRL: *not available*). **Supportive units:** Rainwater harvesting, Buffer tanks and UV disinfection. **Water source(s)**: Rainwater, peri-urban run-off, Industrial wastewater. **Water applications**: For the biofiltration columns - Industrial uses (i.e. cooling, cleaning, storage, redistribution in specific facilities). For bioswale - surface water discharge and other *to be defined.* **By-product(s):** saturated sand and adsorption material (for water filtration, purification of aqueous or gaseous mediums, retention of contaminants). **Smart tech:** Water flow meters, water level floaters for tanks, automatic water quality sensors (pH, conductivity). **Supportive actions:** Research and innovation initiatives. Collaboration with indigenous and local communities. Education programs.

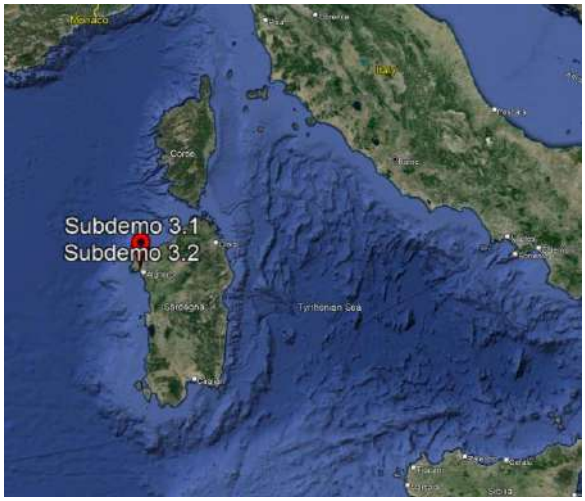
MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION TO SDGs	
	
Regulation and Maintenance Services	Efficient water treatment, Improve quality of surface water, Reduce flood risk, Reduce urban runoff, Stormwater source control
Cultural Services	*not applicable*
Provisioning Services	Preserve surface water supply, Water reuse, Harvest, store and treat rainwater
Other Services	*not applicable*
Limiting factors	Treatment efficiency is directly influenced by the concentrations of pollutants in the inlet; It requires meticulous design considerations and expert input

3.3 DEMO3 - Decarbonisation of agricultural practices in Sardinia

DEMO3 introduces two innovative integrated Sub-DEMOs, aiming to enhance agricultural sustainability while managing water resources. Sub-DEMO3.1 focuses on the further improvements of irrigation water quality and safety through tertiary and quaternary wastewater treatments. Additionally, NBS will be integrated to reduce the impact



of drainage and runoff water loads in receiving water bodies. Sub-DEMO3.2 will assess the possible implementation of NBS to support the transferability of the sub-DEMO3.1 results in the Calich Lagoon. Additionally, there will be the implementation of mussels as a bioindicator of the water quality. These strategies aim to boost agricultural productivity, promote sustainable water management practices, and improve ecosystem health.

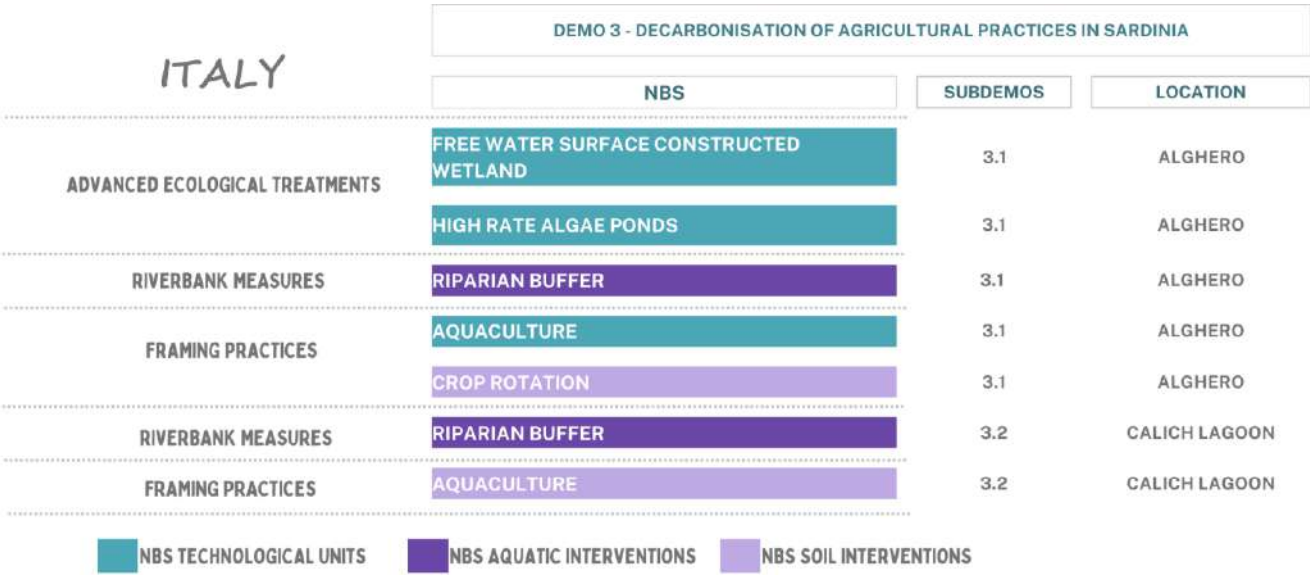
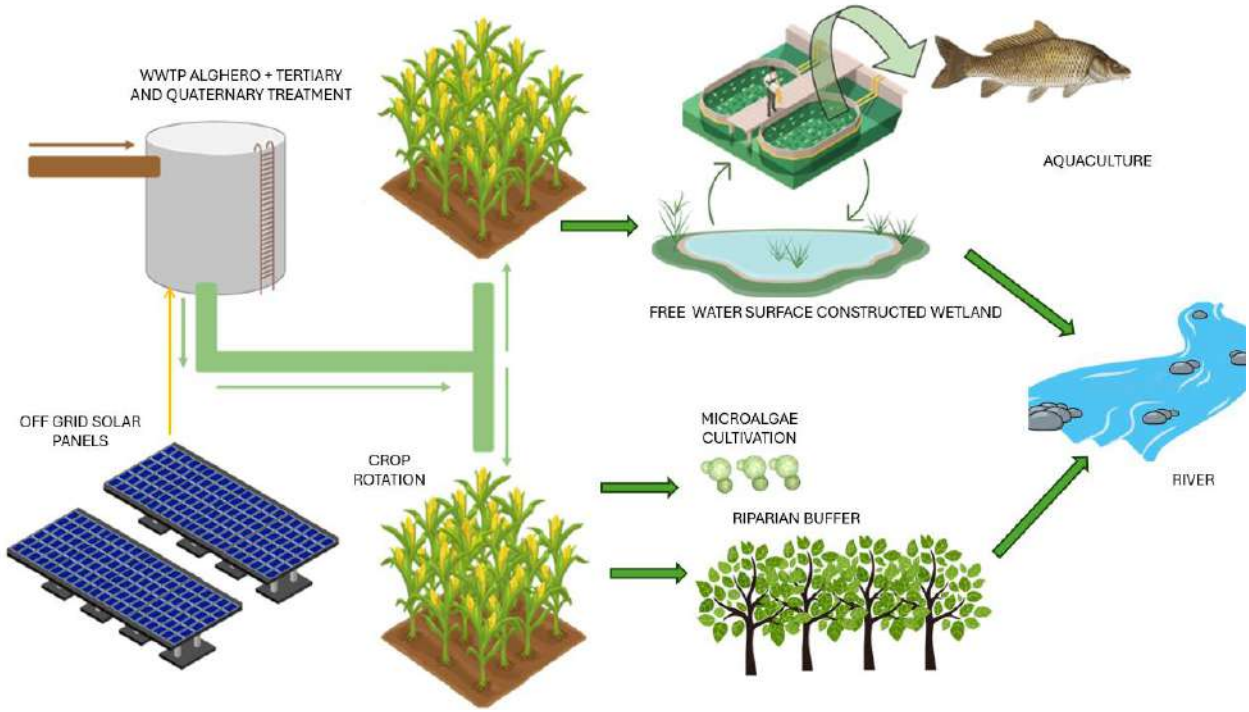


Figure 8. DEMO3 overview of the 2 sub-DEMOs and respective NBS.

CARDIMED	Sub-DEMO3.1 - Optimising Crop Productivity and Water Quality and Safety Through combined NBS

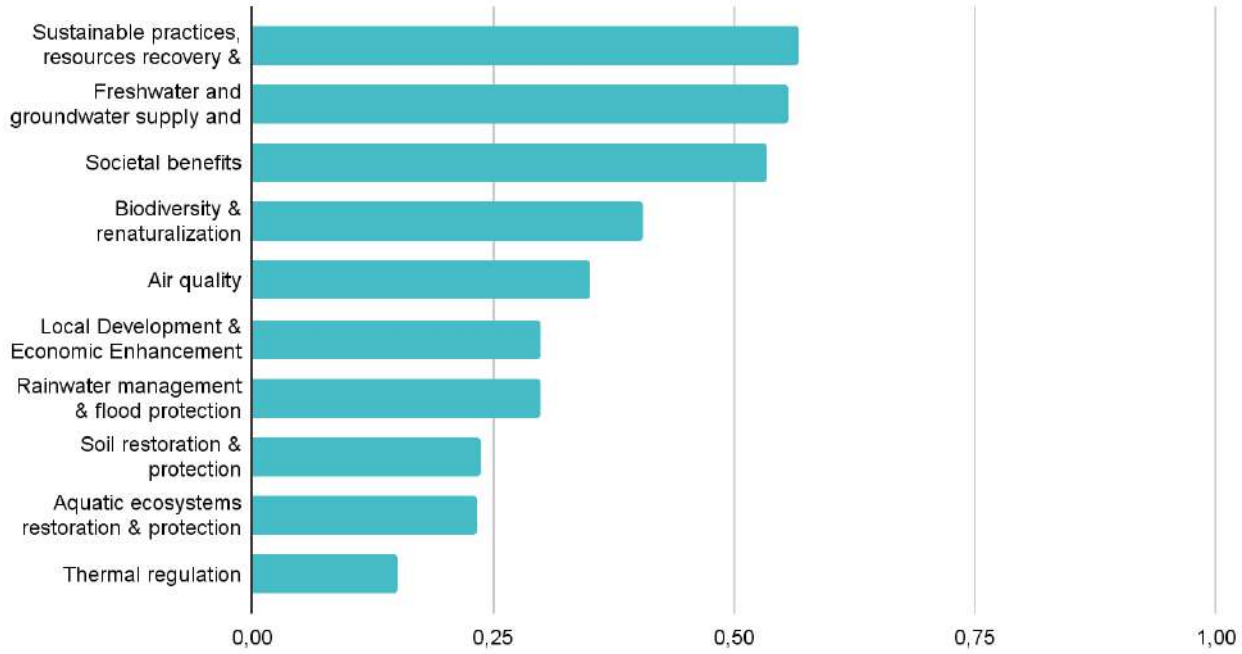
Description: crop rotation (wheat, alfalfa, maize)) will be irrigated with treated wastewater from San Marco wastewater treatment plant (Alghero), where additional tertiary and quaternary treatment will be implemented to further improve water quality and safety. Renewable energy from solar panels will be used to power either the irrigation system or the treatment technologies. Crop rotation is used to alleviate water stress and improve crop health. Additionally, a **free water surface constructed wetland**, **high rate algae pond**, and a **riparian buffer**, all operating in parallel, will treat agricultural drainage and runoff water. Part of the treated water will be utilised in **aquaculture**, while the rest will be checked in terms of water quality before being discharged into a nearby river. The physiological responses of the fish will be closely evaluated, focusing on target pathways such as oxidative stress, heavy metal exposure, and immune response. **Location:** Alghero, Italy**. TRL** 6-7**: SRL:** *not available.* **Sub-DEMO area:** 6-8 ha. **Scale**: Peri-urban (private land). **Stakeholders**: Universities (Marche

Polytechnic University - UNIVPM and University of Bologna - UNIBO), Municipality (Alghero). **CAPEX** and **OPEX:** *not available*.



NBS_{tu}: Free water surface constructed wetland (400 m^2; TRL: 7), high rate algae ponds (1-2 m^2; TRL: 6 **,** aquaculture (3 tanks each with 1-2m^3 capacity and a total area of 5-6 m^2; TRL: 5-6) **NBS_{tu}:** riparian buffer (300m length and a total area of 450 m^2; TRL: 7) **NBS_{si}:** crop rotation (4-6 ha ; TRL 8). **Supportive units:** Solar panels and water tertiary and quaternary treatment in a WWTP. **Water source(s):** Effluent of WWTP and agricultural runoff **Water applications:** Surface water discharge. **By-product(s):** Harvested microalgal biomass (for fertiliser) Organic biomass from aquaculture (for fertiliser). **Smart tech:** Online weather station (rainfall, humidity, T, solar power), smart irrigation, underwater webcam and self feeders. **Supportive actions:** not available.

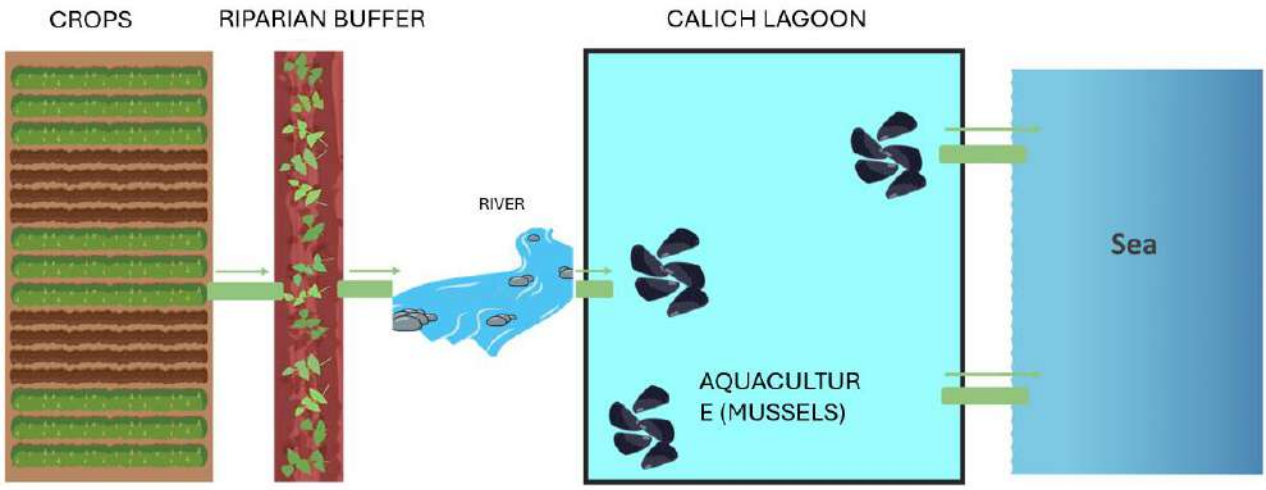
MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION TO SDGs	
	
Regulation and Maintenance Services	Efficient water treatment, Improve quality of surface water, Mitigate desertification, Increase green areas around urban rivers, Reduce sediment flow in the river, Reduce sediments deposition in river beds, Stabilise soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilise water retention
Cultural Services	Support environmental awareness
Provisioning Services	Preserve surface water supply, Production of biomass, Provide raw material, Nutrient recovery, sustainable food production
Other Services	*not applicable*
Limiting factors	Treatment efficiency is directly influenced by the concentrations of pollutants in the inlet, seasonal and climate fluctuations can significantly affect the proper functioning of systems in terms of resilience and treatment efficacy.

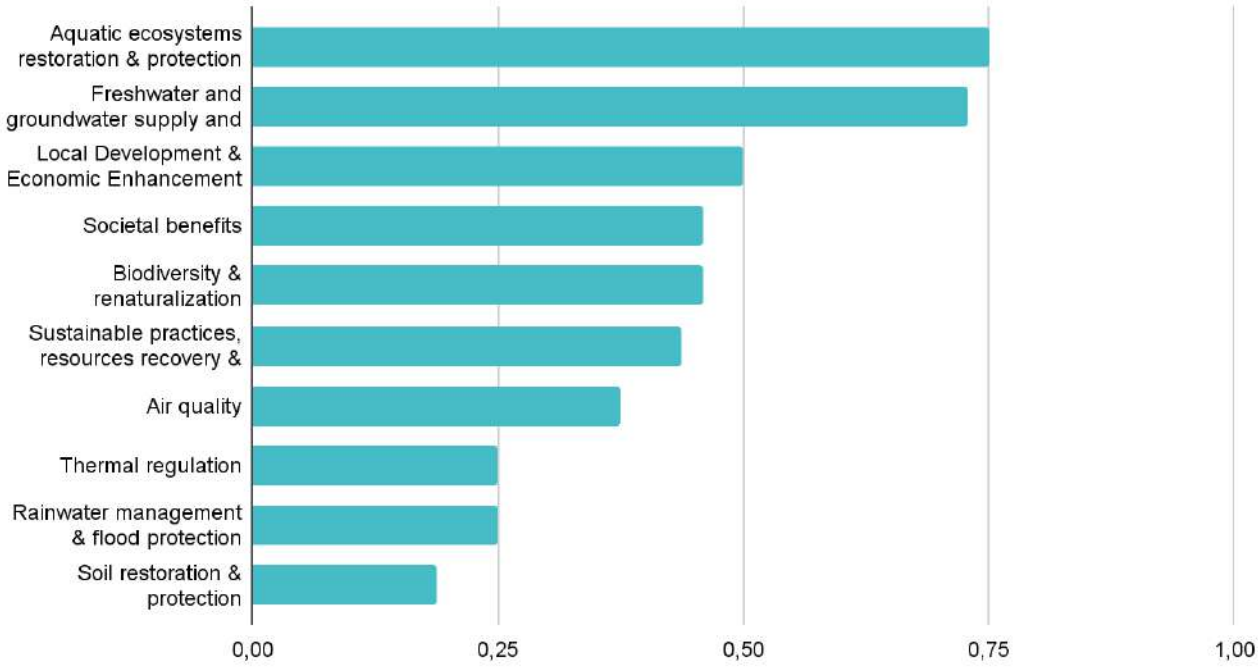
CARDIMED	Sub-DEMO3.2 Waterwise Farming: Enhancing Crop Health with Aquatic Solutions

Description: In Sub-DEMO3.2 the results from Sub-DEMO3.1, which is discharging in the Calich Lagoon catchments, will be used for the assessment of a possible implementation of NBS to support the transferability of the main findings in the while Calich Lagoon catchment**.** The water quality results of the agricultural drainage and runoff water, treated by the NBS' s implemented in the DEMO3.1, will be used to simulate possible scenarios for the reduction of the concentration of different contaminants typical of agricultural drainage and runoff water reaching the Calich Lagoon. Feasibility studies of possible implementation of the tested NBSs in a larger area/basin will be developed to support the transferability of the DEMO results in the lagoon. Additionally, possible tests on optimization of mussel physiological conditions will be studied to assess the effects of the water quality during different seasons. **Location:** Calich lagoon, Italy. **TRL:** *not applicable* **SRL:** *not available.* **Sub-DEMO area (m^2):** *not applicable.* **Scale**: Rural (public land). **Stakeholders**: *not available*. **CAPEX** and **OPEX:** *not available.*



NBS$_{tu}$: Aquaculture. **NBS$_{tu}$:** Riparian buffer**. Water source(s):** Agricultural runoff and agricultural wastewater. **Water applications:** Surface water discharge and further feed natural lagoon (mussels production)**. By-product(s):** *not available.* **Smart tech:** *not available.* **Supportive actions:** *not available.*

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION SDGs	
	
Regulation and Maintenance Services	Improve quality of surface water, Efficient water treatment, River flood protection, Increase green areas around urban rivers, Restore aquatic habitats, Reduce sediment flow in the river, Reduce sediments deposition in river beds
Cultural Services	*not applicable*
Provisioning Services	Preserve surface water supply, Water reuse
Other Services	*not applicable*
Limiting factors	Treatment efficiency is directly influenced by the concentrations of pollutants in the inlet, seasonal and climate fluctuations can significantly affect the proper functioning of systems in terms of resilience and treatment efficacy, Success depends on local, environmental and climate conditions

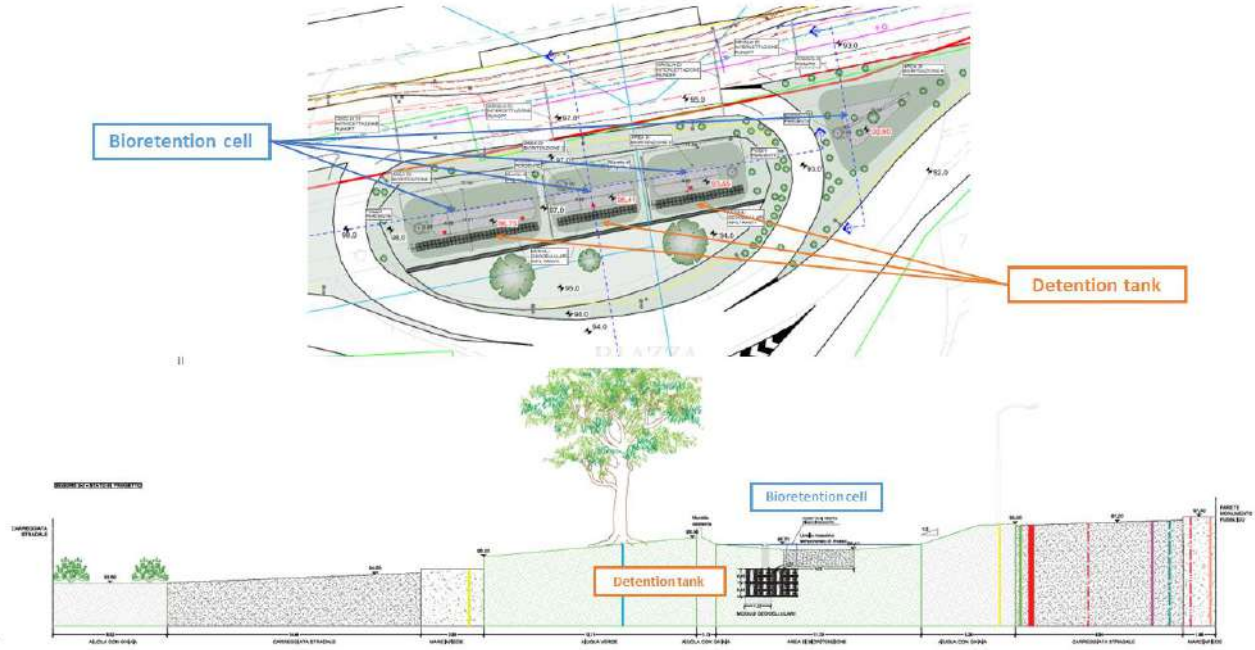
3.4 DEMO4 - Rain gardens and vertical greening systems in Sicily

DEMO4 is located in Sicily (Italy) and presents two innovative approaches aimed at addressing water management challenges in urban environments, responding to growing concerns regarding stormwater runoff and increased pressures on water availability and quality. Sub-DEMO4.1, involves intercepting a portion of the stormwater runoff using bioretention cells (rain garden) retrofitted in existing green areas. Meanwhile, Sub-DEMO4.2, features a wall-based green facade installed on three facades of the primary school, enhancing aesthetic appeal while treating greywater from washbasins for onsite reuse.

Figure 9. DEMO4 overview of the 2 sub-DEMOs and respective NBS.

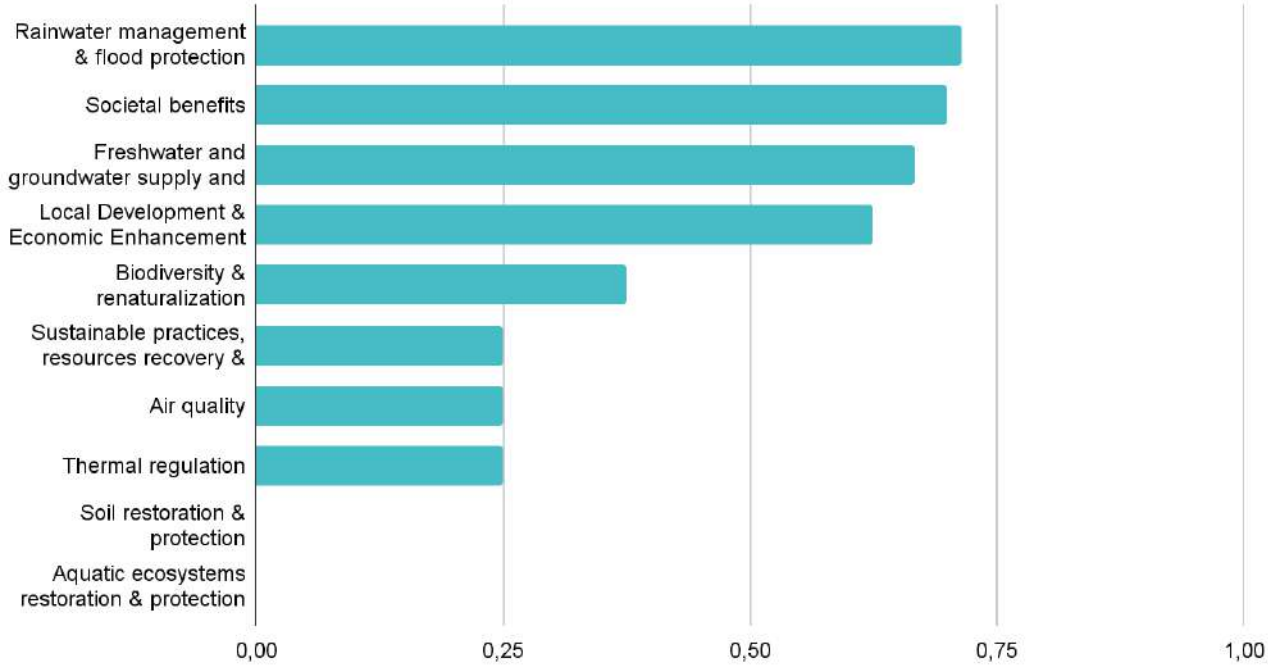
CARDIMED	Sub-DEMO4.1 - SuDS Retrofitting for Improved Stormwater Management

Description: A portion of the stormwater runoff from Alessandro Doria Avenue is intercepted by **bioretention cells (rain garden)** retrofitted in the existing green areas around the Tondo Gioeni, in particular roundabout or green elements along the road. This innovative approach not only helps mitigate urban runoff pollution but also enhances flood control, contributing to the overall sustainability, resilience and climate change adaptation of an urban environment affected by pluvial flooding risks. **Location:** Catania, Italy. **TRL:** 7. **SRL:** 6. **Sub-DEMO area (m^2):** 4400m^2. **Scale**: Urban (public land) **Stakeholders**: University (University of Catania), Municipality (Catania) , Regional government (Sicily Region). **CAPEX:** 380,000€ . **OPEX:** 5000 - 8000 €/y.



NBS_{tu}: Bioretention cell (rain garden) (4400 m^2; TRL 7) **Supportive units:** Detention tanks **Water source(s):** urban runoff. **Water applications:** Aquifer recharge, irrigation of green areas, overflow directed to sewage (if any) **By-product(s):** harvested organic biomass (for fertilizer). **Smart tech:** flow metres, soil moisture and water level sensors. **Supportive actions:** Research and innovation activities, Capacity building and training to local stakeholders.

MAIN CHALLENGES TARGETED

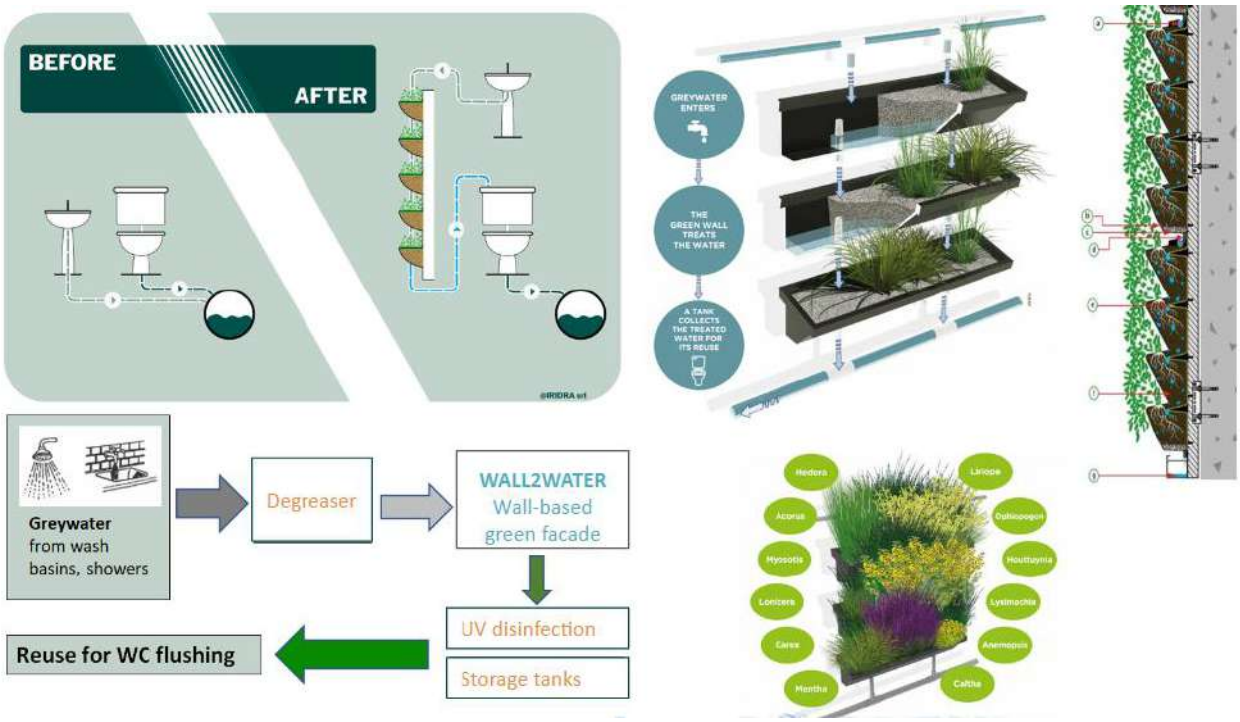


POTENTIAL CONTRIBUTION SDGs	
	
Regulation and Maintenance Services	Efficient water treatment, Reduce urban runoff, Stormwater source control Permeability restoration
Cultural Services	Facilitate education, Support environmental awareness
Provisioning Services	Water reuse
Other Services	Reduced costs in comparison with other solutions
Limiting factors	Lack of supportive policies & conflicting legal frameworks, Lack of financial resources / lack of financial incentives, Potential demand on existing infrastructure adaptation, Property ownership complexities, It requires meticulous design considerations and expert input

CARDIMED

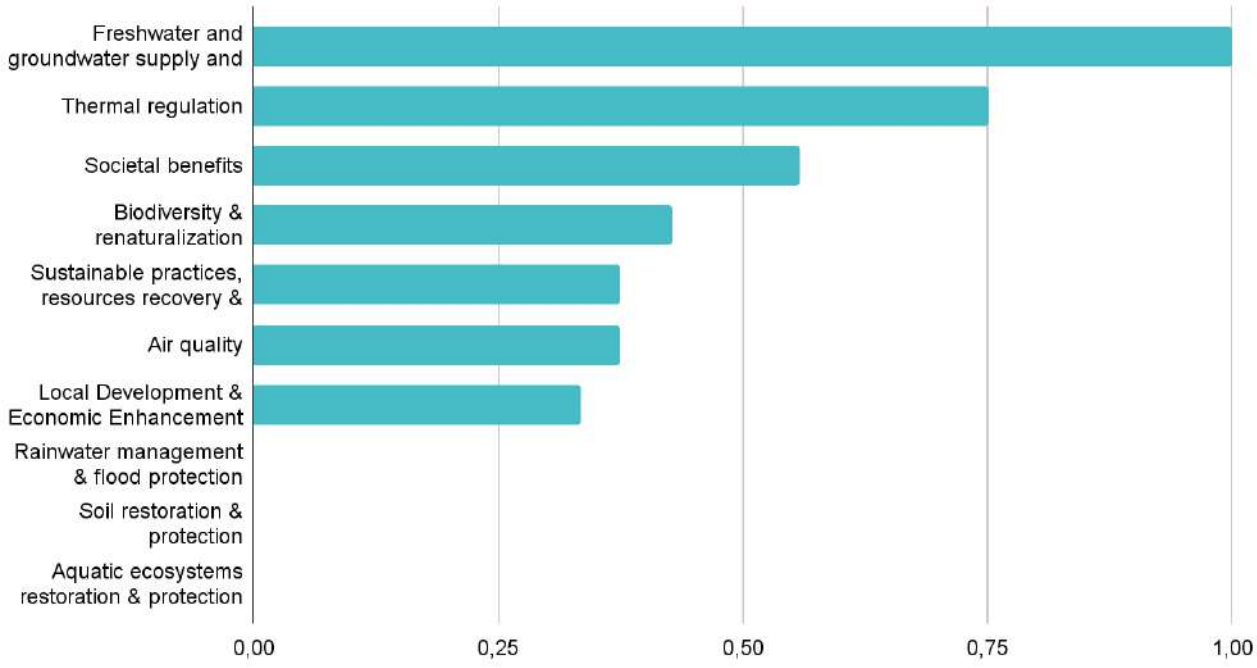
Sub-DEMO4.2 - Beyond Aesthetics:Wall-based green facade for sustainable water management

Description: The installation of a **wall-based green facade** on three facades of the primary school Istituto Comprensivo Statale Valle dell'Anapo in Ferla represents a forward-thinking approach to sustainable water management. This innovative system not only enhances the aesthetic appeal of the school but also serves a crucial function by treating greywater from washbasins. By repurposing this greywater, the system reduces the reliance on potable water for toilet flushing, thereby conserving valuable resources and promoting environmental sustainability. **Location:** Ferla, Italy **TRL:** 7. **SRL:** 6. **Sub-DEMO area (vertical surface cover in m^2):** 30. **Scale**: Urban (Public Building. **Stakeholders**: Municipality (Ferla), schools (Istituto Comprensivo Valle dell'Anapo) and university (University of Catania). **CAPEX:** 60.000,00 €. **OPEX:** 500 - 3000 €/y.



NBS$_{tu}$: Wall-based green facade (vertical surface covering of 30 m^2; TRL 5). **Supportive units:** Degreaser, UV disinfection, storage tanks. **Water source(s):** Greywater (from washbasins). **Water applications:** Toilet flushing. **By-product(s):** Harvested organic biomass (for fertiliser). **Smart tech:** Flow metres, T sensor (3 different orientation, NE, NW, SW). **Supportive actions:** Community engagement and education programme, Research and innovation activities, Capacity building and training to local stakeholders.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION SDGs	
	
Regulation and Maintenance Services	Reduce water withdrawals, Efficient water treatment, Provide thermal isolation
Cultural Services	Increase aesthetic and patrimonial or cultural value, Facilitate education, Support environmental awareness
Provisioning Services	Water reuse
Other Services	Reduced water footprint
Limiting factors	Potential for high costs related to operation, maintenance and the use of expensive media, regarding environmental issues, Potential demand on existing infrastructure adaptation, It requires meticulous design considerations and expert input.

3.5 DEMO5 Micro-forests and unsealed soils in Provence-Alpes-Cote d'Azur

DEMO5 is located in Marseille (France) and subdivided in two different sub-DEMO, one in Saint Jérome (peri-urban) and Saint Charles (urban, city center). Both sites present ways of curbing the major problems caused by global warming, such as urban heat islands and heavy rainwater run-off. Therefore, DEMO5 involves the creation of a large unsealing area with the major goal being to improve the infiltration rate of the area and reduce the temperature in summer.

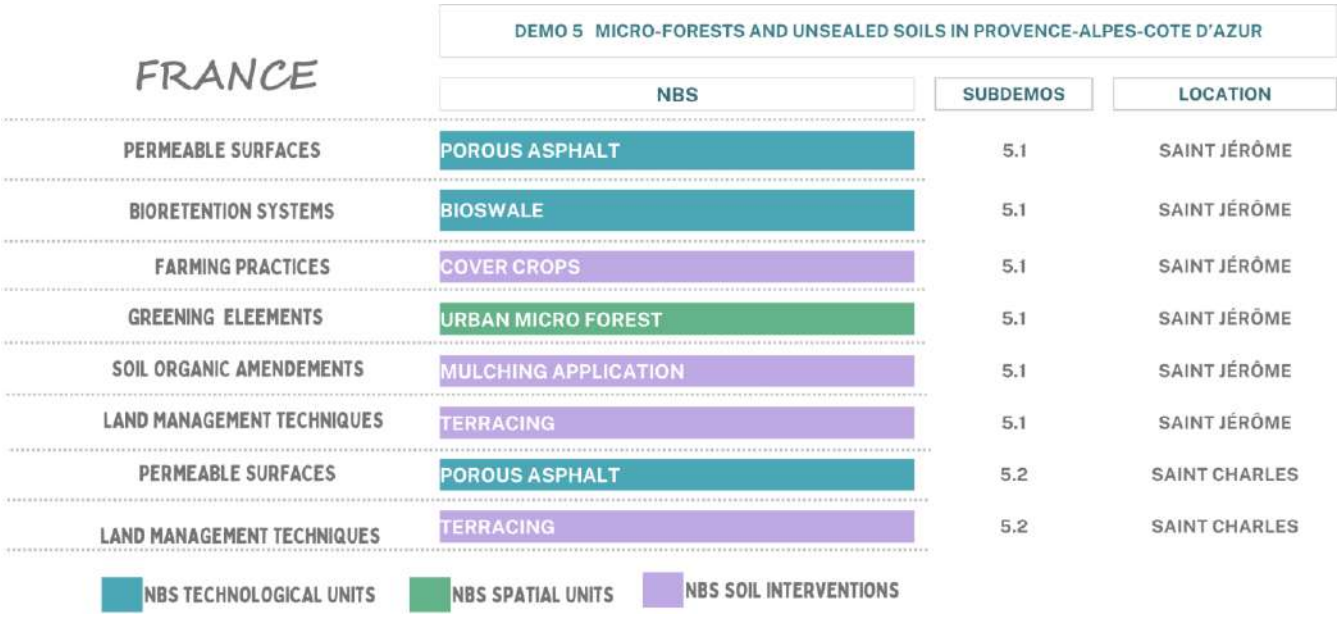
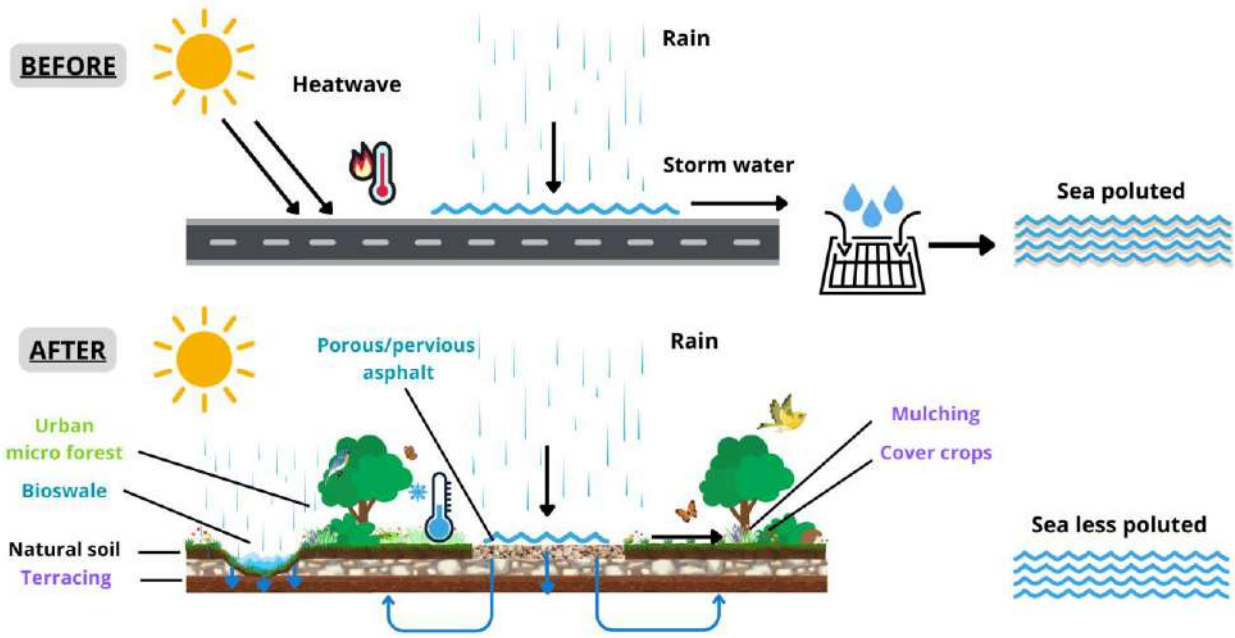


Figure 10. DEMO5 overview of the 2 sub-DEMOs and respective NBS.

CARDIMED

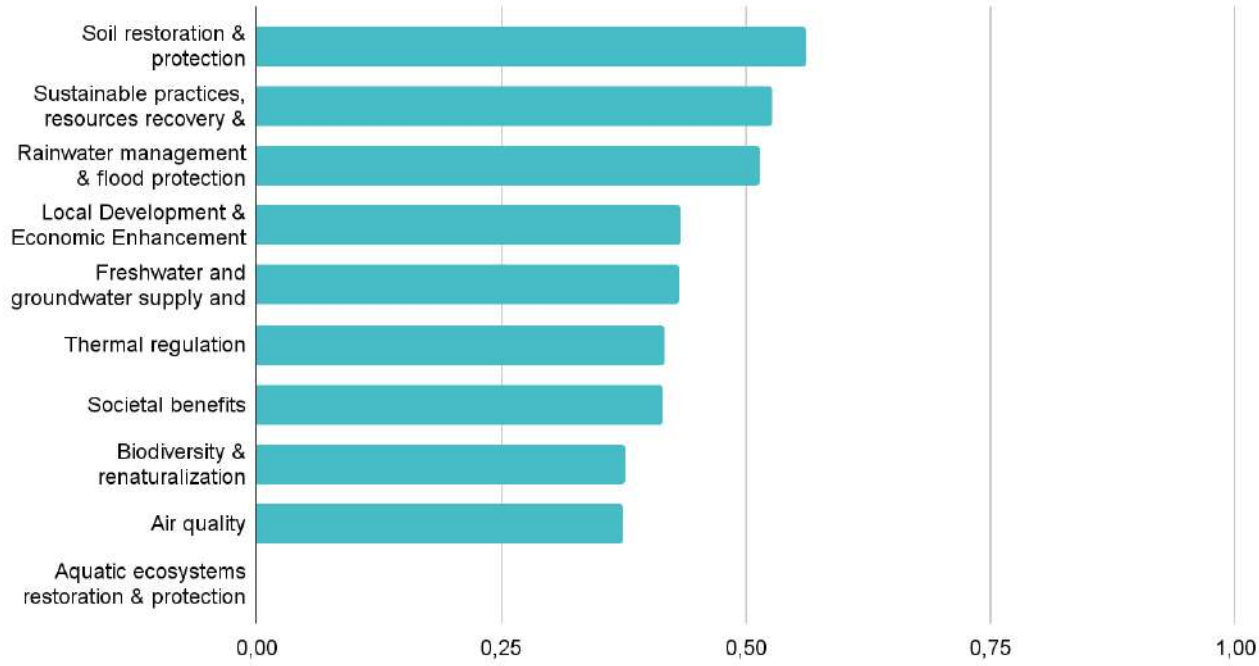
Sub DEMO5.1 - Eco-Friendly Campus: Reducing Runoff and Heat with Porous Materials and Green Spaces

Description: The waterproof asphalt has been removed from the university's forecourt, as well as from access roads and car parks. Terracing has been done to change the shape of the area and reduce the stormwater runoff. Terracing was applied and part of the unsealed area has been replaced by **porous asphalt** and porous concrete in order to maintain access paths. 3 **bioswale** were installed and planted using **cover crops**. A main bioswale was also installed and an **urban micro forest** planted around it. **Mulching** has been used to help the tree grow. Micro-forests and soil unsealing will reduce heat island effects and important water runoff, improving air quality and providing a suitable habitat for biodiversity. **Location:** Saint Jérôme, France. **TRL: Bioswale** 6-7. **SRL:** 6. **Sub-DEMO area (m^2):** 6000. **Scale**: Peri-urban (Private land owned by the University). **Stakeholders**: Municipality departments (Marseilles - Metropolitan City administration), University (University of Aix-Marseille), Community groups (students), Public body for water management, Regional government (Regional Sud- for compliance with regional Climate adaptation plan). **CAPEX: 572.000** €. **OPEX: 8.000** €/y.



NBS_{tu}: Bioswale (2478 m^2; TRL 7) and porous asphalt (1312m^2, TRL 9). **NBS_{su}**: Urban micro forest (2758 m^2; TRL 6) **NBS_{si}:** Mulching application (264 m^2 ; TRL 8), cover crops (3905 m^2; TRL 7), and terracing (2375 m^2; TRL 8). **Supportive units: Water source(s):** Rainwater and urban runoff. **Water applications:** Aquifer recharge. **By-product(s):** Mowing hay (for livestock and other animals), harvested fruits (for mulching). **Smart tech:** Sensors for measuring air humidity, wind speed and direction, rainfall, solar radiation, and volatile organic compounds. **Supportive actions:** Community engagement and education programs, building and training for local stakeholders.

MAIN CHALLENGES TARGETED



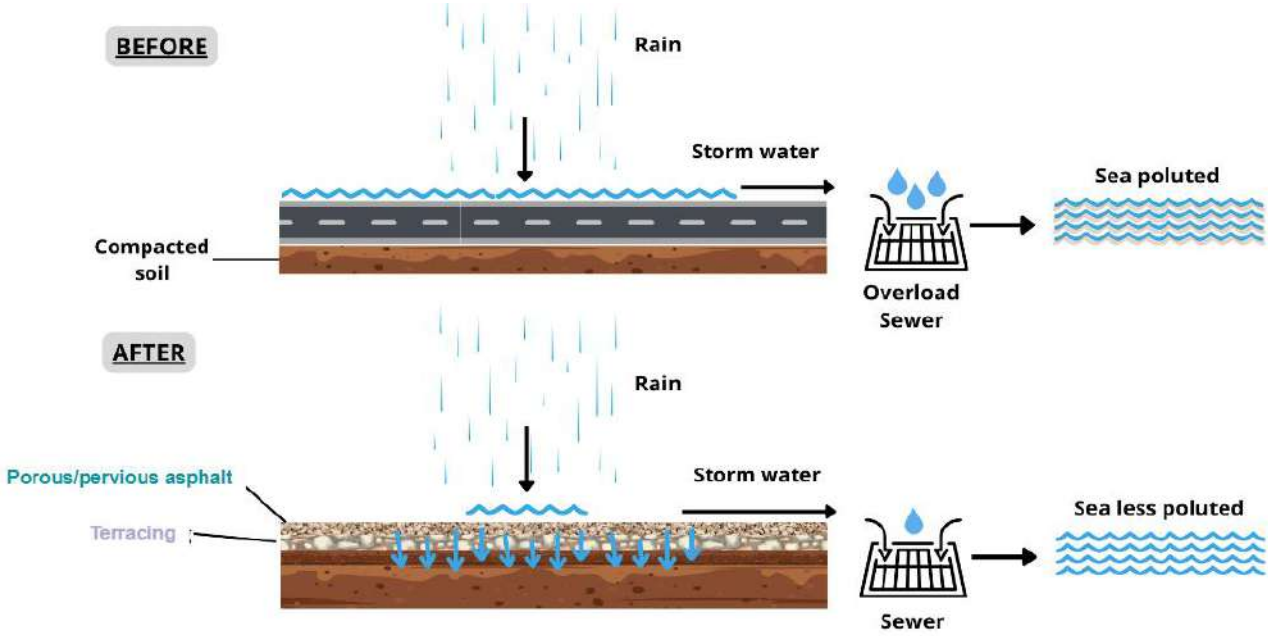
POTENTIAL CONTRIBUTION SDGs

Regulation and Maintenance Services: Improve quality of groundwater, Efficient water treatment, Reduce flood risk Reduce sediment flow into drainage systems, Reduce combined sewer overflows, Reduce landslides, Reduce urban runoff, Stormwater source control, Permeability restoration, Create or restore habitat, Create or restore fauna and flora, Support pollination, Forest creation and/or restoration, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Reduce changes on soil characteristics, Stabilise soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilise water retention, Improve carbon sequestration, Provide thermal regulation / cooling
Cultural Services: Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Facilitate education, Support environmental awareness, Promote mental health Reconnect people with nature
Provisioning Services: Preserve groundwater supply, Provide nutrition sources for birds and insects, Production of biomass, Nutrient recovery
Other Services: Reduced costs in comparison with other solutions
Limiting factors: Lack of skilled subcontractors, procurement procedures allowing to attract innovative

	companies; Potential for high costs related to operation; maintenance and the use of expensive media; Lack of political will and long-term commitment / lack of sense of urgency regarding environmental issues; Potential demand on existing infrastructure adaptation; It requires meticulous design considerations and expert input

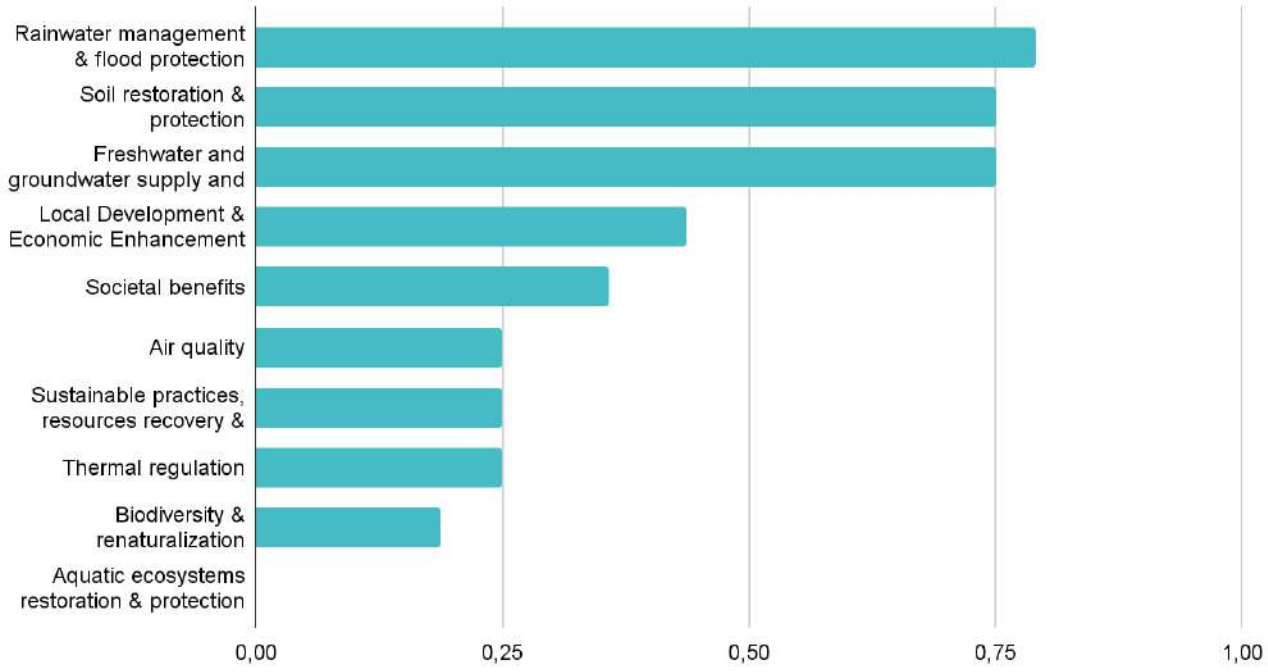
CARDIMED — Sub-DEMO5.2 - From Concrete to green: A Natural-Driven Journey Towards Sustainability

Description: This sub-DEMO is located in the heart of the city of Marseille near the main train station. The site doesn't allow as much freedom of changes as the first one because of its large number of visitors and its small size. Surface unsealing and terracing will take place on the site porous asphalt and concrete will be set up. In a second step trees will also be planted as an urban micro forest**. Location:** Saint Charles, France. **TRL:** 8-9. **SRL:** 2. **Surface (m^2):** 4000. **Scale**: Urban (Private land owned by the University). **Stakeholders**: Municipality departments (Marseilles - Metropolitan City administration), University (University of Aix-Marseille), public body for water management, regional government (Regional Sud for compliance with regional Climate adaptation plan). **CAPEX:** Estimated 330.000€. **OPEX:** Estimated 2000€/y.



NBS_{tu}: Porous asphalt (1700 m^2, TRL 9). **NBS_{si}:** Terracing (1700 m^2, TRL 8) **Supportive units: Water source(s):** rainwater, urban runoff. **Water applications:** Aquifer recharge**. By-product(s):** *not applicable.* **Smart tech:** Sensors of T, humidity, wind strength and direction, rainfall, solar radiation and volatile organic components (VOC). **Supportive actions**: Community engagement and education programs, building and training for local stakeholders.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION SDGs	
	
Regulation and Maintenance Services	Efficient water treatment, Reduce flood risk, Reduce sediment flow into drainage systems, Reduce combined sewer overflows, Reduce urban runoff, Permeability restoration, Stabilise soil / substrate, Enhance and stabilise water retention
Cultural Services	Facilitate education
Provisioning Services	Preserve groundwater supply
Other Services	Contribute to local employment
Limiting factors	Potential for high costs related to operation, maintenance and the use of expensive media, Lack of financial resources / lack of financial incentives, Bureaucratic burden, Potential demand on existing infrastructure adaptation, Property ownership complexities, It requires meticulous design considerations and expert input, Complex synergies between NBS, governance and community engagement processes at an operational and financial level,

	Limitations of accessibility, Shortage of real-time data on biodiversity indicators & aquifer recharge due to limited monitoring time.

3.6 DEMO6 - Forest management and heatwave resilience in Aragon

The DEMO6 addresses the decline of Aleppo and Scots pine forests caused by mistletoe infestations, along with fostering environmental education and promoting sustainability practices among students and staff. Sub-DEMO6.1 focuses on mapping mistletoe afflictions and controlling invasive alien species through pruning and thinning in pine forests. Sub-DEMO6.2 implements diverse Nature-Based Solutions in two primary schools to promote environmental education and sustainability practices.

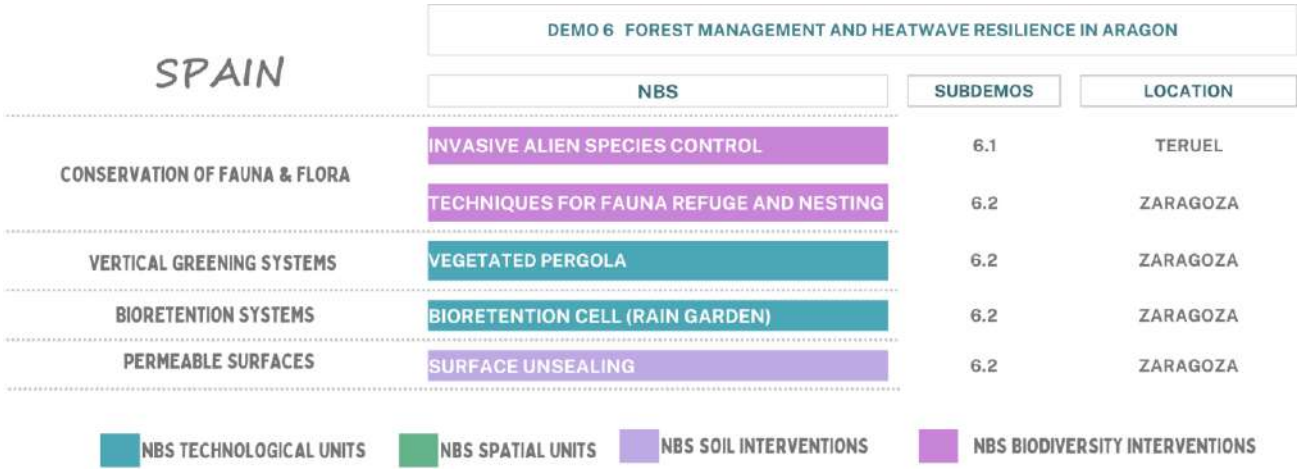
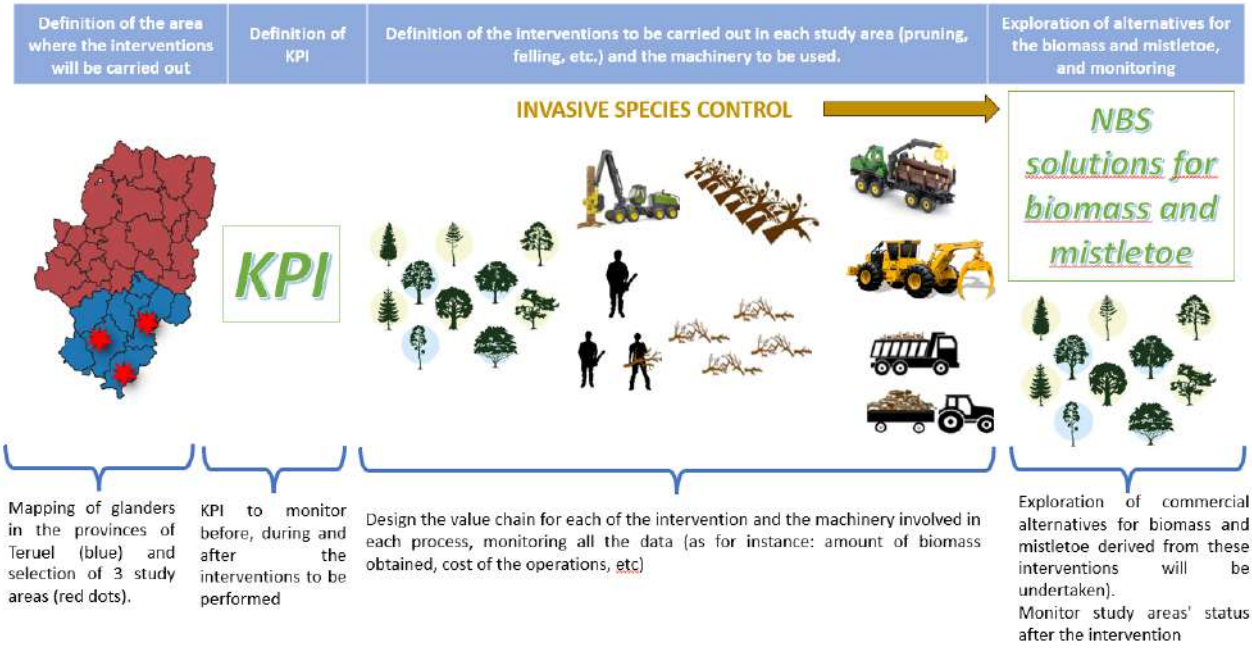


Figure 11. DEMO6 overview of the 2 sub-DEMOs and respective NBS.

CARDIMED — Sub-DEMO6.1 - Tackling Mistletoe Infestation: Mapping and Control Strategies in Pine Forests

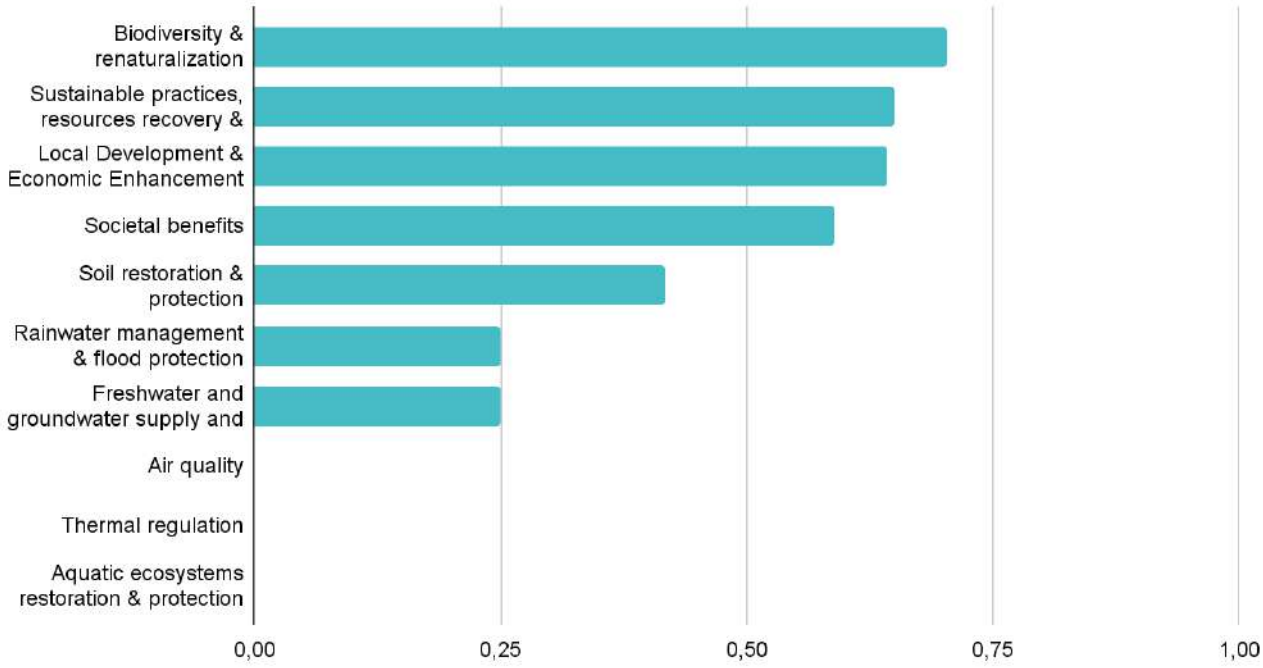
Description: In recent decades, mistletoe has emerged as the primary biotic agent contributing to the decline of Aleppo and Scots pine forests in Teruel. Therefore, sub-DEMO6.1 will focus on mapping mistletoe afflictions in Teruel's pine forests and selecting representative study areas for invasive alien species control, primarily through *pruning and thinning.* The status of intervention zones will be monitored throughout the entire process. Additionally, exploration of commercial alternatives for biomass and mistletoe derived from these interventions will be undertaken. **Location:** Teruel, Spain. **TRL:** 2. **SRL:** 4. **Sub-DEMO area (m^2):** *not available.* **Scale**: Rural (Public

land - degraded area). **Stakeholders**: regional government (Aragon), Forestry engineers. **CAPEX and OPEX:** *not available.*



NBS_{bi}: Invasive alien species control (m^2, TRL 2). **Supportive units:** *not applicable*. **Water source(s):** Rainwater. **Water applications:** *not applicable*. **By-product(s):** Harvested organic biomass (commercial alternatives will be explored). **Smart tech:** GIS, drone. **Supportive actions:** Research and innovation initiatives, collaboration with indigenous and local communities, public-private partnerships for financing and implementation, adaptive management and planning processes.

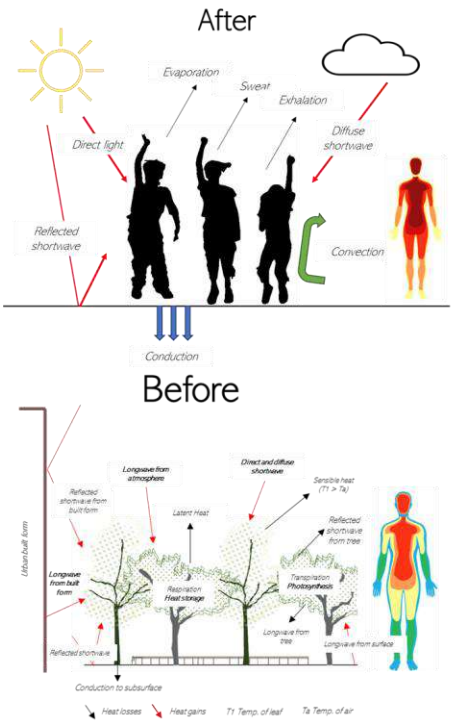
MAIN CHALLENGES TARGETED

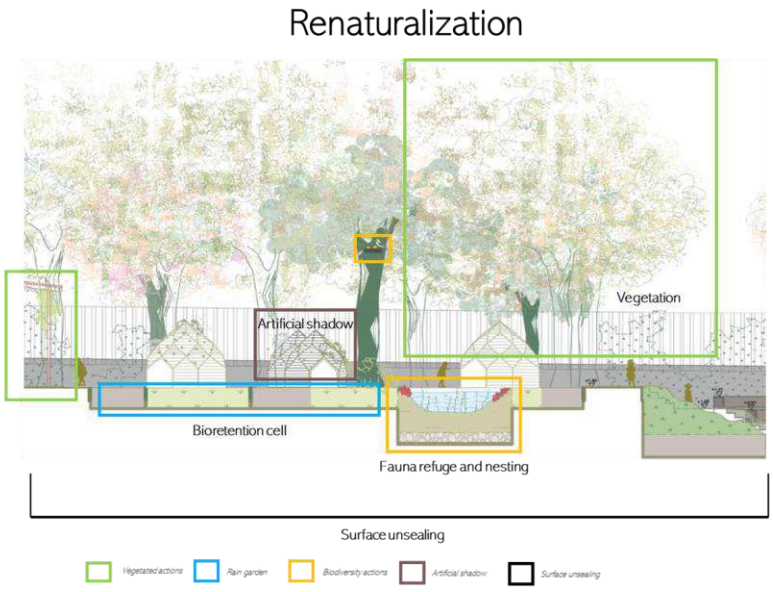


POTENTIAL CONTRIBUTION SDGs	
	
Regulation and Maintenance Services	Create or restore habitat,Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Forest creation and/or restoration, Develop resilience of green spaces, Restore natural forest fire regime, Reduce risk of pest and diseases
Cultural Services	Increase recreational and socialisation value, Facilitate education, Promote mental health
Provisioning Services	Produce biochemicals, natural medicines and pharmaceuticals, Production of biomass, Provide raw material,
Other Services	Contribute to new or existing business, Favour green economy (reuse of local by-products)
Limiting factors	Potential demand on existing infrastructure adaptation; Propagation and potential habitat of undesired insects, pests, plants, and animals; Biomass harvesting is an essential requirement; Property ownership complexities; Lack of awareness of benefits High land footprint / Competition for space; Shortage of real-time data on biodiversity indicators & aquifer recharge due to limited monitoring time.

CARDIMED	Sub-DEMO6.2 - Sustainable Learning Spaces: NBS Implementation in Zaragoza's Primary Schools

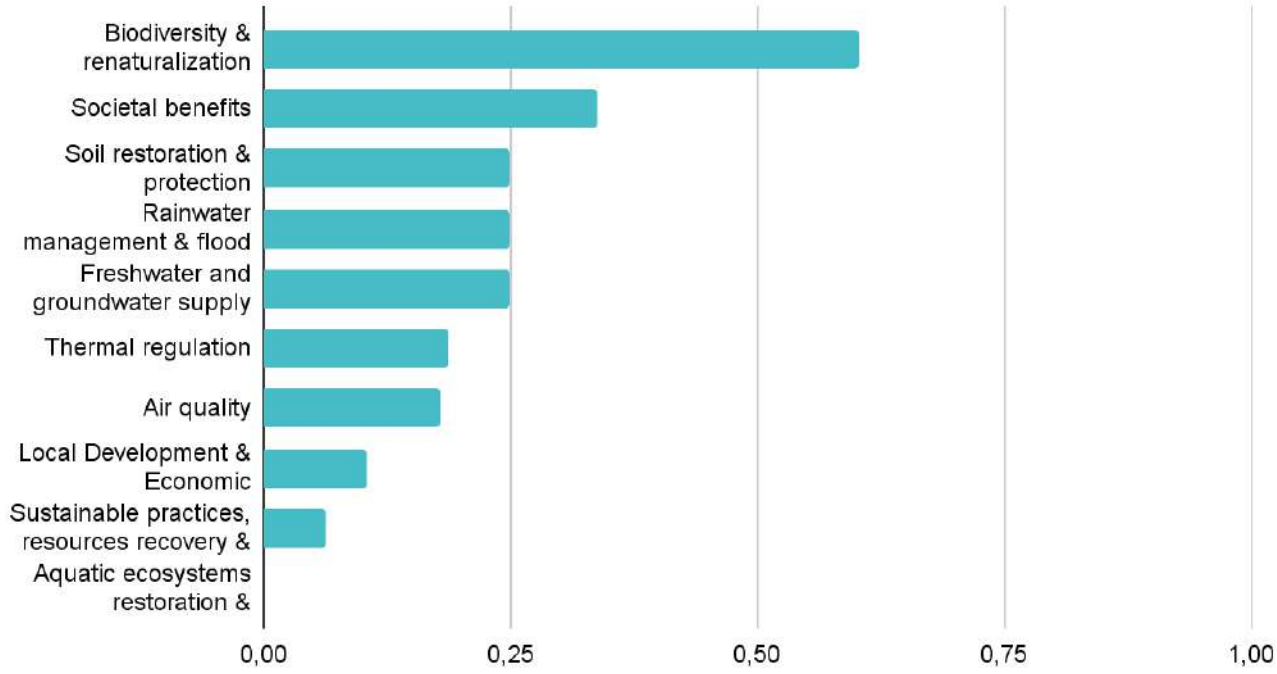
Description: This sub-DEMO encompasses a combination of diverse NBS implemented in two primary schools, aimed at fostering environmental education and promoting sustainability practices among students and staff. The intervention features an innovative **vegetated pergola** to support the growth of shading vines and plants, enhancing the aesthetic appeal of the area while providing natural cooling. Concrete is removed **(Surface unsealing)**, permeable surfaces are installed to facilitate rainwater infiltration, and **bioretention cell (rain garden)** are for creating a buffer for water infiltration. Moreover, to enhance biodiversity, **techniques for fauna refuge and nesting** will be built (i.e insect hotels, bird houses, bat houses, and amphibian ponds). **Location:** Zaragoza, Spain. **TRL:** 9. **SRL:** 4. **Sub-DEMO area (m^2):** 7500 **Scale**: Urban (Public land). **Stakeholders**: regional government (Aragon), Schools, Municipality (Zaragoza). **CAPEX:** 200,000€ **OPEX:** *not available*.





NBS$_{tu}$: Vegetated pergola (8.12 m^2; TRL 9) Bioretention cell (rain garden) (9.25 m^2; TRL 9). **NBS$_{si}$:** Surface unsealing (*to be defined* m^2; TRL 9). **NBS$_{bi}$:** Techniques for fauna refuge and nesting (2 ud; TRL 9), **Supportive units:** *not applicable.* **Water source(s)**: Rainwater and irrigation. **Water applications:** Aquifer recharge. **By-product(s):** *not applicable.* **Smart tech:** Sensors of T, air quality, solar radiation, wind (velocity and direction) and air humidity. **Supportive actions:** *not available*.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION TO SDGs	
	
Regulation and Maintenance Services	Efficient water treatment , Improve quality of groundwater, Permeability restoration, Create or restore habitat, Mitigate desertification, Create or restore flora and fauna, Support pollination, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Stabilise soil / substrate, Enhance and stabilise water retention
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Facilitate education Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Increase physical and mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Preserve groundwater supply, Provide nutrition sources for birds and insects
Other Services	*not applicable*
Limiting factors	Potential for high costs related to operation, maintenance and the use of expensive media; Bureaucratic burden; Potential demand on existing infrastructure adaptation; Propagation and potential habitat of undesired insects, pests, plants, and animals; Biomass harvesting is an essential requirement, Property ownership complexities; It requires meticulous design considerations and expert input; Lack of awareness of benefits; High land footprint / Competition for space; Shortage of real-time data on biodiversity indicators and aquifer recharge due to limited monitoring time.

3.7 DEMO7 - Cultural landscape restoration in Region of Central Alentejo

DEMO7 focuses on the restoration and conservation of riparian woodlands and Mediterranean water streams vegetation, as well as the neighbouring Montado habitat. Sub-DEMO7.1 emphasises ecological restoration efforts targeting riparian woodlands and riverside vegetation. Sub-DEMO7.2 addresses the biodiversity loss and increased fire risk through restoration efforts. Together, these initiatives aim to enhance habitat connectivity, restore ecological balance, and mitigate wildfire risks in the Montado region.

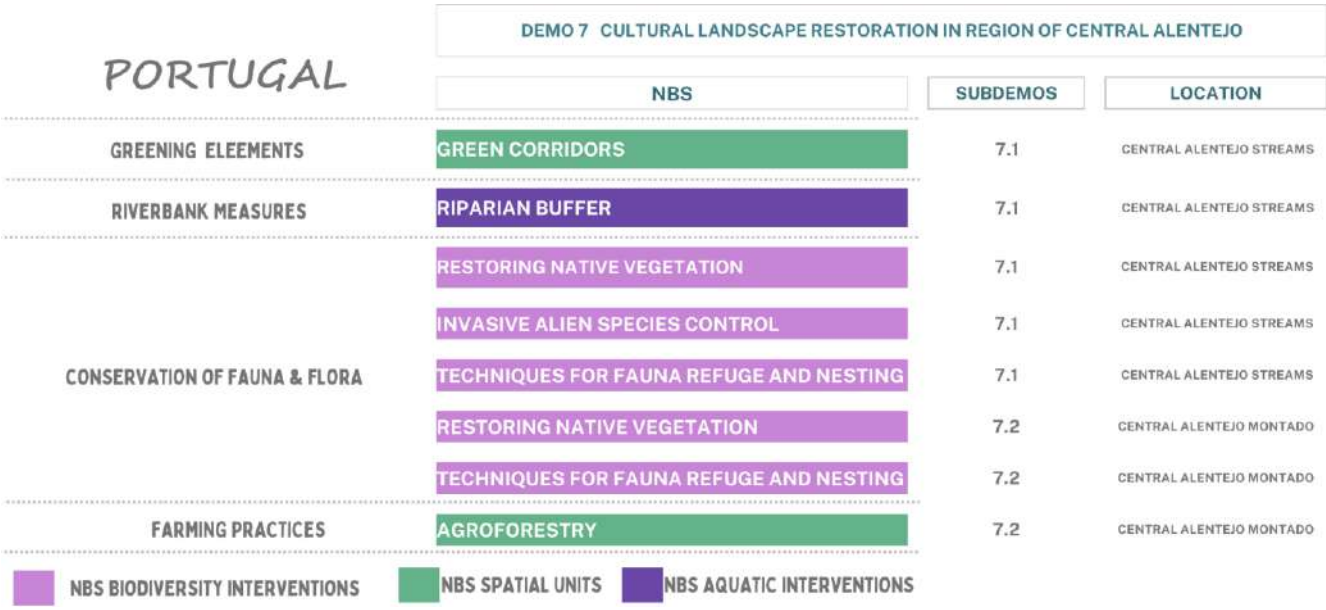
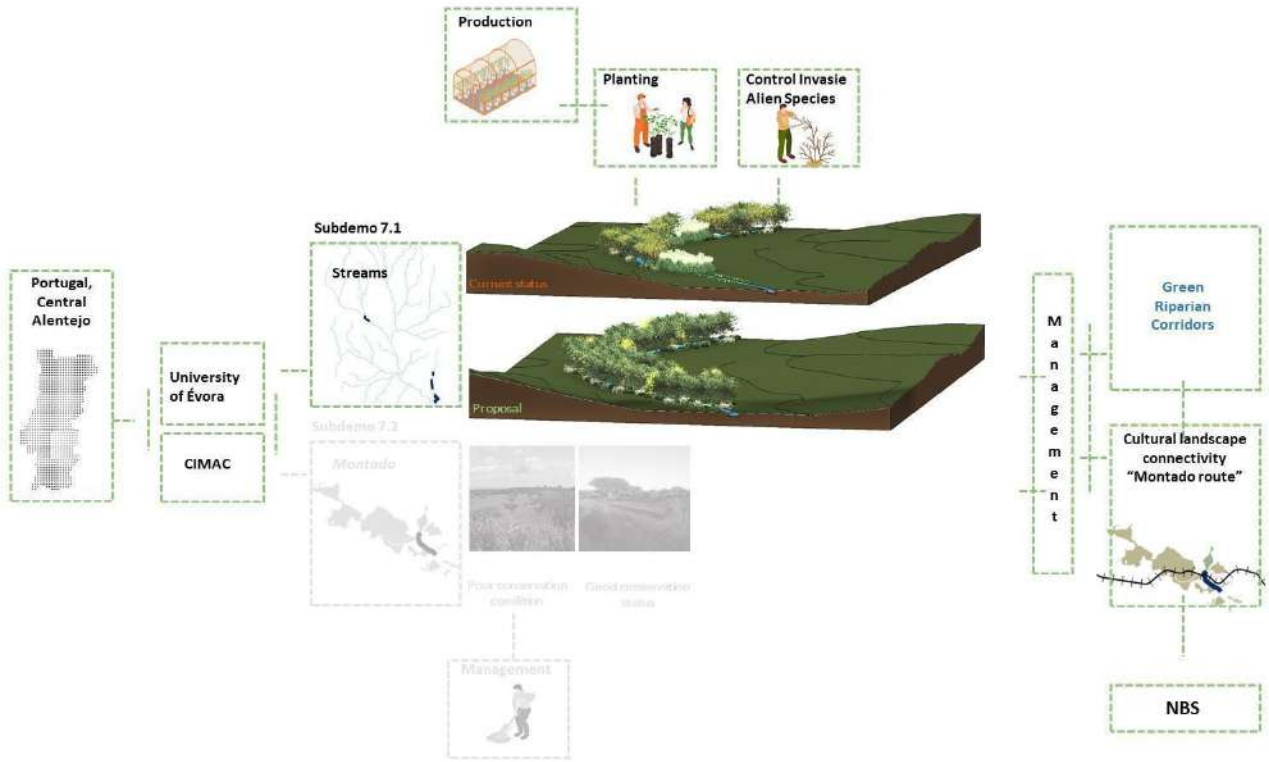


Figure 12. DEMO7 overview of the 2 sub-DEMOs and respective NBS.

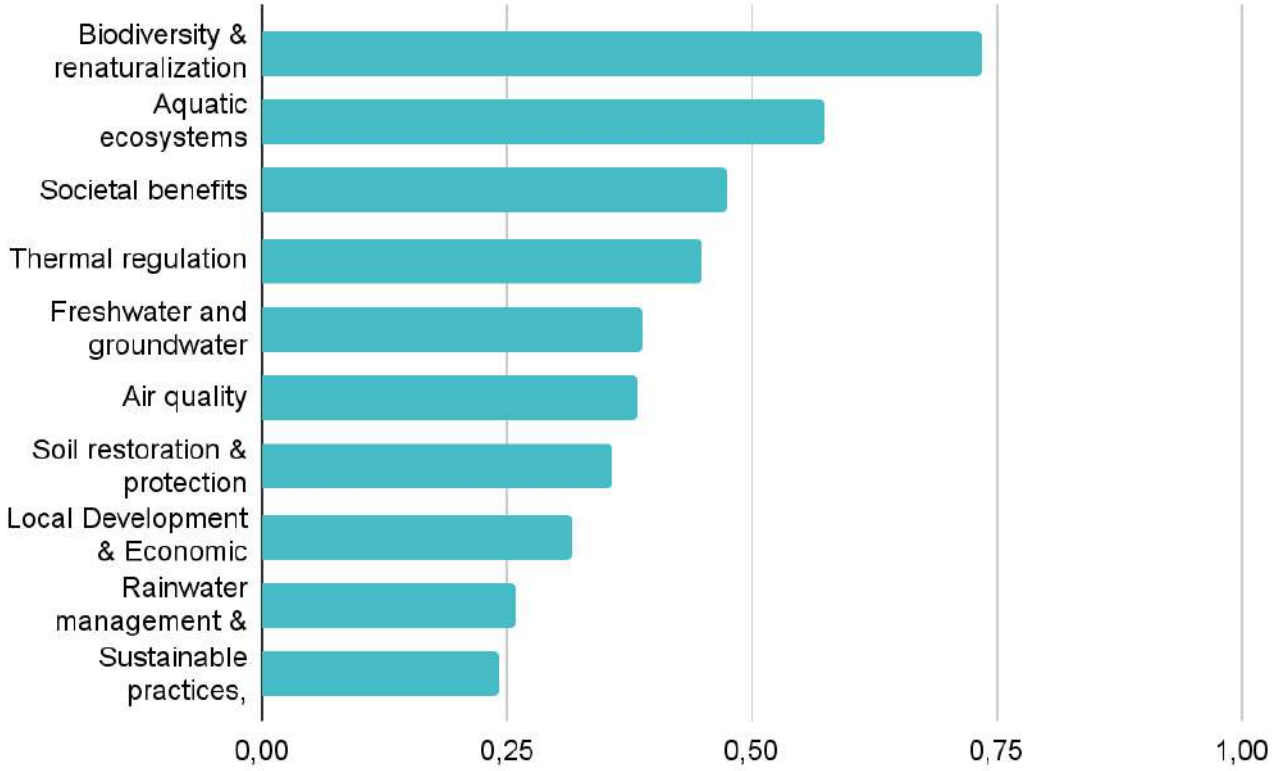
CARDIMED Sub-DEMO7.1 - Towards Sustainable Mediterranean Streams: Restoring Riparian Vegetation

Description: The promotion of conservation, restoration, and enhancement of riparian woodlands and/or Mediterranean water streams vegetation has been acknowledged in regional plans as a priority for addressing climate change. Based on native vegetation models, ecological restoration efforts targeting riparian woodlands and riverside vegetation will be addressed. This includes implementing NBS such as **invasive alien species control**, **restoring native vegetation**, employing **techniques for fauna refuge and nesting**, to establish **riparian buffers** and **green corridors**. These NBS interventions aim to improve the health and resilience of riparian ecosystems, contributing to broader conservation objectives and climate change mitigation efforts in the region. **Location:** Central Alentejo - Streams, Portugal. **TRL:** *not applicable.* **SRL:** 3 **Sub-DEMO area (m^2):** 100,000. **Scale**: Rural (Public land). **Stakeholders**: Farmers, Regional government (APA/ARH-Alentejo and CIMAC), Municipalities (Reguengos and Évora), University (University of Évora). **CAPEX** and **OPEX:** *not available.*



NBS_{su}: Green corridors (100 000m^2). **NBS_{ri}:** Riparian buffer (100 000 m^2). **NBS_{bi}:** Restoring native vegetation (20 000 m^2), invasive alien species control (7 000 m^2, TRL?), techniques for fauna refuge and nesting (30 m^2). **Supportive units:** *not applicable.* **Water source(s):** rainwater. **Water applications:** natural maintenance of green areas. **By-product(s):** *not available.* **Smart tech:** not available. **Supportive actions:** *not available*.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION SDGs	
	
Regulation and Maintenance Services	Improve quality of surface water, Create or restore habitat, Restore degraded areas Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Wetland creation and/or restoration, Forest creation and/or restoration, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Restore natural forest fire regime, Restore aquatic habitats, Reduce sediment flow in the river, Reduce sediments deposition in river beds, Reduce changes on soil characteristics, Improve carbon sequestration, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Preserve cultural and historic heritage, Facilitate education, Promote mental health
Provisioning Services	Preserve surface water supply, Provide nutrition sources for birds and insects, Produce biochemicals, natural medicines and pharmaceuticals, Production of biomass, Provide raw material

Other Services	Increase land/property monetary value, Increase tourism
Limiting factors	Authorization delays; No companies interested/available to carry out the work; Unsuccessful planting due to high summer Ts; Difficulty (cost) in controlling invasive species.

CARDIMED

Sub-DEMO7.2 - Enhancing Habitat Connectivity and Ecological Balance with NBS

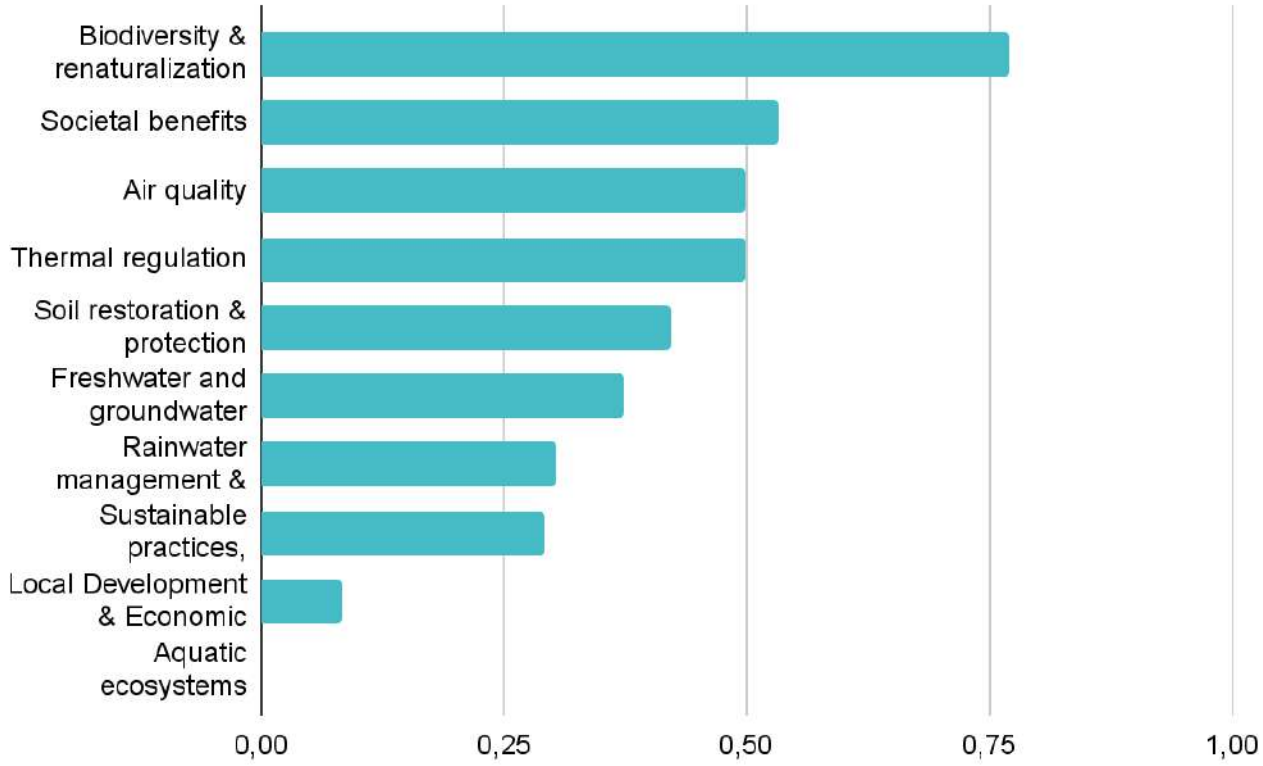
Description: In the Montado, a prevalent neighbouring habitat of Mediterranean water streams, traditional practices have been abandoned, resulting in biodiversity loss and heightened fire risk. To address these challenges and promote ecosystem health, restoration efforts will prioritise the implementation of NBS, including **restoring native vegetation** and **agroforestry**, and deploying **techniques for fauna refuge and nesting**. These initiatives aim to enhance habitat connectivity, restore ecological balance, and mitigate risk of wildfires in the Montado region. **Location:** Central Alentejo Montado, Portugal. **TRL:** *not available.* **SRL:** 3 **Sub-DEMO area (m²):** 10000. **Scale**: Rural (private land). **Stakeholders**: *not available.* **CAPEX** and **OPEX:** *not available.*

the

Diagram not available

NBS_b: Restoring native vegetation (10 000m²) and techniques for fauna refuge and nesting (30 m²). **NBS_{su}**: Agroforestry (10000 m²). **Supportive units:** *not available.* **Water source(s):** Rainwater. **Water applications:** natural maintenance of green areas. **By-product(s):** *not available.* **Smart tech:** *not available.* **Supportive actions:** *not applicable*.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION SDGs	
	
Regulation and Maintenance Services	Improve quality of groundwater Create or restore habitat, Restore degraded areas Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora Connect green spaces Develop resilience of green spaces Reduce changes on soil characteristics Stabilise soil / substrate, Improve soil fertility / biodiversity, Improve carbon sequestration Provide thermal regulation / cooling Reduce risk of pest and diseases
Cultural Services	Increase aesthetic and patrimonial or cultural value, Preserve cultural and historic heritage, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Provide nutrition sources for birds and insects, Production of biomass, Provide raw material, Sustainable food production

Other Services	*not applicable*
Limiting factors	Authorization delays; No companies interested/available to carry out the work; Risk of lack of cooperation from the owner in future years' management; Risk of plant mortality following plantation

3.8 DEMO8 - Indigenous production landscapes in Izmir

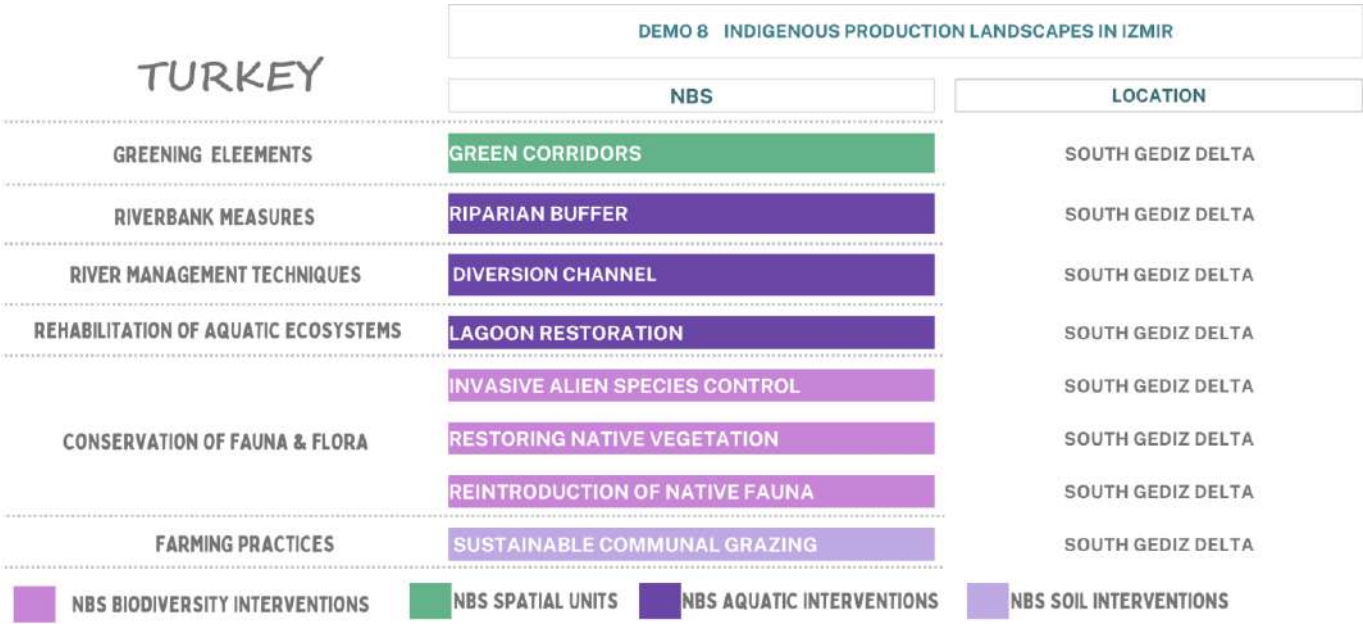
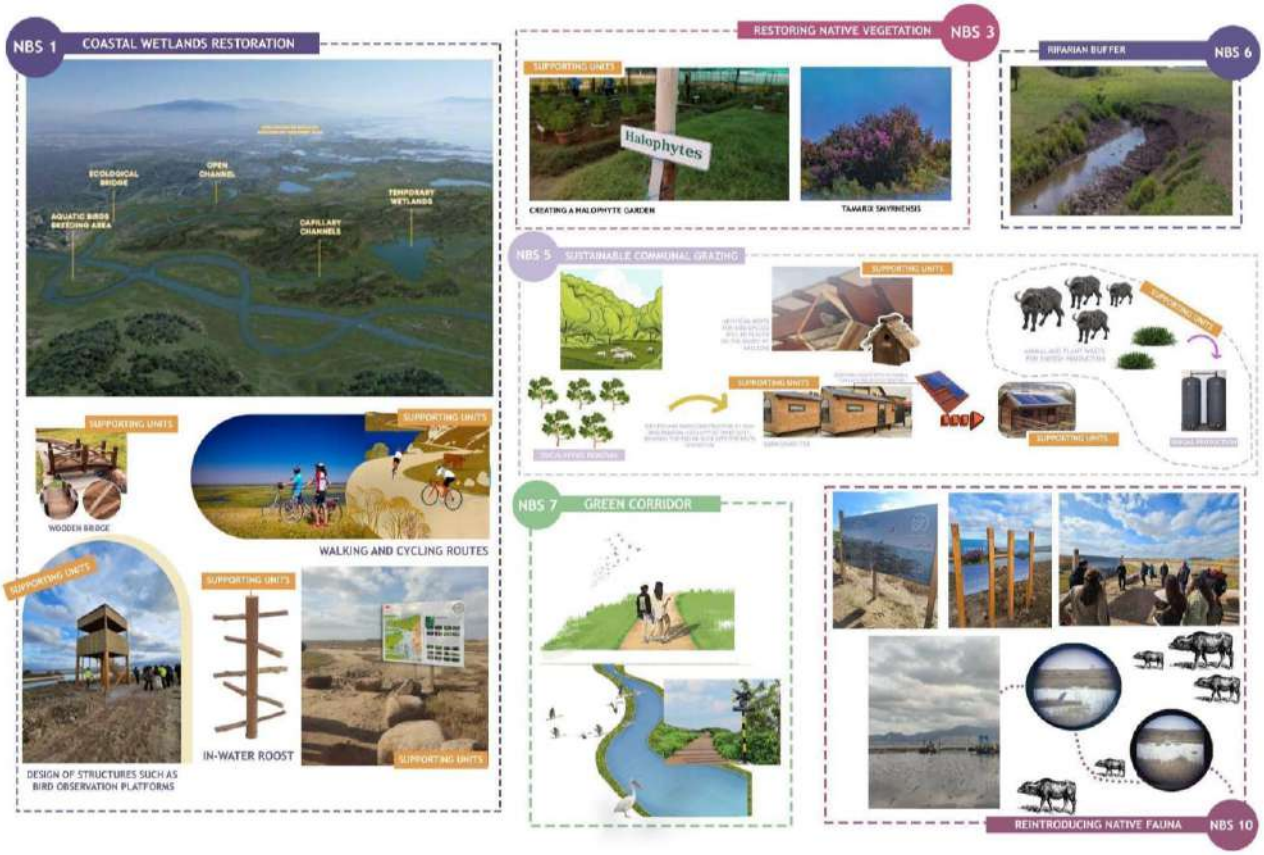


Figure 13. DEMO8 overview of NBS.

CARDIMED	Indigenous production landscapes in Izmir

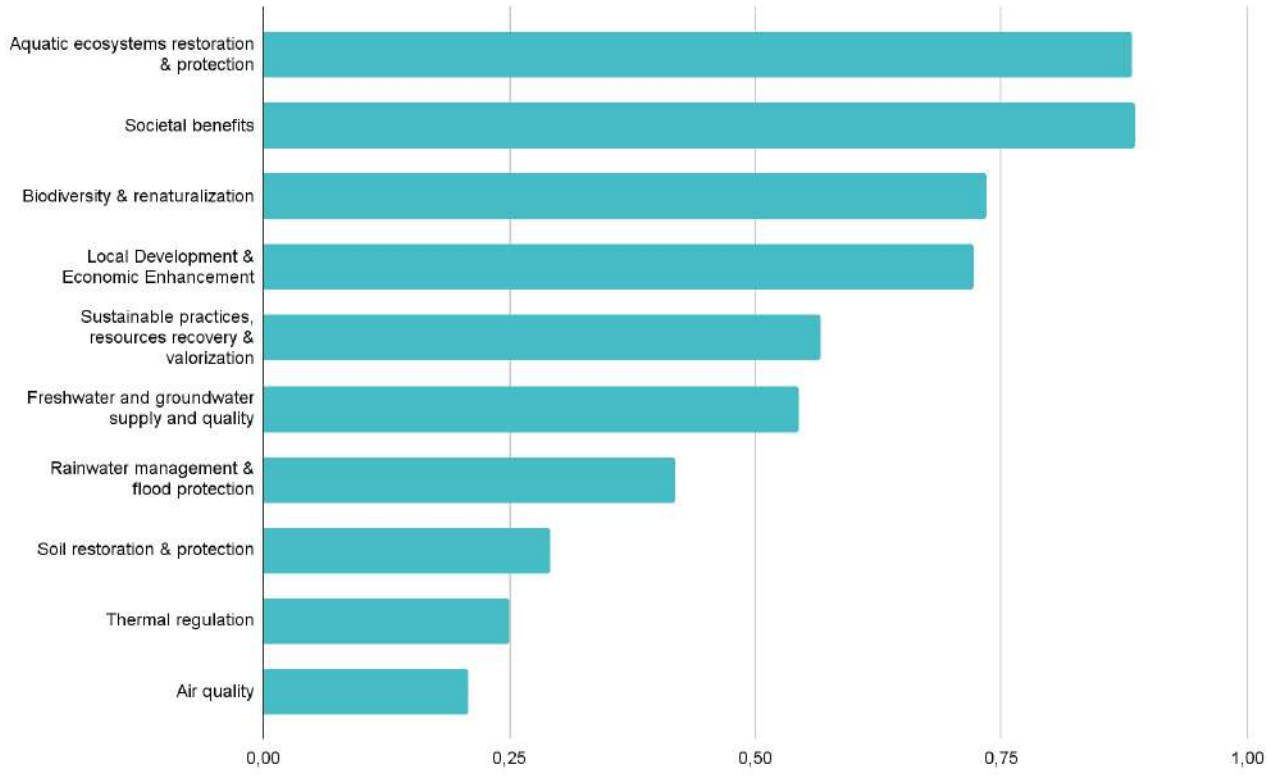
Description: Sub-DEMO8.1 presents a comprehensive plan for coastal wetland restoration, integrating various NBS to address environmental and social challenges. The initiative begins with the deployment of **riparian buffer** areas to ensure that the quality of effluent from Çiğli wastewater treatment plants, discharged into the main open channel, meets the required standards according to local regulations. Next, **diversion channels** are constructed along the open channel to facilitate the inflow of freshwater into existing wetlands. This measure aims to reduce salinity levels and promote a healthier habitat for indigenous flora and fauna. Additionally, **green corridors** will be developed within these diversion channels to enhance ecological connectivity. Next, techniques for **lagoon restoration** will be employed to mitigate erosion risks and bolster resilience against coastal erosion. **Invasive alien species control** will be prioritised, targeting species that consume excessive water and degrade habitats along with **restoring native vegetation** and **reintroduction of native fauna**, such as buffaloes, to enhance biodiversity and ecosystem resilience within the delta region. **Sustainable communal grazing** practices will be introduced to regulate animal husbandry, alleviating ecological pressures on the delta ecosystem. Finally, these collective restoration efforts aim to revitalise coastal wetlands,

conserve biodiversity, and ensure the long-term sustainability of the delta ecosystem. **Location:** South Gediz Delta, Turkey. **TRL:** 9. **SRL:** 3-6 (depending on the NBS). **Surface (km^2):** 60 **Scale:** Rural, Peri-urban. **Stakeholders:** Shepherds, Sasalı Mukhtar's Office, Sasalı Social Solidarity and Development Association, Izmir Municipality Parks and Gardens Directorate, Şemikler Aquaculture Cooperative, Izmir Institute of Technology. CAPEX: 600,000 €. OPEX: *not available*.



NBS_{ri}: Riparian buffer (2 Km^2, TRL?), diversion channel (3.3 Km, TRL?), lagoon restoration (6 Km^2, TRL?) . **NBS_{bi}:** Invasive alien species control (0.5 Km^2, TRL?), restoring native vegetation (2.5 Km^2, TRL?) and reintroduction of native fauna (9 Km^2, TRL?). **NBS_{si}:** Sustainable communal grazing (9 Km^2, TRL?). **NBS_{su}:** Green corridors (120m , TRL 9) . **Supportive units:** Equipping shelter roofs with PV panels, installation of a small-scale biogas plant at the DEMO site, placing artificial nests for bird species on the roofs of shelters, creating a halophyte garden, construction of walking and cycling routes in the DEMO area, construction of observation platforms, bird-watching towers, bird perches and information signs. **Water source(s):** Effluent of WWTP, rainwater, runoff **Water applications:** surface water discharge, natural maintenance of green areas. **By-product(s):** Harvested organic biomass (for landscaping, fertiliser, biofuels and energy production). **Smart tech:** Groundwater monitoring; Camera traps. **Supportive actions**: Monitoring biodiversity change after freshwater entry into the area; groundwater monitoring; conducting community engagement and educational programs through the Flamingo Nature Park which aims to provide bird habitats, connect İzmir residents with nature, and offer recreational facilities, situated near the demonstration area, bird-watching events by Doga, Izdoga's flamingo bus and boat tours and Halophyte Garden; advocating for policies and coordinating stakeholders for the protection of the delta; participating in the development of the Management Plan for Gediz Delta; collaborating with indigenous and local communities to promote and safeguard the delta; establishing cooperatives to support local businesses; forming public-private partnerships to finance and execute restoration activities in the delta.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION SDGs

Regulation and Maintenance Services	Efficient water treatment, Improve quality of surface water, Create or restore habitat, Restore degraded areas, Mitigate desertification, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Connect green spaces, Connect blue and green spaces, Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Increase green areas around urban rivers, Restore natural forest fire regime, Re-establish hydrologic connection, Improvement of the hydromorphological functioning, Restore aquatic habitats, Reduce sediment flow in the river, Reduce sediments deposition in river beds, Enhance and stabilise water flow (Sustain river flow),Reduce changes on soil characteristics, Improve soil fertility / biodiversity, Improve carbon sequestration, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Reduce undesired behaviours, activities and vandalism, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	preserve groundwater supply, preserve surface water supply, Water reuse, Provide nutrition sources for birds and insects, Production of biomass, Provide raw material, Material reuse, Provide genetic resources, Sustainable food production
Other Services	Contribute to local employment, Increase land/property monetary value, Increase tourism, Contribute to new or existing business, Reduced costs in comparison with other solutions
Limiting factors	Potential for high costs related to operation, maintenance and the use of expensive media; Treatment efficiency is directly influenced by the concentrations of pollutants in the inlet; Bureaucratic burden; It requires additional energy consumption for operation and maintenance; Seasonal and climate fluctuations can significantly affect the proper functioning of systems in terms of resilience and treatment efficacy; It requires meticulous design considerations and expert input; Complex synergies between NBS, governance and community engagement processes at an operational and financial level; Requires complex technology and additional devices, such as syphons, pumps, and aeration apparatus.

3.9 DEMO9 Gardens of the future in the heart of Nicosia city

DEMO9 focuses on bolstering Nicosia's water supply infrastructure and raising water quality standards. Sub-DEMO9.1 utilises innovative microalgae techniques to refine groundwater quality, while Sub-DEMO9.2 introduces a pioneering subsurface rainwater harvesting system for sustainable irrigation. Sub-DEMO9.3 enhances urban green spaces with wall-based green facades, promoting food security through vertical gardening and hydroponic cultivation. Together, these initiatives are poised to significantly strengthen Nicosia's water supply infrastructure's resilience, ensuring its sustainability for future generations while promoting environmental conservation and fostering community resilience.

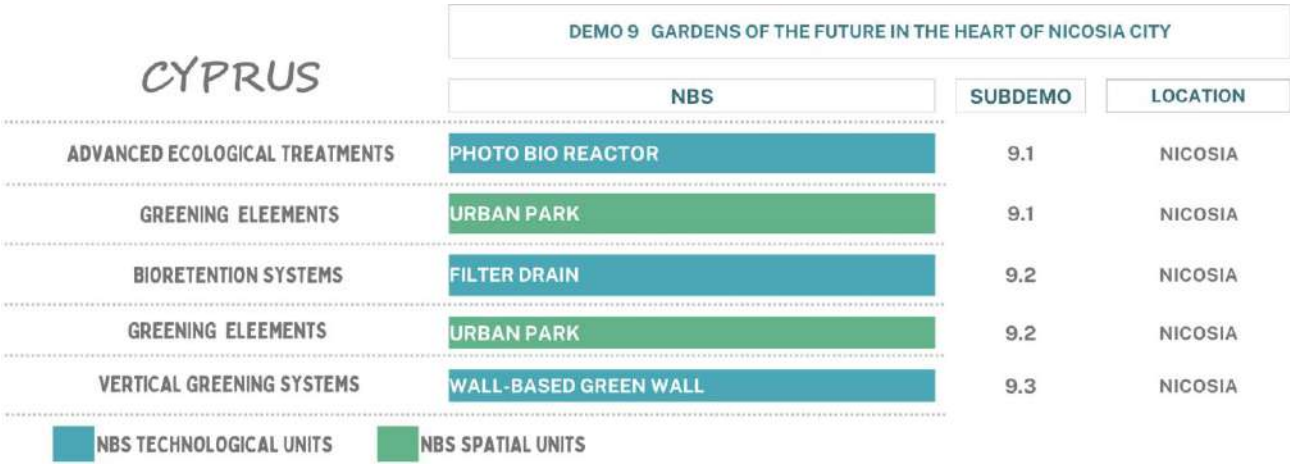
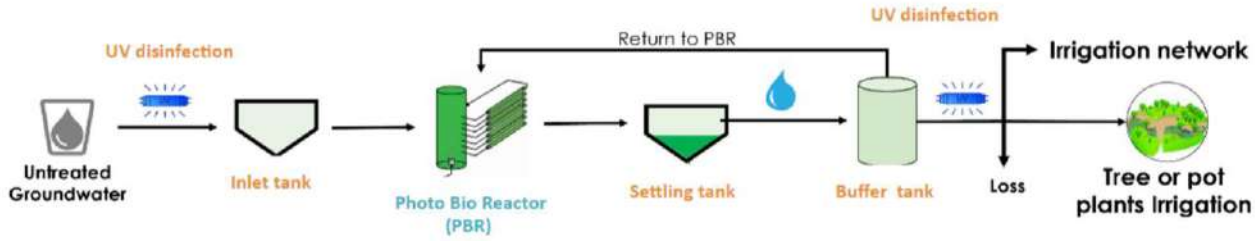


Figure 14. DEMO9 overview of the 3 sub-DEMOs and respective NBS.

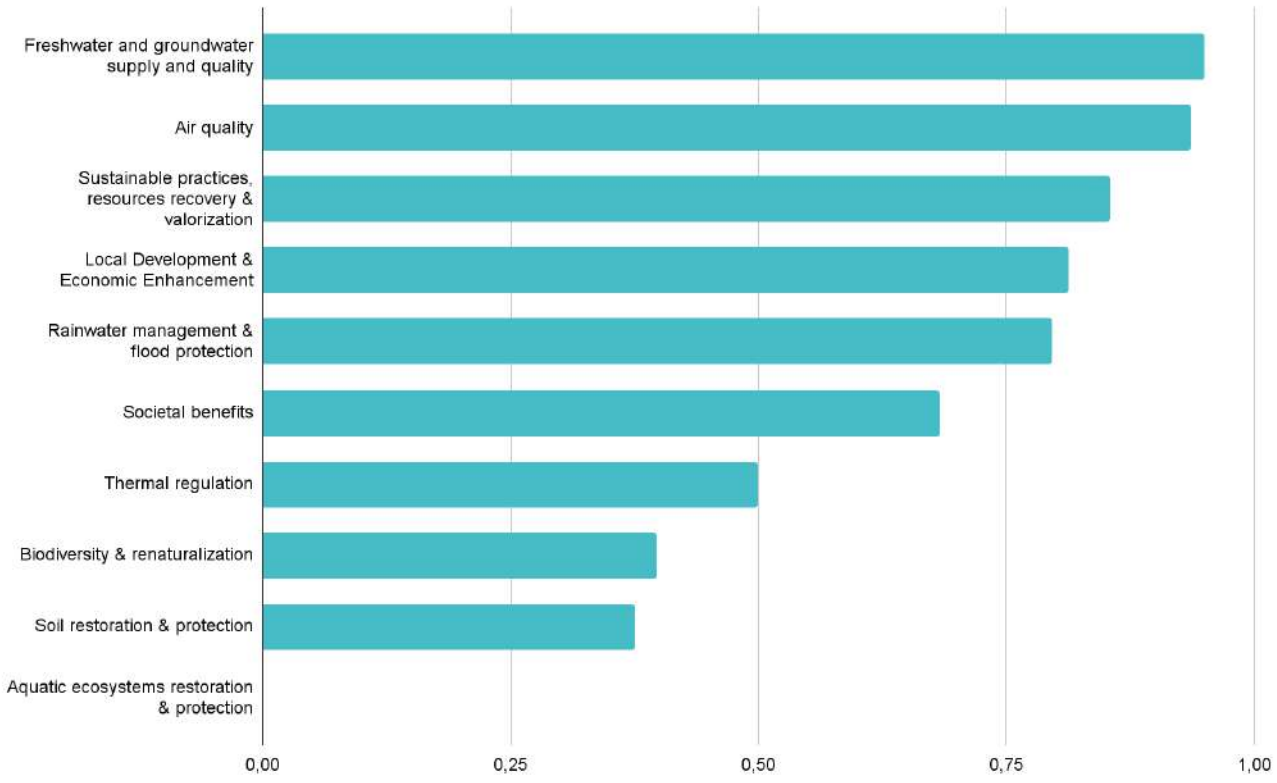
CARDIMED Sub-DEMO9.1 - Improvement of groundwater quality using microalgae

Description: A large-scale **Photo bio reactor** will be developed and installed in an **urban park** (Makrigiannis Park). This system will focus on removing salinity and hardness from the groundwater for further irrigation for green areas of the Park. **Location:** Nicosia, Cyprus. **TRL:** 2. **SRL:** *not available.* **Sub-DEMO area (m²):** 2400 **Scale**: Urban (Public land). **Stakeholders**: Municipality departments, Municipality (Nicosia), Private foundations (EBOS), University (National Technical University of Athens - NTUA), Private foundations (HYDRASPIS, IRIDRA and GOTF). **CAPEX** and **OPEX**: *not available.*



NBS_{tu}: Photo bio reactor (*not available.* m^2, TRL 2), NB_{Su}: Urban park (*not available* m2, TRL *not applicable*). **Supportive units:** UV disinfection, inlet/settling/ buffer tanks**. Water source(s):** Groundwater. **Water applications:** irrigation of green area**s. By-product(s): the** feasibility of using microalgae Biomass as Biofertilizer will be assessed. **Smart tech:** Sensors of water quality (T, pH, conductivity, chlorophyll, DO, etc.), light radiation, water flow/level sensors. **Supportive actions:** Community engagement and educational visits - tech tours, research and innovation initiatives, capacity building and training for local stakeholders, collaboration with indigenous and local communities.

MAIN CHALLENGES TARGETED



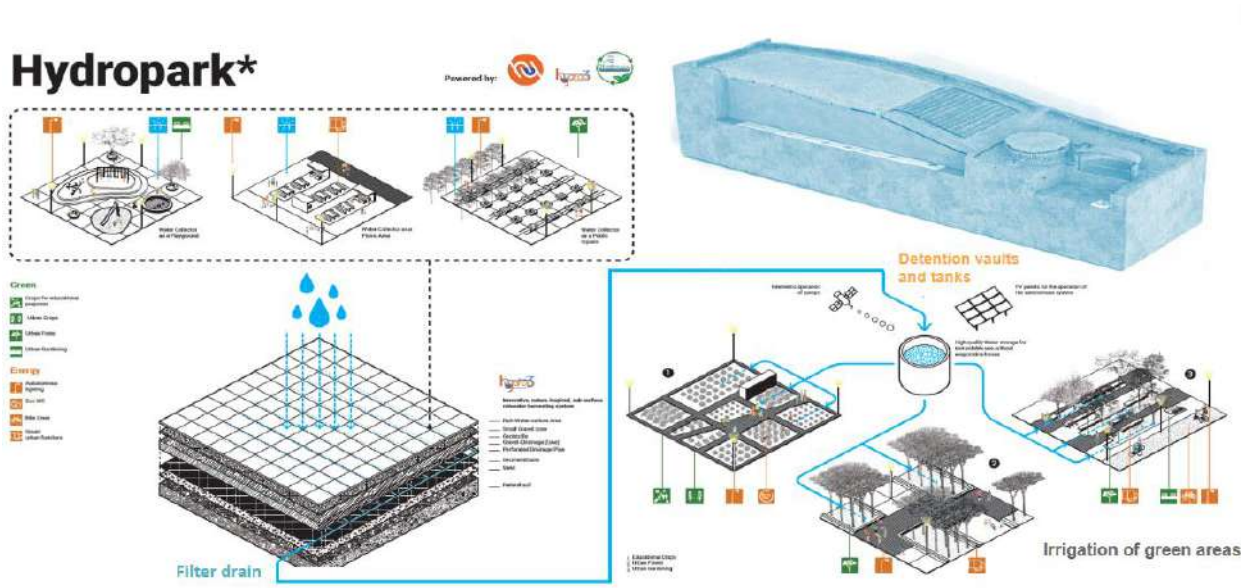
POTENTIAL CONTRIBUTION SDGs

Regulation and Maintenance Services	Improve quality of groundwater, Efficient water treatment, Reduce water withdrawals, Reduce sediment flow into drainage systems, Reduce urban runoff, Stormwater source control, Permeability restoration, Restore degraded areas, Create or restore fauna and flora, Support pollination, Forest creation and/or restoration, Connect green spaces, Support free movement of species, Refuge for farm and wild animals, Restore natural forest fire regime, Stabilize soil / substrate, Enhance and stabilize water retention, Improve carbon sequestration, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling, Reduce risk of pest and diseases
Cultural Services	Health and Well-Being improvement, increase recreational and socialisation value Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Facilitate education, Support environmental awareness, Enhance acoustic comfort, Promote mental health, Reconnect people with nature
Provisioning Services	Preserve groundwater supply, Water reuse, Provide nutrition sources for birds and insects, Production of biomass, Provide raw material, Nutrient recovery.
Other Services	Reduced carbon footprint, Contribute to local employment, Increase land/property monetary value, Reduced costs in comparison with other solutions
Limiting factors	Success depends on local, environmental and climate conditions; It requires additional energy consumption for operation and maintenance; Biomass harvesting is an essential requirement; Seasonal and climate fluctuations can significantly affect the proper functioning of systems in terms of resilience and treatment efficacy; It requires meticulous design considerations and expert input.

CARDIMED	**Sub-DEMO9.2 - The Rainwater Harvesting when Nature Inspires: An innovative filter drain for rainwater harvesting in the urban environment**

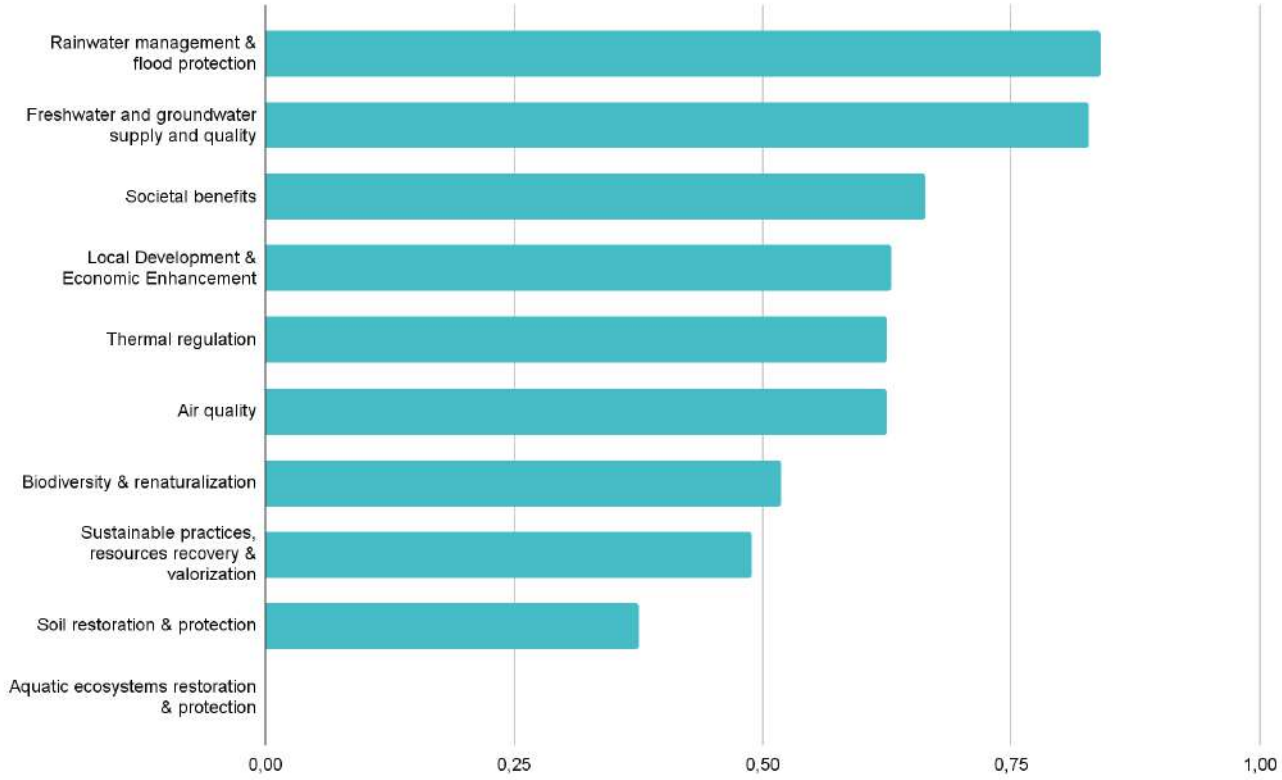
Description: An innovative filter drain promotes subsurface rainwater harvesting to address water scarcity and inefficient irrigation practices. This NBS enhances harmony in the urban landscape as it is situated in a hydro-pocket **urban park** in the heart of Nicosia, Cyprus. Through innovative techniques, the rainwater drops are captured directly, headed by draining and then transferred through a hydraulic pipeline network into the supportive storage unit(s) This solution ensures immediate relief from water scarcity while promoting long-term sustainability and resilience. This Nature Inspired Solution will be developed to face social challenges providing multiple benefits, based on multilateral and creative approach, to be simple, effective and efficient, with a robust design. This solution is characterised by low construction and operational cost, being highly sustainable and harmonised with the landscape architecture.**Location:** Nicosia, Cyprus. **TRL:** 6. **SRL**: 6 **Sub-**

DEMO area (m²): 860 **Scale**: Urban (public land). **Stakeholders**: Private foundations (EBOS, GOTF, HYDRASPIS), Municipality (Nicosia). **CAPEX** and **OPEX:** *not available.*



NBS_{tu}: Filter drain (*not available* m²; TRL 6), NB_{Su}: Urban park (*not available* m2, TRL *not applicable*). **Supportive units:** Detention vault and tanks. **Water source(s):** Rainwater. **Water applications:** Irrigation of green areas and natural aquifer recharge . **By-product(s):** *not applicable.* **Smart tech:** weather station (air quality and T), sensors of water (storage capacity, pH, conductivity, T), sensors of soil moisture. **Supportive actions:** Community engagement and educational visits - tech tours, research and innovation initiatives, capacity building and training for local stakeholders, collaboration with indigenous and local communities.

MAIN CHALLENGES TARGETED



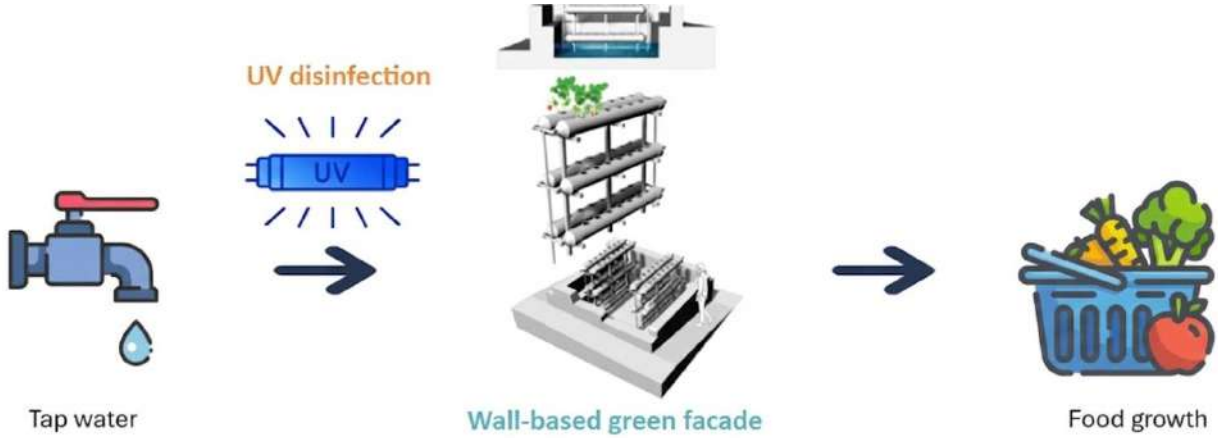
POTENTIAL CONTRIBUTION TO SDGS

Regulation and Maintenance Services	Reduce flood risk, Reduce sediment flow into drainage systems, Reduce water withdrawals, Improve quality of groundwater, Efficient water treatment, Reduce urban runoff, Stormwater source control, Permeability restoration, Restore degraded areas, Mitigate desertification, Create or restore flora, Support pollination, Connect green spaces Connect blue and green spaces, Develop resilience of green spaces, Coastal restoration & protection/ Promote resilience against natural disasters, Stabilize soil / substrate Enhance and stabilize water retention, Improve carbon sequestration, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling, Reduce water withdrawals, Efficient water treatment (rainwater)
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces Facilitate education, Support environmental awareness, Increase stakeholder engagement, Promote mental health, Reconnect people with nature
Provisioning Services	Water reuse preserve groundwater supply, Harvest, store and treat rainwater, preserve groundwater supply

Other Services	Reduced water footprint, Reduced carbon footprint, Increase land/property monetary value, Increase tourism, Reduced costs in comparison with other solutions
Limiting factors	Lack of supportive policies & conflicting legal frameworks.

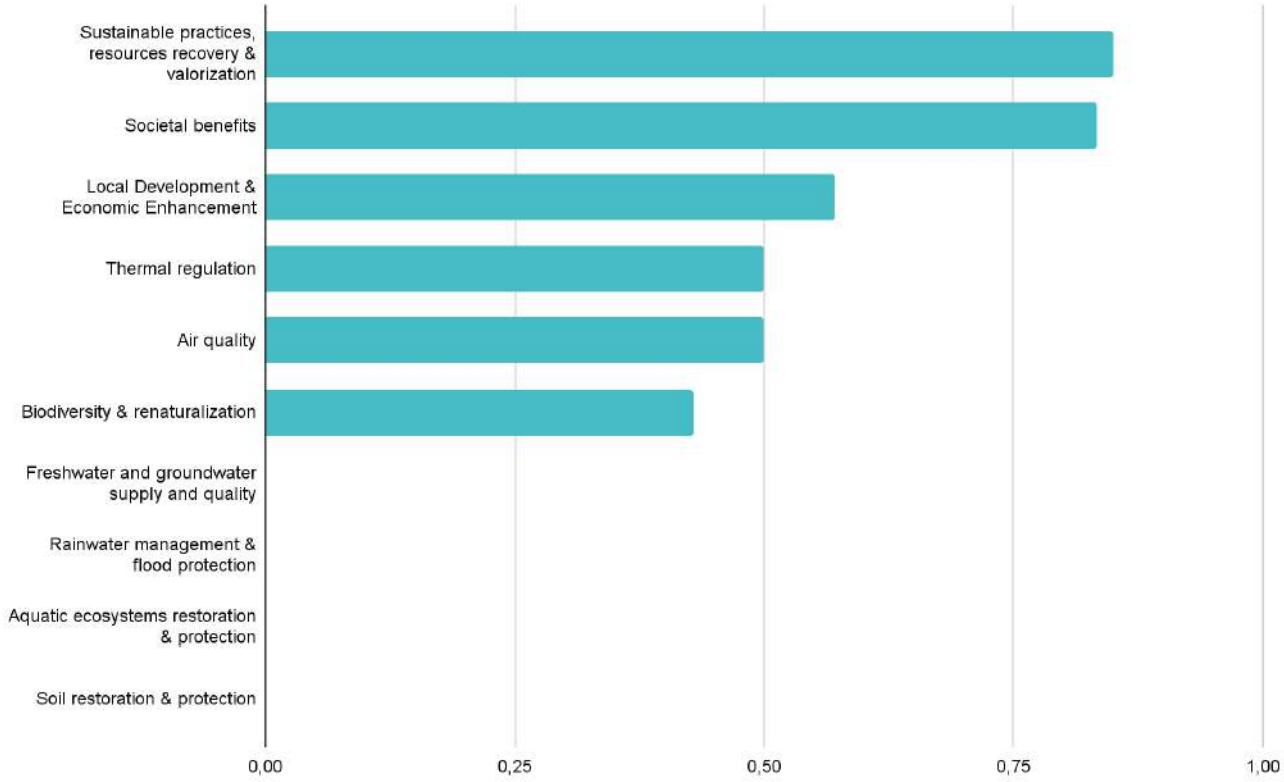
CARDIMED	Sub-DEMO9.3 - Nurturing Urban Nature: Enhancing Food Security with Wall-Based Green Facades

Description: A **Wall-based green facade** emerges as a solution to urban food insecurity, addressing the challenges of limited access to fresh produce and reliance on distant supply chains. By integrating NBS this innovative approach utilises vertical space to cultivate food within the city, reducing transportation emissions and promoting local food resilience. **Location:** Nicosia, Cyprus. **TRL:** 4. **SRL:** *not available.* **Sub-DEMO area (vertical surface cover in m^2):** 500. **Scale**: Urban (Private property that is publicly accessible). **Stakeholders**: Private foundations (GOTF, IRIDRA, EBOS), Municipality (Nicosia). **CAPEX** and **OPEX:** *not available.*



NBS_{tu}: Wall-based green facade (500 m^2; TRL 4). **Supportive units:** UV disinfection. **Water source(s):** Tapwater (the possibility of using greywater is under evaluation). **Water applications:** hydroponic food production. **By-product(s):** *not applicable.* **Smart tech:** Temperature sensors with internal data logger. **Supportive actions:** Community engagement and educational visits - tech tours, research and innovation initiatives, capacity building and training for local stakeholders, collaboration with indigenous and local communities.

MAIN CHALLENGES TARGETED



POTENTIAL CONTRIBUTION TO SDGs	
	
Regulation and Maintenance Services	*Not applicable*
Cultural Services	Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Facilitate education, Reduce undesired behaviours, activities and vandalism, Support social cohesion and justice, Support environmental awareness, Increase stakeholder engagement, Promote mental health, Reconnect people with nature
Provisioning Services	Production of biomass, Nutrient recovery, Material reuse, Sustainable food production
Other Services	Increase land/property monetary value, Favour green economy (reuse of local by-products)
Limiting factors	Potential for high costs related to operation, maintenance and the use of expensive media; Success depends on local, environmental and climate conditions; It requires

	additional energy consumption for operation and maintenance; Seasonal and climate fluctuations can significantly affect the proper functioning of systems in terms of resilience and treatment efficacy; It requires meticulous design considerations and expert input; Functional & performance uncertainties.

4. Conclusions

The CARDIMED catalogue presents an **innovative classification system** that underscores the multifunctionality of NBS from a holistic perspective. Unlike traditional methods, this approach allows for flexibility, recognizing that various types of NBS can serve common applications. This adaptability enables tailored selection and implementation of NBS according to specific needs and contexts. Furthermore, the catalogue introduces the **concept of "NBS systems,**" integrating diverse NBS typologies alongside supportive units and actions to address challenges in a unified manner.

Moreover, the catalogue serves as a pivotal tool for fostering a shared understanding of NBS and addressing multifaceted climate resilience challenges. Through standardised data collection and analysis, it provides valuable insights into the potential and performance of NBS within the Mediterranean context, effectively consolidating expert perspectives and existing knowledge. Additionally, it evaluates diverse NBS systems across various climate and social contexts, offering valuable insights into their impact and performance.

This consolidation serves as a foundational resource, offering a panoramic view of ongoing endeavours within the project. This comprehensive overview not only aids in understanding the current landscape but also paves the way for fostering collaborative efforts across various work packages. Furthermore, the catalogue not only facilitates knowledge transfer and sharing within the project but also functions as a resource within the project consortium and extends its reach to a broader audience. By facilitating knowledge transfer and sharing, it disseminates best practices, lessons learned, and innovative approaches to address climate resilience challenges through NBS. Moreover, the catalogue will serve as the basis for the development of diverse communication and dissemination materials, where updated information regarding the monitoring of site effectiveness in addressing predetermined challenges will be added. Ultimately, the CARDIMED catalogue transcends its role as a repository of information, emerging as a catalyst for collaboration, innovation, and knowledge sharing across wider networks.

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