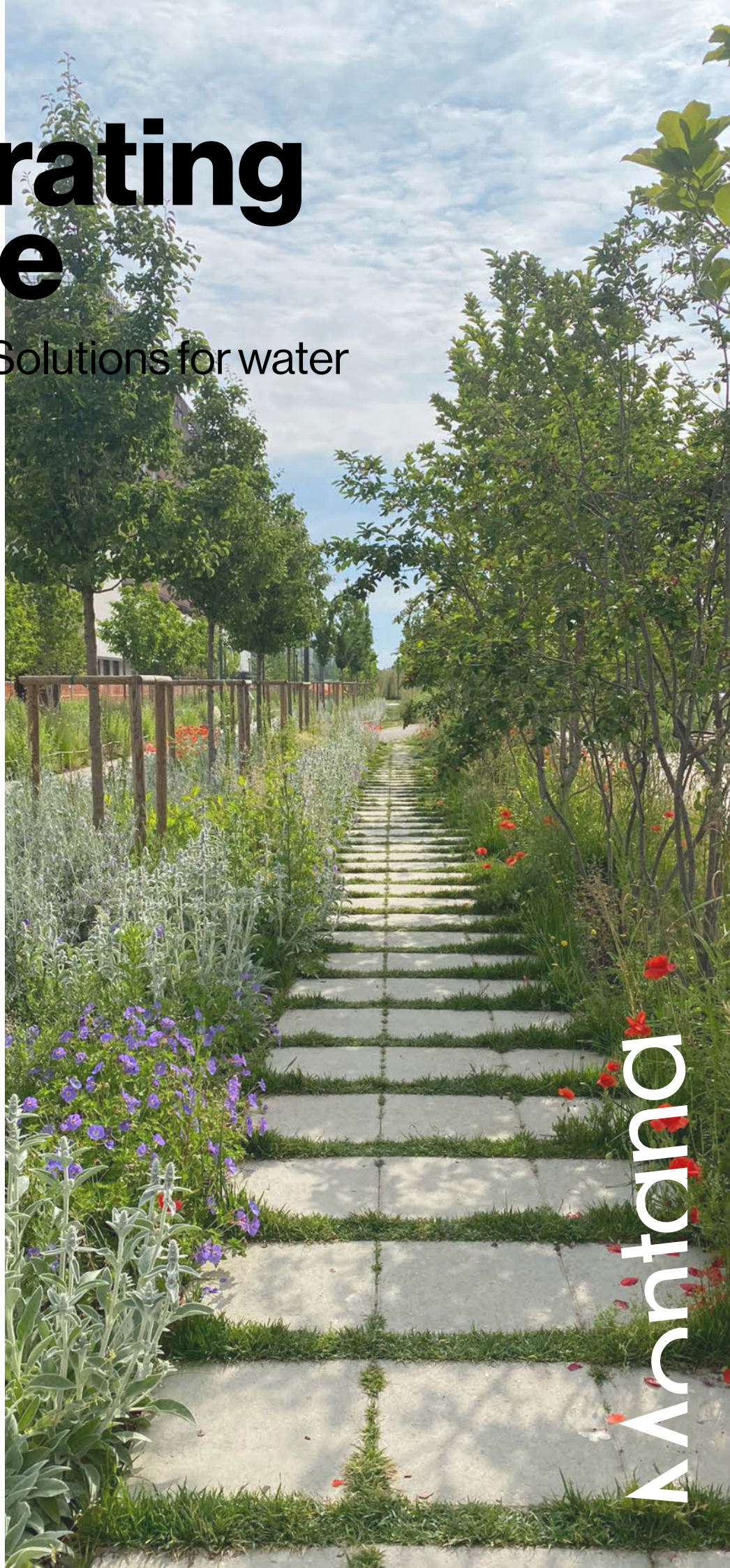


Integrating nature

Nature-based Solutions for water positive design



Antony

Integrating nature

Nature-based Solutions for water positive design

Elena Lauro
Fabio Lassini
Linda Chimento
Lorenzo Bucciarelli
Mariana Marchioni

Integrating Nature

Nature based Solutions for water positive design

by Elena Lauro, Fabio Lassini, Linda Chimento, Lorenzo Bucciarelli, Mariana Marchioni

First edition: May 2026

Copyright© 2026 Montana S.p.A. - Milano

All rights reserved.

No part of this book may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher, except in the case of brief quotations used for review or scholarly purposes.

Cover photograph by Montana S.p.A

Illustrations and graphics by Elena Lauro and Linda Chimento

Typesetting: Linda Chimento

Montana

Who we are

Founded in 1991, Montana is an environmental engineering and advisory company backed by a private equity fund, expanding through both organic growth and strategic acquisitions. Our mission is to create a positive impact on environment, society, and economy by addressing past environmental challenges and fostering a sustainable future. From concept to completion, we support our clients throughout the full project life cycle with integrated and coordinated services: with strong in-house expertise and a commitment to innovation and excellence, we develop tailor-made solutions that ensure consistency, efficiency, and quality, responding effectively to the technical, regulatory, and operational challenges of each project. Today, leveraging the synergy of over 150 highly qualified professionals, we offer specialized and integrated multidisciplinary services on national and international scale to both private and public sectors through our Business Units: Remediation and Landfills, Waste and Industry, Energy, Urban & Land Development, all working in close synergy and with a unified vision.

Where we are

Post Via Angelo Carlo Fumagalli, 6,
20143 Milano (Italia)

Telephone +39 02 54118173

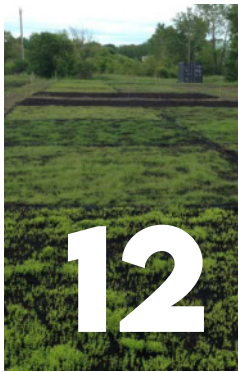
Website <https://montanambiente.com/en/>



CONTENTS

TABLE OF

What are the Nature-based Solutions	10
<i>NbS as an umbrella concept</i>	11
A vision towards NbS	12
IUCN Global Standard for NbS	14
<i>Eight criteria</i>	15
Sustainable Development Goals	16
Water-related green infrastructure	18
<i>What can a Nature Based Solution effectively deliver?</i>	19
How to read the catalogue	20
Building-scale interventions	22
<i>Blue roof</i>	24
<i>Green roof</i>	30
<i>Green wall</i>	40
<i>Rainwater harvesting</i>	46
Public and urban spaces interventions	54
<i>Bioretention area</i>	56
<i>Bioswale</i>	66
<i>Detention pond</i>	78
<i>Detention tank</i>	86
<i>Filter strip</i>	90
<i>Floodable park</i>	96
<i>Infiltration systems</i>	102
<i>Pervious paving</i>	112
<i>Rain garden</i>	120
<i>Trees</i>	128
<i>Tree filter box</i>	132
<i>Underground detention</i>	138
Interventions for natural areas and rural lands	142
<i>Phytodepuration</i>	144
<i>Phytoremediation</i>	150
<i>Pocket forest</i>	156
<i>Riparian buffer</i>	160
<i>Sand filter</i>	164
<i>Wet pond</i>	170
<i>Wetland</i>	176
Bibliography and sitography	184



What are the Nature-Based Solutions

NbS are cost-effective **strategies inspired by and supported by nature** that offer environmental, social, and economic benefits while enhancing resilience. These solutions integrate diverse natural features and processes into urban, rural, and marine environments through locally tailored, resource-efficient, and systemic interventions.

The primary goal of NbS is to **protect, sustainably manage and restore natural or modified ecosystems improving their overall health and functionality**. NbS have several key characteristics that address various environmental, social, and economic challenges.

NbS deliver ecosystem services that

contribute to a water management positive outcome. These solutions use or mimic natural processes to enhance water availability, improve water quality and reduce risks associated with water-related disasters and climate change.

Green infrastructure translates the NbS concept on water management design, enhancing urban environments by incorporating green spaces, green roofs, permeable pavements, and constructed wetlands. These measures help mitigate urban heat islands, manage stormwater, and provide recreational areas for communities. Additionally, effective water management strategies are a crucial component of NbS.

↓
Nature-based Solutions to address global societal challenges
Pic source: IUCN, Nature-based Solutions to address global societal challenges, 2016.



Climate change mitigation and adaptation Disaster risk reduction Economic and social development Human health Food security Water security Environmental degradation and biodiversity loss

NbS as an umbrella concept

When framing NbS and their uses, it helps to view them as an umbrella concept encompassing a variety of ecosystem-focused approaches designed to address societal challenges. These approaches fall into five main categories.

↓
Categories and examples of NbS approaches
Pic source: IUCN, Nature-based Solutions to address global societal challenges, 2016.
↓ 2
NbS as an umbrella term for ecosystem-related approaches
Pic source: IUCN, Nature-based Solutions to address global societal challenges, 2016.

Category of NbS approaches	Examples
Ecosystem restoration approaches	Ecological restoration Ecological engineering Forest landscape restoration
Issue-specific ecosystem-related approaches	Ecological-based adaptation Ecological-based mitigation Climate adaptation services Ecosystem-based disaster risk reduction
Infrastructure-related approaches	Natural infrastructure Green infrastructure
Ecosystem-based management approaches	Integrated coastal zone management Integrated water resource management
Ecosystem protection approaches	Area-based conservation approaches including protected area management



A Vision Towards NbS

Montana has a long and trusted history of contributing to sustainable development, working to align societal and economic progress with a deep sense of responsibility toward the environment.

This trajectory has always been grounded in a simple but demanding idea: that **infrastructure and territory must evolve together**, in balance, rather than in opposition.

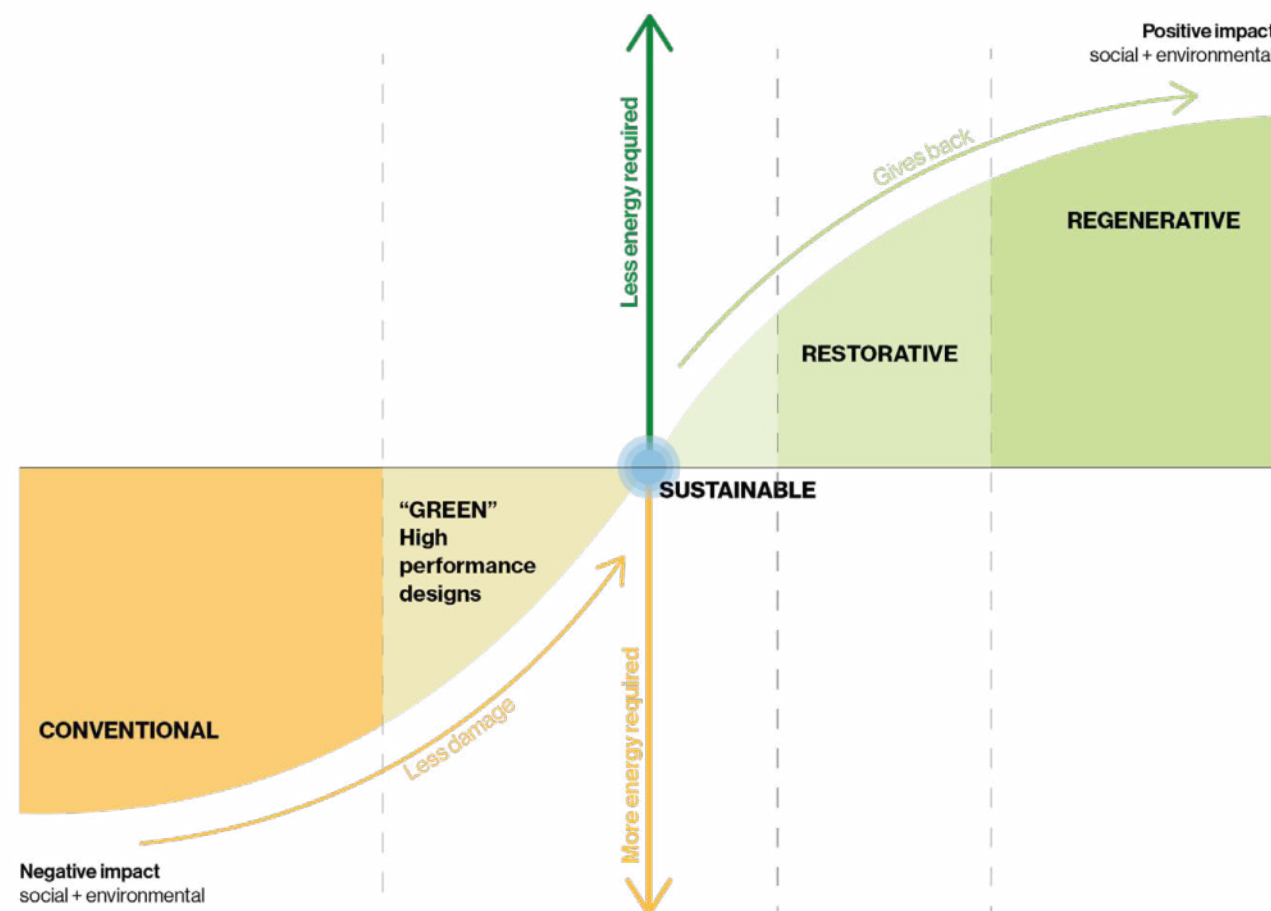
Within this perspective, the transition toward NbS is not a rupture, but a natural continuation of this path. It reflects a way of designing infrastructure that takes inspiration from the logic of natural systems, seeking not to control them, but to work with them, while ensuring the long-term health and functionality of ecosystems.

In this sense, NbS become a **concrete contribution to the achievement of the Sustainable Development Goals**, translating global ambitions into

spatial and operational design choices. NbS are understood here not as isolated technical elements or decorative green features, but as living landscape infrastructures. They interact with natural processes and actively participate in them. Through this interaction, they **restore ecological functions and deliver a broad spectrum of ecosystem services**. These include water regulation, climate regulation, soil processes, biodiversity support, and cultural and recreational benefits. At the same time, they contribute to human well-being by improving microclimatic comfort, enhancing the quality and inclusiveness of public spaces, and re-establishing a more direct relationship between

↓
Paradigm shift from conventional design to regenerative design approach. [1]

Source: Inspired from the work of Bill Read and Craft et al.



people and the landscapes they inhabit.

A key dimension of this approach is its inherently **multidisciplinary nature**. NbS emerge from the convergence of different fields of expertise, engineering, agronomy, biology, and landscape design, each bringing essential knowledge. Their value, however, lies not in their coexistence, but in their integration.

Landscape thinking acts as the connective framework that weaves these disciplines together into a coherent design language, where ecological processes, hydraulic dynamics, and spatial structures are considered as parts of a single system. In this context, **landscape engineering becomes a central tool for translation**: it transforms a diverse set of techniques and knowledge into functional, implementable, and measurable solutions. The role of design thus evolves from a primarily formal or mitigating function to an active role in shaping regenerative systems.

This vision is already being applied in a series of ongoing projects, particularly in water management, where a green infrastructure approach is being developed and tested. These projects represent an important step in building an internal company framework: a

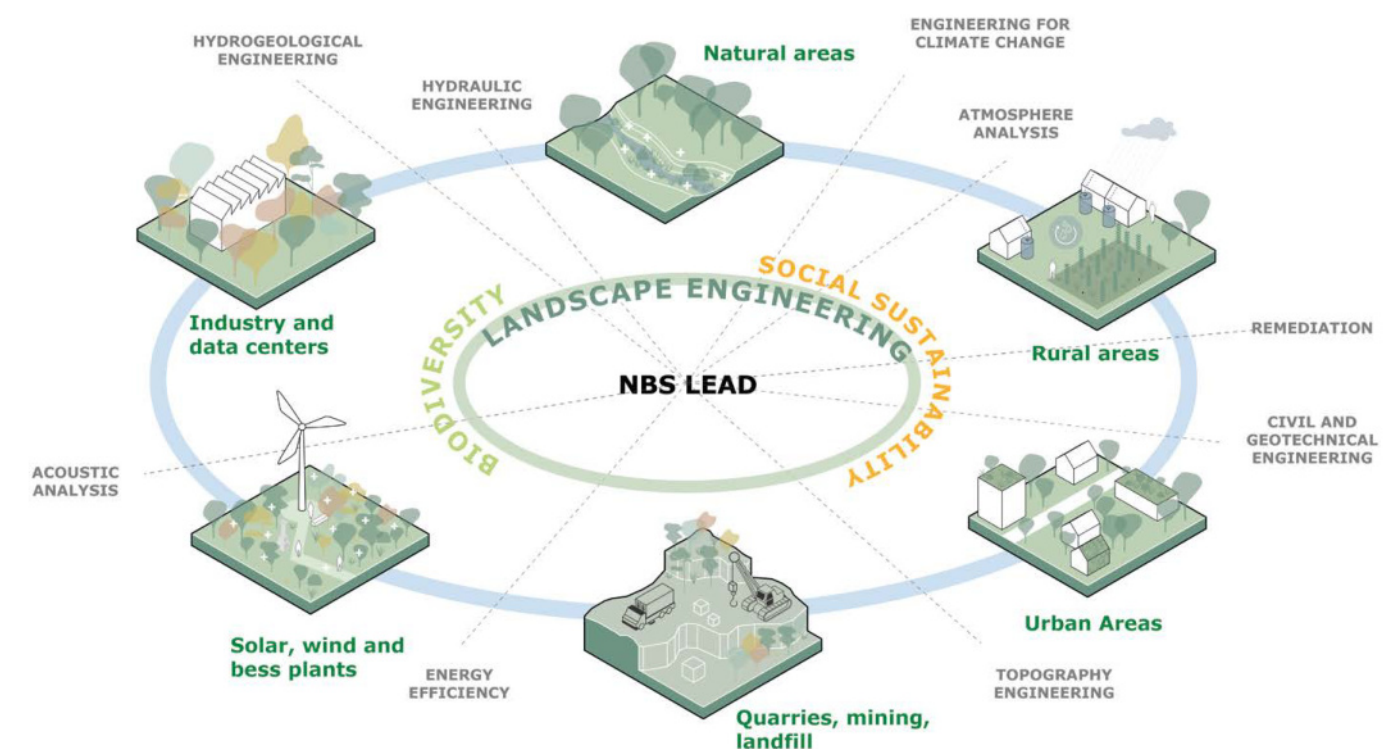
set of tools and methods capable of evaluating interventions according to NbS principles, with a clear focus on ecosystem service delivery and performance-based assessment.

Ultimately, the landscape is understood as a living system, one that absorbs, filters, cools, shelters, connects, and evolves over time. From this perspective, NbS offer a way to move beyond the idea of "doing less harm" and toward an approach that actively restores and strengthens natural systems. By integrating ecological, hydraulic, climatic, and social dimensions, they help shape environments that are more resilient, more adaptive, and capable of generating lasting value for both nature and society.

By integrating technological innovation with nature-based and landscape-led strategies, Montana directs its evolution towards the vision represented in the diagram below [1]: a **progressive transition from reducing negative impacts to generating positive environmental and social value**.

↓
NbS-led landscape engineering framework across different territorial contexts and technical disciplines.

Diagram: Montana Sp.A



Need for a Global Standard

IUCN Global Standard for NbS

Nature-based Solutions (NbS) are a powerful way to **address societal challenges**, such as climate change, biodiversity loss, and food security.

As the world works toward achieving the *UN Sustainable Development Goals*, it is essential that **investments in nature enhance both human well-being and the health of the planet**.

The **IUCN Global Standard for Nature-based Solutions** provides guidance for designing and implementing NbS so that ecosystems can effectively deliver their services. Developed through a public consultation involving more than 800 practitioners and experts from over 100 countries, the Global Standard **is a robust framework** designed to increase the quality, impact, and scale of NbS.

The Global Standard is a **multi-dimensional and versatile tool** for users at the local, national and global level. It also sets clear benchmarks to track and evaluate the performance of these solutions.

The Global Standard for NbS is a facilitative Standard that is aimed at enabling wider uptake, and improving design and execution, rather than regulating processes to achieve specific results or outcomes. The Standard will enable practitioners to standardise the design and implementation of NbS, by:

1. Setting a common basis of understanding for what an NbS is and is not;
2. Contributing to transformational changes, by improving NbS practice;
3. Supporting the clarification and development of NbS-related policy.

Standardise the design and implementation

Eight Criteria

The framework is built around 8 criteria and 28 indicators, each supported by guiding questions that help users assess and refine their initiatives.

Criterion 1

This criterion ensures that the Nature-based Solution is clearly designed to respond to specific societal challenges, such as climate change, disaster risk, or food and water security. Stakeholders and rights-holders work together to identify and agree on the key problems they face. By clarifying these needs from the start, the solution can be better targeted and more meaningful for the people it aims to support.

Criterion 2

Criterion 2 focuses on understanding the wider social, economic and ecological context in which the solution takes place. Even if actions are implemented at a local site, they are influenced by larger-scale dynamics such as regional policies, markets, or ecosystem processes. Taking these broader factors into account helps ensure that the solution is robust, realistic, and sustainable over the long term.

Criteria 3, 4 and 5

outline processes that can enhance the chances of positive outcomes for biodiversity, society and the economy. However, in order to achieve these three Criteria with respect to both immediate, short-term and long-term outcomes, trade-offs

need to be determined and made, which are directly addressed in Criterion 6, in order to give this issue visibility and importance.

Criterion 6

Criterion 6 addresses the fact that NbS may involve trade-offs between different benefits, stakeholders, or timeframes. These trade-offs must be openly identified, discussed, and managed in a transparent and fair way. Decision-making processes should be inclusive and equitable, so that the costs and benefits are not unfairly distributed and the rights of vulnerable groups are respected.

↓
The eight Criteria that make up the IUCN Global Standard for NbS are all interconnected

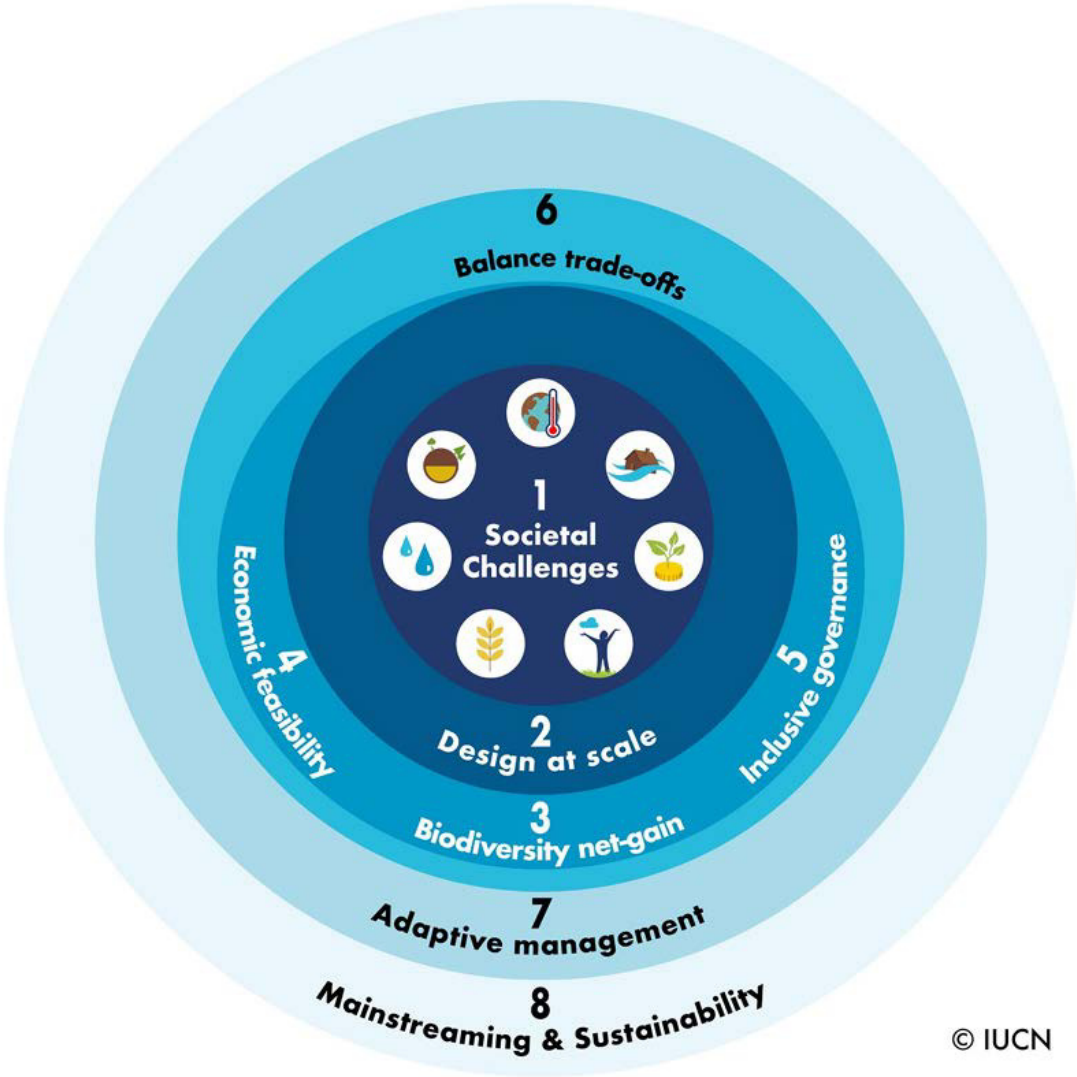
Pic source: IUCN Global Standard for Nature-based Solutions: first edition

Criterion 7

This criterion supports an adaptive approach, where the NbS is regularly monitored, evaluated, and adjusted as conditions change or new information becomes available. A clear theory of change helps to link activities to expected results and guides learning. By embracing experimentation and iterative learning, practitioners can improve the effectiveness and resilience of the solution over time.

Criterion 8

focuses on processes for mainstreaming NbS in spatial and temporal scales, whereby actions and impacts may be sustained beyond stand-alone projects, in order to fully realise the potential of nature as a tool providing a solution to societal challenges



Sustainable Development Goals

The Sustainable Development Goals are a call for action by all countries – poor, rich and middle-income – to promote prosperity while protecting the planet. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection.



1 NO POVERTY
Eradicate extreme poverty for all people everywhere, currently measured as living on less than \$1.90 a day. Implement social protection systems, ensure equal rights to economic resources, and build the resilience of the poor and those in vulnerable situations.



5 GENDER EQUALITY
Achieve gender equality and empower all women and girls. End all forms of discrimination and violence against women and girls, ensure full participation in leadership and decision-making, and provide equal opportunities in education, employment, and economic resources.



2 ZERO HUNGER
End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. Ensure access to safe, nutritious, and sufficient food for all people, especially the poor and vulnerable, and improve agricultural productivity and sustainability.



6 CLEAN WATER AND SANITATION
Ensure availability and sustainable management of water and sanitation for all. Achieve universal access to safe and affordable drinking water, adequate sanitation, and hygiene for all, and improve water quality by reducing pollution and minimizing release of hazardous chemicals.



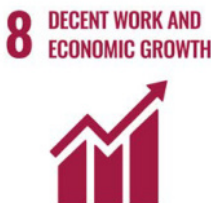
3 GOOD HEALTH AND WELL-BEING
Ensure healthy lives and promote well-being for all at all ages. Reduce maternal mortality, end preventable deaths of newborns and children under five, combat epidemics, reduce non-communicable diseases, and ensure universal access to health care services and medicines.



7 AFFORDABLE AND CLEAN ENERGY
Ensure access to affordable, reliable, sustainable, and modern energy for all. Increase the share of renewable energy in the global energy mix, improve energy efficiency, and enhance international cooperation to facilitate access to clean energy research and technology.



4 QUALITY EDUCATION
Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Ensure all children complete free, equitable, and quality primary and secondary education, and have access to affordable and quality technical, vocational, and tertiary education.



8 DECENT WORK AND ECONOMIC GROWTH
Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. Achieve higher levels of economic productivity, promote policies that support job creation and entrepreneurship, and protect labor rights.



9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. Develop quality, reliable, sustainable, and resilient infrastructure, support economic development, and promote innovation and technological advancements.



10 REDUCED INEQUALITIES
Reduce inequality within and among countries. Empower and promote the social, economic, and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion, or economic or other status, and ensure equal opportunity and reduce inequalities of outcome.



11 SUSTAINABLE CITIES AND COMMUNITIES
Make cities and human settlements inclusive, safe, resilient, and sustainable. Ensure access to adequate, safe, and affordable housing and basic services, provide access to safe, affordable, accessible, and sustainable transport systems, and enhance inclusive and sustainable urbanization.



12 RESPONSIBLE CONSUMPTION AND PRODUCTION
Ensure sustainable consumption and production patterns. Promote resource and energy efficiency, sustainable infrastructure, and provide access to basic services, green and decent jobs, and a better quality of life for all.



13 CLIMATE ACTION
Take urgent action to combat climate change and its impacts. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters, integrate climate change measures into policies and planning, and improve education, awareness, and human and institutional capacity on climate change mitigation and adaptation.



14 LIFE BELOW WATER
Conserve and sustainably use the oceans, seas, and marine resources for sustainable development. Prevent and significantly reduce marine pollution, sustainably manage and protect marine and coastal ecosystems, and regulate harvesting to restore fish stocks.



15 LIFE ON LAND
Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Take urgent action to end poaching and trafficking of protected species and integrate ecosystem and biodiversity values into national and local planning.



16 PEACE, JUSTICE AND STRONG INSTITUTIONS
Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels. Reduce all forms of violence, end abuse and exploitation, promote the rule of law, and ensure inclusive and participatory decision-making.



17 PARTNERSHIPS FOR THE GOALS
Strengthen the means of implementation and revitalize the global partnership for sustainable development. Enhance international support for implementing effective and targeted capacity-building, mobilize financial resources, and promote sustainable development partnerships among governments, the private sector, and civil society.



Water-related green infrastructure

Ecosystems perform many of the same roles as conventional “grey” infrastructure, including the collection, purification, storage and conveyance of water. In this sense, water-related ecosystem services can be understood as having an “infrastructure-like” function. Infrastructure is generally defined as the stock of facilities, services and installations required for the functioning of society; accordingly, built infrastructure has natural counterparts within watersheds that can complement, enhance or even replace conventional structures such as reservoirs, dams, levees and canals.

In the context of the EU Green Infrastructure Strategy, the European Commission defines green infrastructure as “a **strategically**

Functions

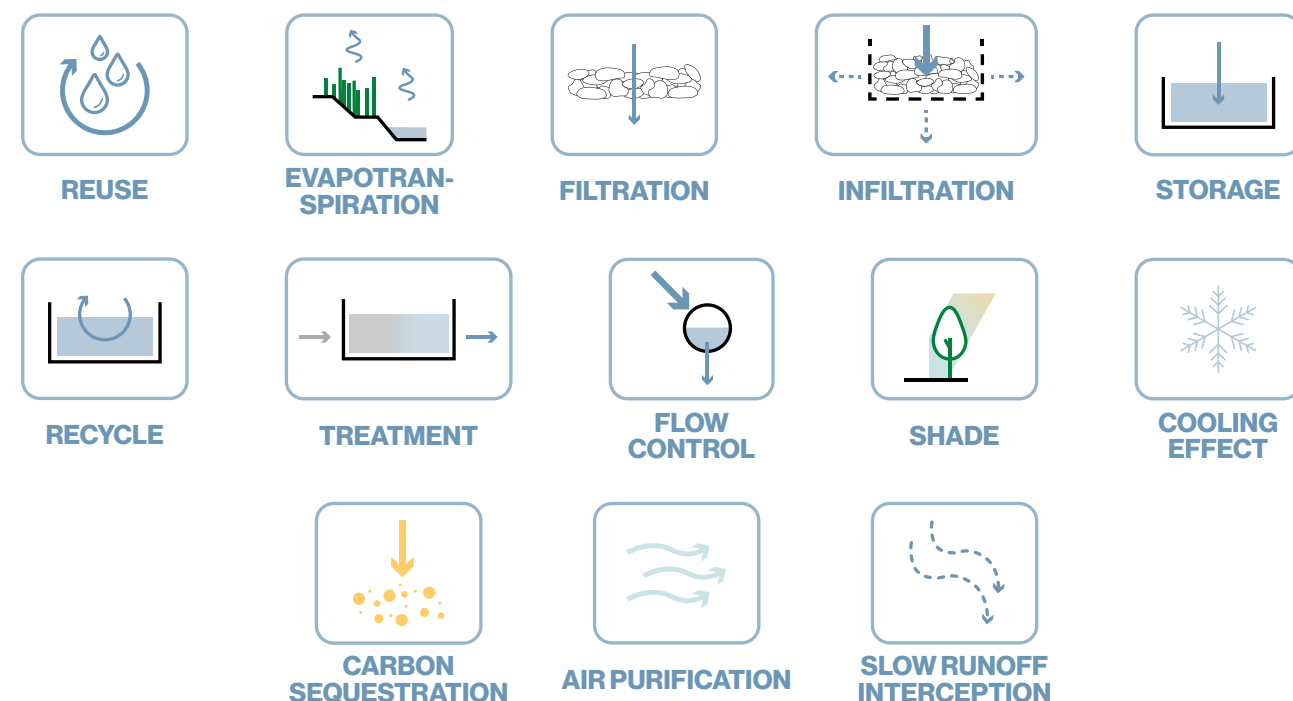
Nature-based solutions for water resources management involve the planned and deliberate use of ecosystems to improve water quantity and quality and to **increase resilience to climate change**. These NbS **not only address specific water management challenges but also provide co-benefits such as enhanced biodiversity and improved**

planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services” (European Commission, 2013).

A green infrastructure approach explicitly integrates conservation values and actions into land development, growth management and built infrastructure planning, thereby differing from traditional open-space planning approaches (Benedict & McMahon, 2002). Because of its broad scope, the concept of green infrastructure is used both as a theoretical framework and as a practical planning tool. In this document, we focus specifically on water-related green infrastructures and their role in providing water-related ecosystem services.

public health. By integrating natural processes into urban and rural water management, these solutions promote sustainable and resilient communities.

Water-related NbS and stormwater management NBS can be categorized in **different macro functions** indicating the main role they can deliver.



Benefits

NbS offer a multitude of benefits across various domains. Environmentally, NBS **enhance air and water quality, increase biodiversity, and contribute to both climate change mitigation and adaptation**.

For instance, urban green areas not only mitigate the urban heat island effect but also provide essential habitats for flora and fauna, thereby reducing habitat fragmentation in urban landscapes.

Socially, NbS significantly **promote human**

well-being by creating public spaces that encourage physical activity, relaxation, and interaction with nature—key components for maintaining mental and physical health. Additionally, these solutions foster social cohesion by facilitating interactions among diverse communities. They also generate local economic opportunities through sustainable tourism and urban agriculture, thus contributing to community development and resilience.

Natural Water Retention Measures benefits

What can a Nature Based Solution effectively deliver?

NWRM are **multi-functional measures** that aim to protect and manage water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes. Their main focus is to enhance, as well as preserve, the water retention capacity of aquifers, soil, and ecosystems with a view to improving their status.

NbS deliver powerful outcomes when they incorporate NWRMs, as these measures **enhance a landscape’s ability to store, slow, and filter water**.

By restoring wetlands, reconnecting floodplains, improving soil structure, or increasing vegetation cover, **NWRMs regulate hydrological processes** that reduce floods, mitigate droughts, and improve water quality. These nature-driven functions also support biodiversity, create habitats, and strengthen ecosystem resilience to climate change.

When framed as NbS, NWRMs additionally **provide social and economic benefits**, such as recreation, cooling, and reduced disaster costs, while contributing to policy goals for climate adaptation, water management, and ecological restoration.

Biophysical impacts

The means by which the measure alters the function or the structure of the ecosystem or the hydrological system

Restore or maintain Ecosystem Services

The benefits that derive from the changes to the function or structure of the ecosystem or hydrological system

Meet Policy objectives

How NBS contribute to meeting EU Policy Objectives

Water-related NbS and stormwater management NbS should be integrated into a systemic approach to managing runoff, reducing flood risk, and enhancing water absorption. These solutions exemplify the ability to deliver multiple co-benefits.

The informations in the paragraph *NWRM Benefits* are copyrighted © NWRM, 2013-2019.

How to read the catalogue

The categorisation of the proposed NbS is structured around their potential scale of application. This approach makes it possible to understand the different types of intervention as a modular, integrated system, in which each site-specific measure becomes part of a broader strategy and contributes to the development of a green-blue infrastructure capable of managing urban stormwater more effectively and sustainably.

01. Building-scale interventions

These solutions can be applied in residential, commercial and industrial contexts, and focus on stormwater management in order to reduce runoff to the sewer network detaching roof downspouts, encouraging harvest and reuse and infiltration infrastructures. These solutions provide multiple benefits; on improving microclimatic comfort and mitigating the urban heat island effect, supported by the presence of vegetation where included; on enhancing the building's energy performance through improved thermal insulation; and, ultimately, on the overall well-being perceived by its users. When implemented in combination or replicated across the urban fabric, their benefits are amplified, helping to make cities more resilient to the impacts of climate change.

02. Public and urban spaces interventions

These solutions, originally designed for public spaces, can also be adapted to private residential or industrial settings. Focusing on the runoff generated by infrastructure and impervious surfaces, they include punctual, combined and more complex interventions that help reduce the risk of pluvial flooding, improve microclimatic comfort and enhance local biodiversity.

03. Interventions for natural areas and rural lands

The solutions presented fall within a set of interventions that can be implemented at a broader territorial scale than the neighbourhood level, but can also be downscaled to smaller areas, particularly with regard to soil and water purification and remediation processes, delivering benefits that are proportional to the extent of the intervention.

Technical note

The technical information provided in this booklet is intended for general guidance only. Each NbS system can be applied at different scales of intervention, depending on the context, site conditions, project objectives, and level of design development. All solutions, dimensions, materials, and performance criteria must therefore be assessed on a case-by-case basis, according to the specific project requirements, applicable regulations, and local environmental conditions. The information presented herein shall not be considered as a definitive design instruction or as a substitute for project-specific technical assessment.



↗
Ricardo Lara linear park, California, USA
Pic source: Landscape Performance Series

→
Parc Clichy-Batignolles – Martin Luther King, Paris, France.
Pic source: AMC Archi

01. Building-scale interventions

- 24 Blue roof
- 30 Green roof
- 40 Green wall
- 46 Rainwater harvesting

→
Urban Farming Office Ho Chi Minh
City,
Pic source: Dezeen



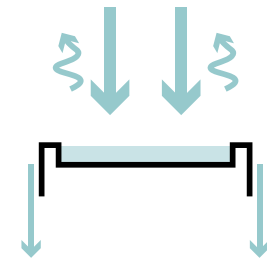
Building-scale interventions

Blue roof

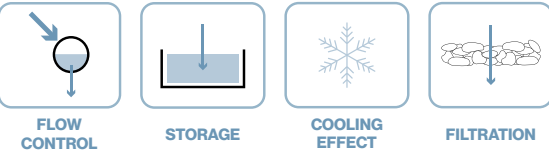
Blue roofs, also known as **controlled flow roof drain systems**, are **detention stormwater management practices** that provide temporary storage and slow release of rainwater on a rooftop.

Blue roof systems are an effective practice for **controlling runoff from buildings with flat or mildly sloped roof surfaces** in urban contexts where flooding is a risk due to a lack of permeable surfaces for water to infiltrate, or seep back into the ground.

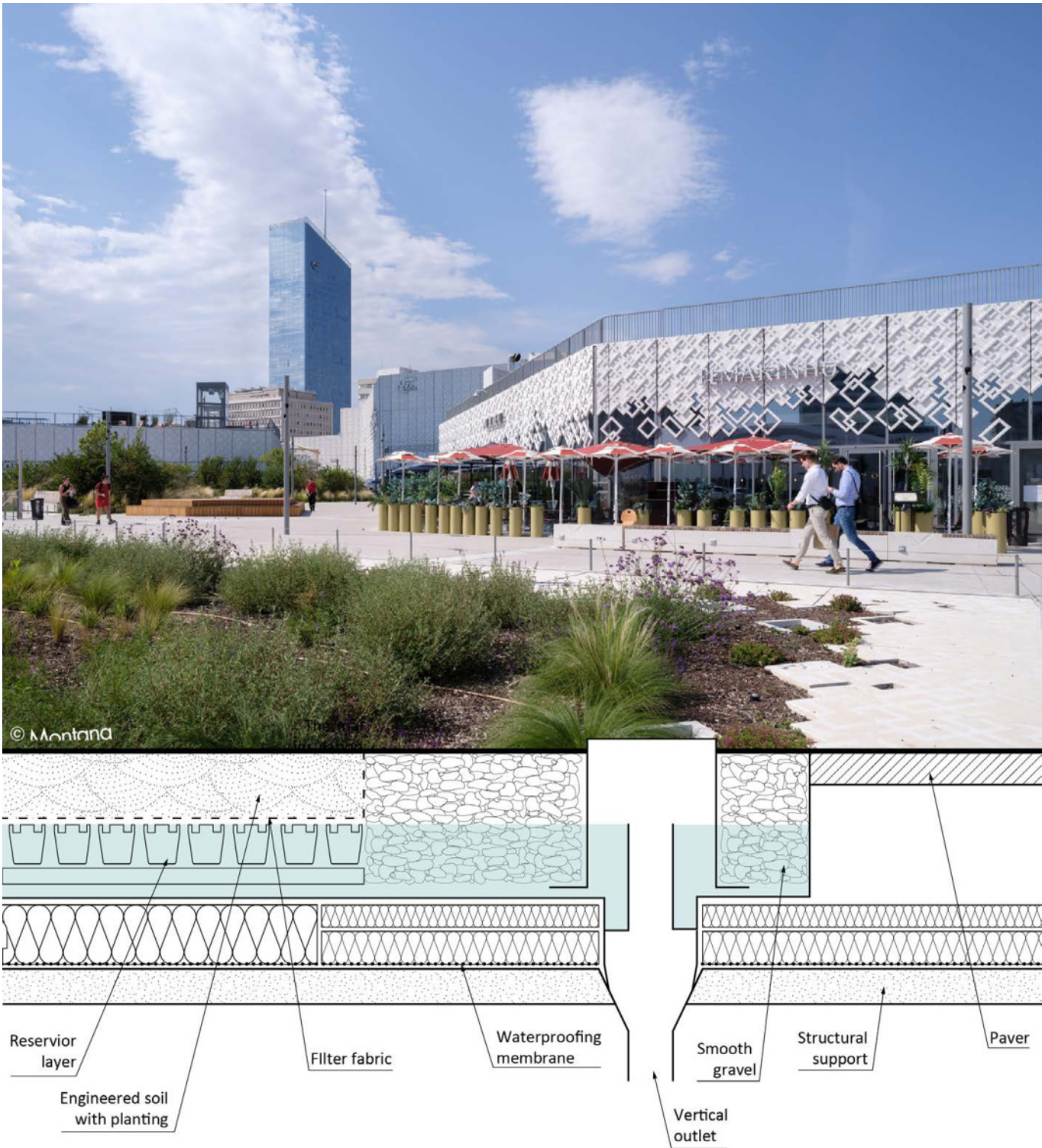
Water is stored in blue roof systems until it either evaporates or is released downstream after the storm event has passed. Blue roofs that are used for **temporary rooftop storage** can be classified as active or passive depending on the types of control devices used to regulate drainage of water from the roof.



FUNCTIONS



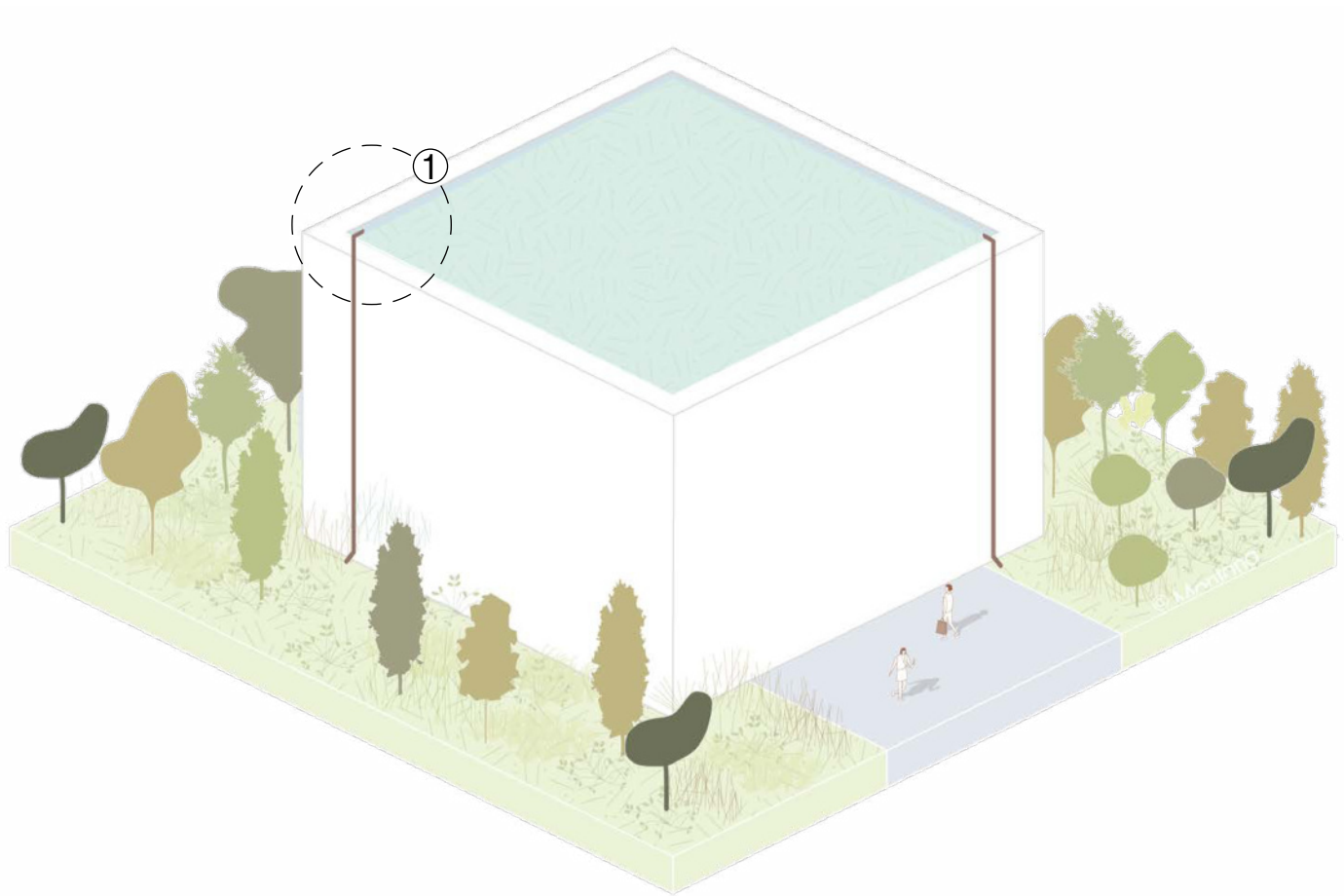
SDGS GOALS



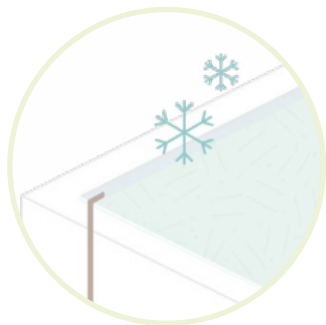
↑
Infographic: Montana S.p.A.
Pic source: Archello

Visualization

Visualization of blue roofs in an urban context

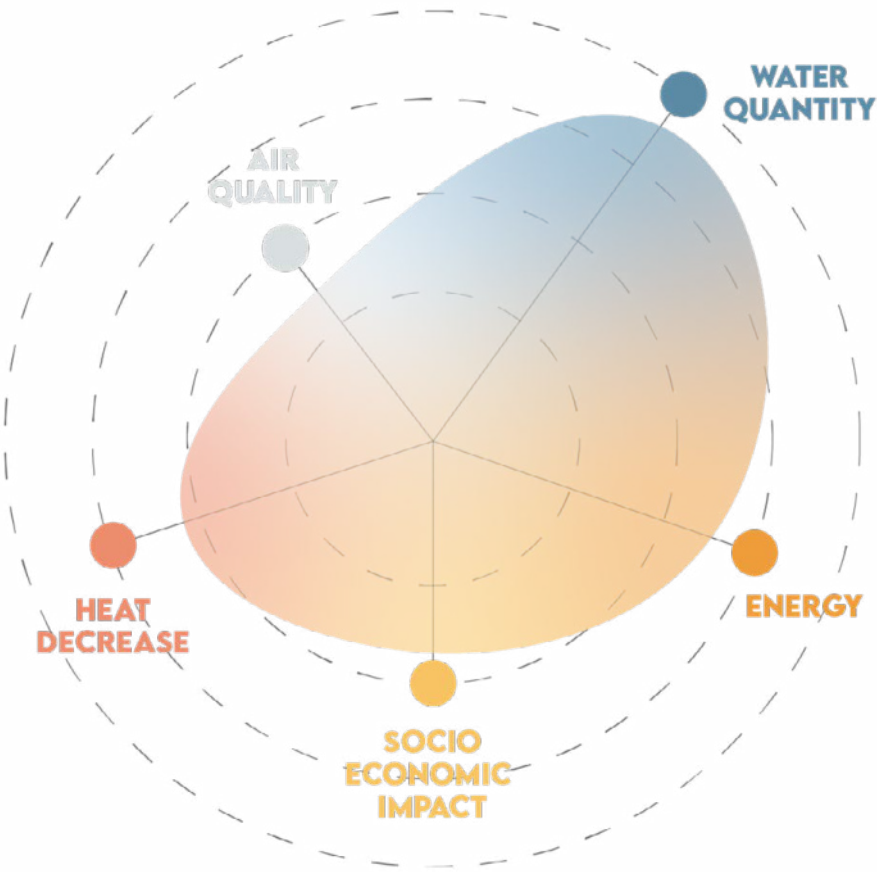


Details of increased benefits for the urban living environment



A blue roof captures and temporarily stores rainwater, reducing runoff and preventing flooding. This system also cools the surrounding environment via the evaporative cooling effect of water. Blue roofs contribute to more sustainable, energy-efficient buildings and urban areas.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quantity and runoff control

Blue roofs retain stormwater at roof level and release it gradually through controlled outlets, reducing runoff volumes and peak flows to the sewer system. In blue roof systems, the added storage layer further delays runoff generation and helps mitigate drainage overload during intense rainfall events. (Cristiano et al., 2023; Pelorosso et al., 2024; Shafique et al., 2025).

Energy management

The water storage layer and, in blue-green roofs, the vegetated substrate increase the thermal inertia of the roof, dampening temperature peaks and lowering summer cooling loads, with potential energy savings compared to conventional roofing solutions (Cristiano et al., 2022; Pelorosso et al., 2024).

Social interaction

As part of broader blue-green infrastructure, blue roofs enhance climate resilience by reducing pluvial flooding, property damage and service disruption, and over time they support safer,

more liveable and less energy-intensive cities, with widespread socio-economic benefits. (Boguniewicz-Zabłocka & Łukasiewicz, 2025; Ramakreshnan & Aghamohammadi, 2024.).

Heat decrease

Blue roofs contribute to mitigating the urban heat island effect through evaporative cooling of stored water and, in blue-green systems, through plant evapotranspiration, which reduces surface temperatures and improves local thermal comfort. (Cristiano et al., 2022; Ramakreshnan & Aghamohammadi, 2024).

Air quality

A blue roof without vegetation has limited direct effects on air quality, but it contributes indirectly by lowering building cooling demand and thus reducing emissions from energy production, with positive impacts on urban smog and exposure to air pollutants (Cristiano et al., 2022; Ramakreshnan & Aghamohammadi, 2024).

Key advantages of blue roofs

The main key advantages of a blue roof system in an urban context are different. For example, they can **manage stormwater runoff without occupying surface-level space** and are well-suited for sites at which roofs make up a large fraction of the total impervious area and for sites with ground-level space constraints. Blue roof typically doesn't require any additional sewer connections besides the ones already provided for the building and it's very easy to install if structural and waterproofing requirements are met.

Limitations of blue roofs

There are a lot of benefits provided by the blue roof systems but it's also important to highlight the limitation of this SuDs system. Regular inspection and maintenance of roof surface and roof drains is highly required, especially following high winds, as algae and debris can develop around roof drains and limit the rate of discharge. And it also require strict adherence to regularly scheduled inspections because the maintenance needs are not easily visible. Blue roof may have **limited storage capacity with slopes greater than 2%**. Blue roof system offers limited benefit on sites where roof area makes up only a small fraction of the total impervious area. They do not improve aesthetics or provide the ancillary environmental benefits associated with vegetated roofs, such as habitat creation and improved air quality.

Maintenance of blue roofs

Maintenance of blue roof systems focuses on the periodic removal of sediment and debris from outlet and storage areas in order to prevent clogging and limit deterioration of the roof membrane. Maintenance activities can generally be performed by individual building owners or site maintenance staff as needed. Blue roof components are relatively easy to maintain due to their simplicity and ease of access. In the both roof check dam and roof drain restrictor systems, maintenance activities are readily conducted at the roof surface. All restrictors and ponded areas must be accessible for periodic inspection and

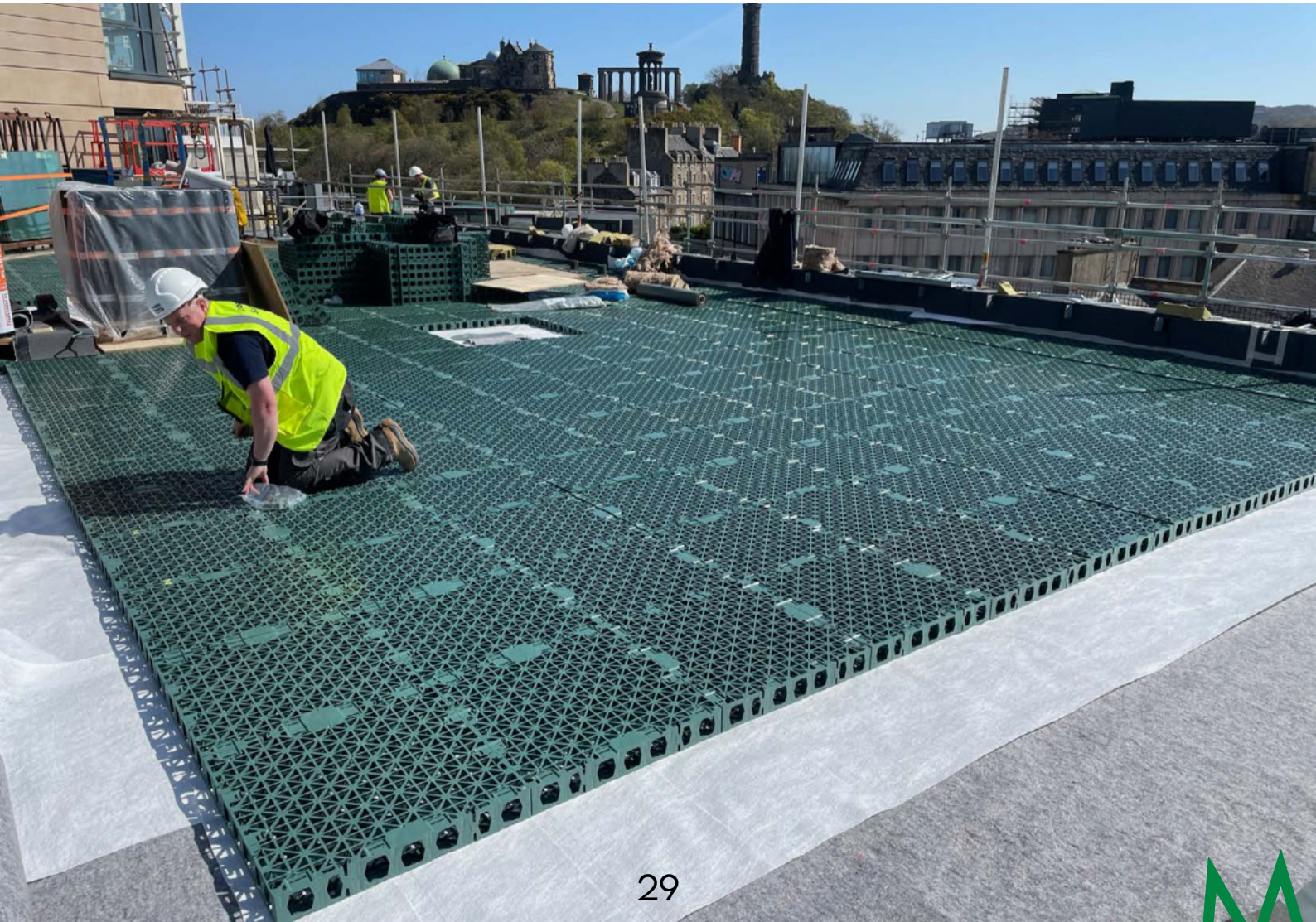
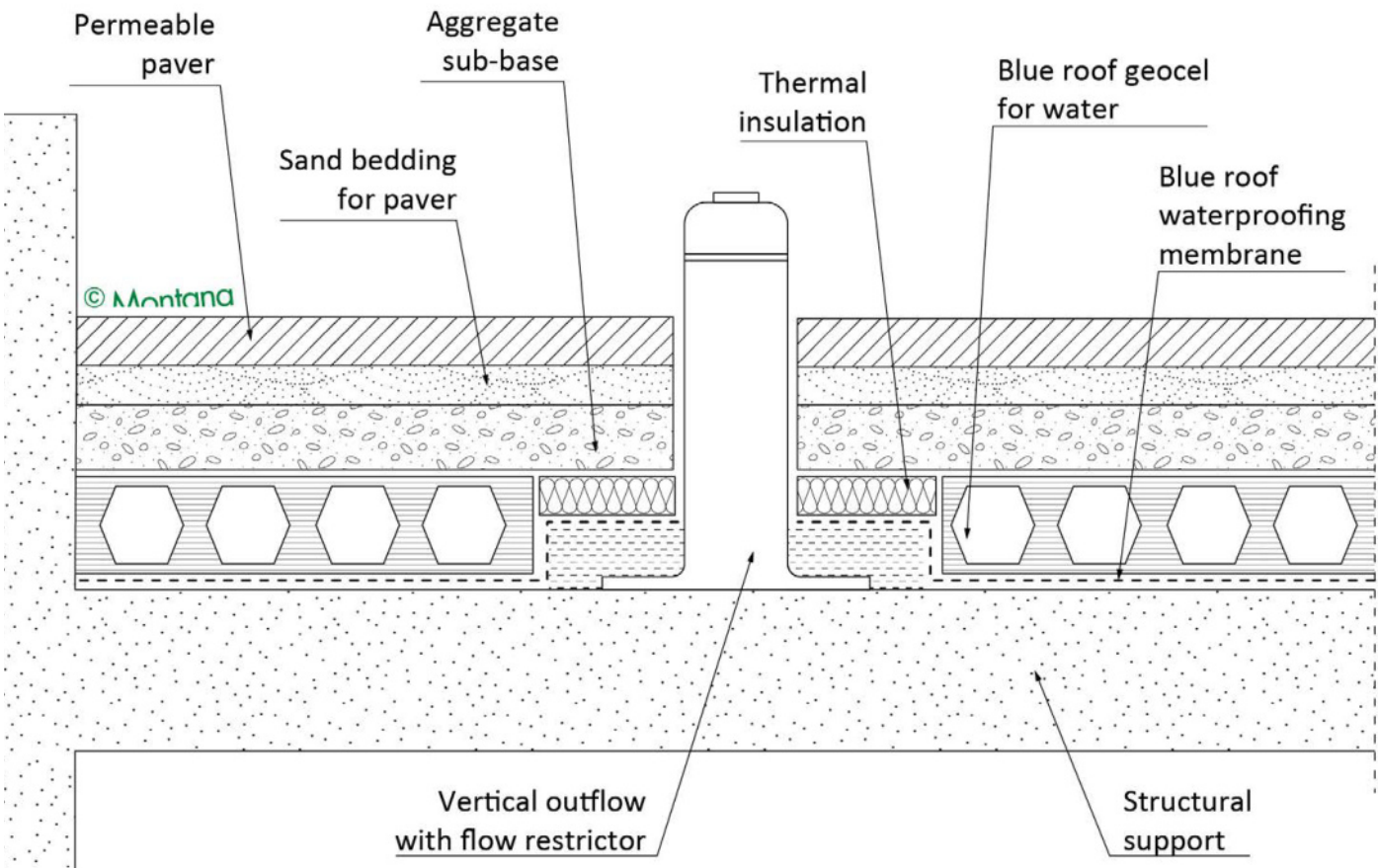
cleaning. Problems with a blue roof system generally fall into two categories: the first one can appear because the system drains too slowly, resulting in buildup of excess water on the roof for extended periods of time, bypasses of the controlled flow roof drains, or bypasses/overflows during small rainfall events; or, the second one, because the system drains too quickly, due to leaking or other issues, exceeding the design drain down rate.



↑
Mount Tabaro's cable car with solar panels.
Pic source: Montana Sp.A.

↗
Section of a blue roof with vertical outflow.
Section: Montana Sp.A.

→
Example of a rooftop detention.
Pic source: Geotexan



Building-scale interventions

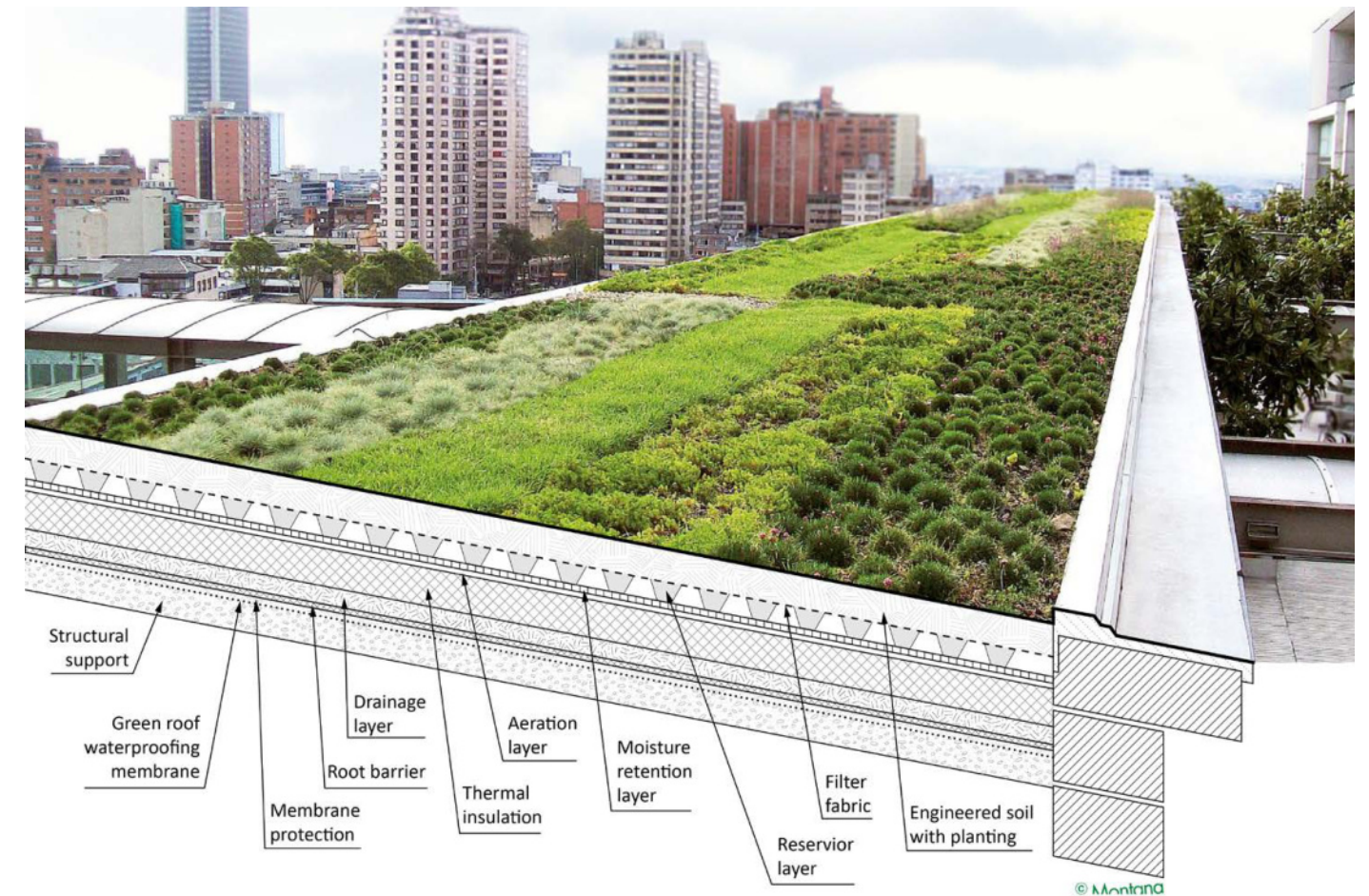
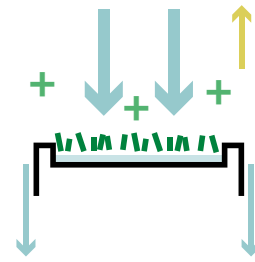
Green roof

Green roofs are areas of living vegetation, installed on the top of buildings. They can provide benefits as visual benefit, ecological value, enhanced building performance and the reduction of surface water runoff. Green roofs are also known as vegetative or eco-roofs.

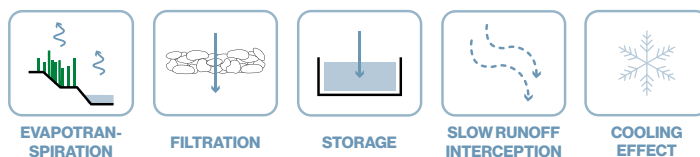
They fall into three main categories: **extensive**, **intensive**, and **semi-intensive** (include features of both of the previous types).

Although green roofs are generally more expensive than conventional roofs to construct and maintain, they can provide many long-term benefits. Green roofs can improve the thermal performance of buildings, potentially **reducing building energy costs**, due to the plants and substrate **cooling the roof** through evapotranspiration during summer months. Winter insulation properties are dependent on the amount of water held by the roof, and in wet winters gains will tend to be low.

Green roofs will help mitigate the **urban heat island effect** where there is a sufficient number in an urban area, as well as contributing to improved air quality by capturing dust particles.



FUNCTIONS



SDGS GOALS



Infographic: Montana S.p.A.

Pic source: Ahora Architettura



Modern Green Roof House
Design San Juan Island,
Washington, USA.

Pic source: Architect Magazine



Extensive green roof
An extensive green roof has a **shallow growing medium** (usually less than 15 cm) with a modest roof load, **limited plant diversity**, **minimal watering requirements**, and is often not accessible. The vegetation is composed by low maintenance plants (eg mosses, succulents, herbs, grasses) often enhanced with wild flowers. Planting often establishes more slowly, but the long-term biodiversity can be of high value. They are **only accessed for maintenance** and can be flat or sloping.



↑
Example of extensive green roof.
Campus, Research Center, Marne
La Vallée, France.
Pic source: Archdaily

Intensive green roof
These are designed to sustain **more complex landscaped environments** that can provide high amenity or biodiversity benefits. They are planted with a range of plants including **grasses, shrubs** and **small trees**, either as ground cover or within planters, and may also include water features and **storage of rainwater for irrigation**. Thus, they have more substantial structural loads and need more frequent maintenance and watering. They are usually **easily accessible**, as they normally require a fairly high level of regular maintenance, and in some cases they are made accessible to the public. Intensive roofs have a deeper substrate, with more than 150 mm growing medium, and therefore impose greater loads on the roof structure.



↑
Example of intensive green roof.
Allen & Overy LLP HQ, Bishop
Square, London.
Pic source: Greenroofs.com

Extensive
green roof

Intensive
green roof

Description	Thin soil No irrigation Stressful conditions for plants	Deep soil Irrigation system Favorable conditions for plants
Advantages	Lightweight Suitable for large areas Suitable for roofs with 0/30° slope Low maintenance No need for irrigation Suitable for retrofit projects Can leave vegetation to grow spon- taneously Relatively inexpensive Looks more natural	Greater diversity of plants and habitats Good insulation properties Can simulate a wildlife garden on the ground Can be made very attractive Often visually accessible Diverse utilization of roof
Disadvantages	More limited choice of plants Usually no access for recreation Unattractive to some, especially in winter	Greater weight loading on roof Need for irrigation and drainage systems , energy, water and materials Higher cost More complex systems

Site selection

Green roofs can be used on a variety of roof types and on any property size. They can be applied to a range of rooftop slopes, but **steeper pitches will normally mean that less storage capacity is available**, and the water drains away faster, unless the underlying drainage layer is specifically designed to capture and control flows.

The environmental parameters at the location where a green roof is to be installed have to be considered in the design process. The height of the roof, its exposure to wind, the roof's orientation to the sun and shading by surrounding buildings during parts of the day will have an impact on the choice and suitability of planting. The general **climate of the area and the specific microclimate on the roof should also be considered.**

Ecological considerations include the bioregion in which the roof lies, the existing habitats (including any green infrastructure or other ecological networks) and the objectives of any local biodiversity strategies.

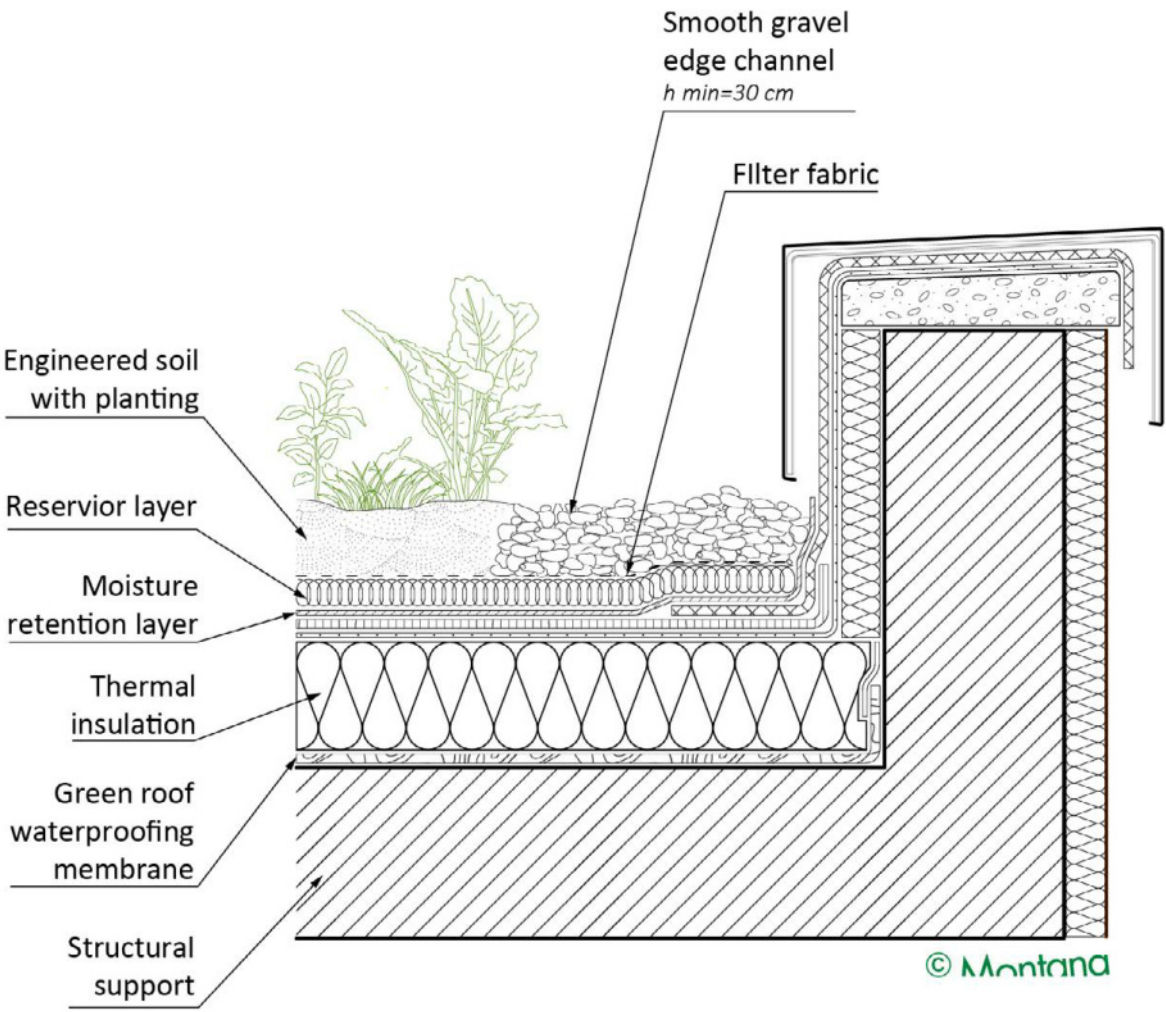
Hydraulic design

Although green roofs **absorb most of the rainfall that they receive during frequent events**, there will always be a need to discharge excess water to the building's drainage system. The hydraulic performance of green roofs once saturated tends to be fairly similar to standard roofs.

Green roofs **should be able to store water** and not dry out too quickly. If this is not possible within the soil substrate, then additional forms of water storage in the base layer can be provided, or irrigation may be appropriate. Irrigation systems are generally not recommended for extensive roofs, due to the costs and operation associated with their implementation and management. However, they are often necessary for intensive roofs. If irrigation is required, base level irrigators that introduce water directly to the root zones via the drainage layer are good for this purpose.

Interception design

The performance of green roofs in terms of reducing or preventing the runoff from normal rainfall events is usually very significant in the summer due to the evapotranspiration processes and temporary storage provided by the roof. Green roofs can provide benefits in terms of **reducing peak flow rates** to the site drainage system, principally for small and medium-sized events. Their impact tends to be most significant in summer, where intense short duration events may generate very little runoff from the roof.



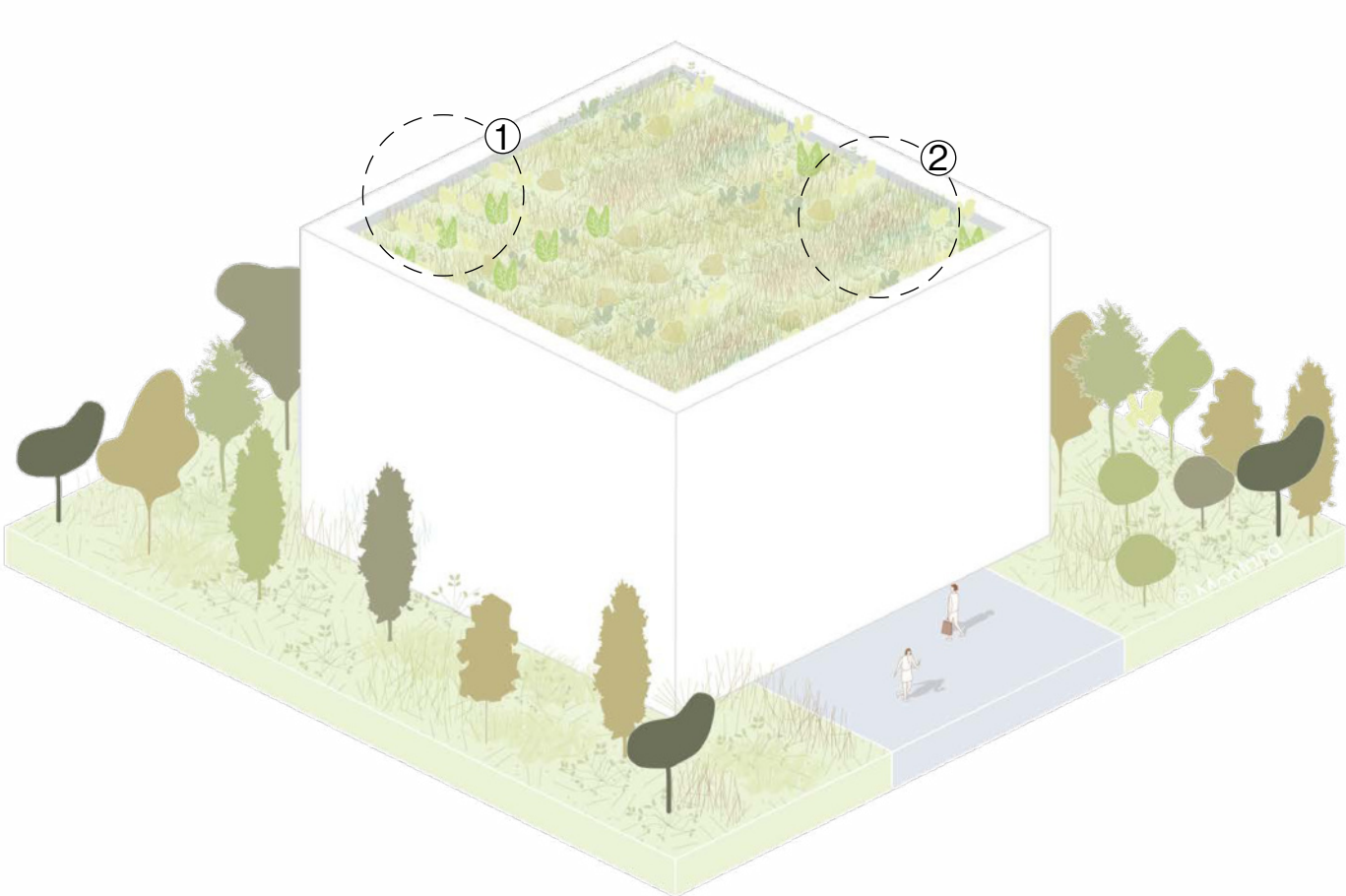
↗
Section of a green roof.
Drawing: Montana S.p.A.
Pic source: Montana S.p.A.

→
Marchesi Antinori Chianti Classico
Cellar, Bargino, Italy.
Pic source: Architectural Digest

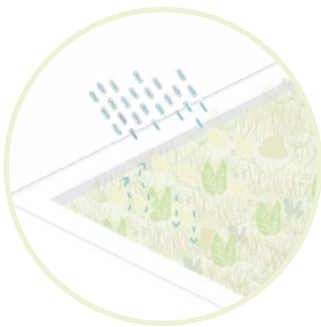


Visualization

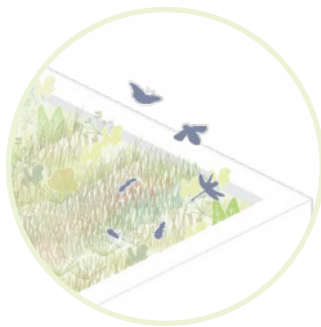
Visualization of green roofs in an urban context



Details of increased benefits for the urban living environment

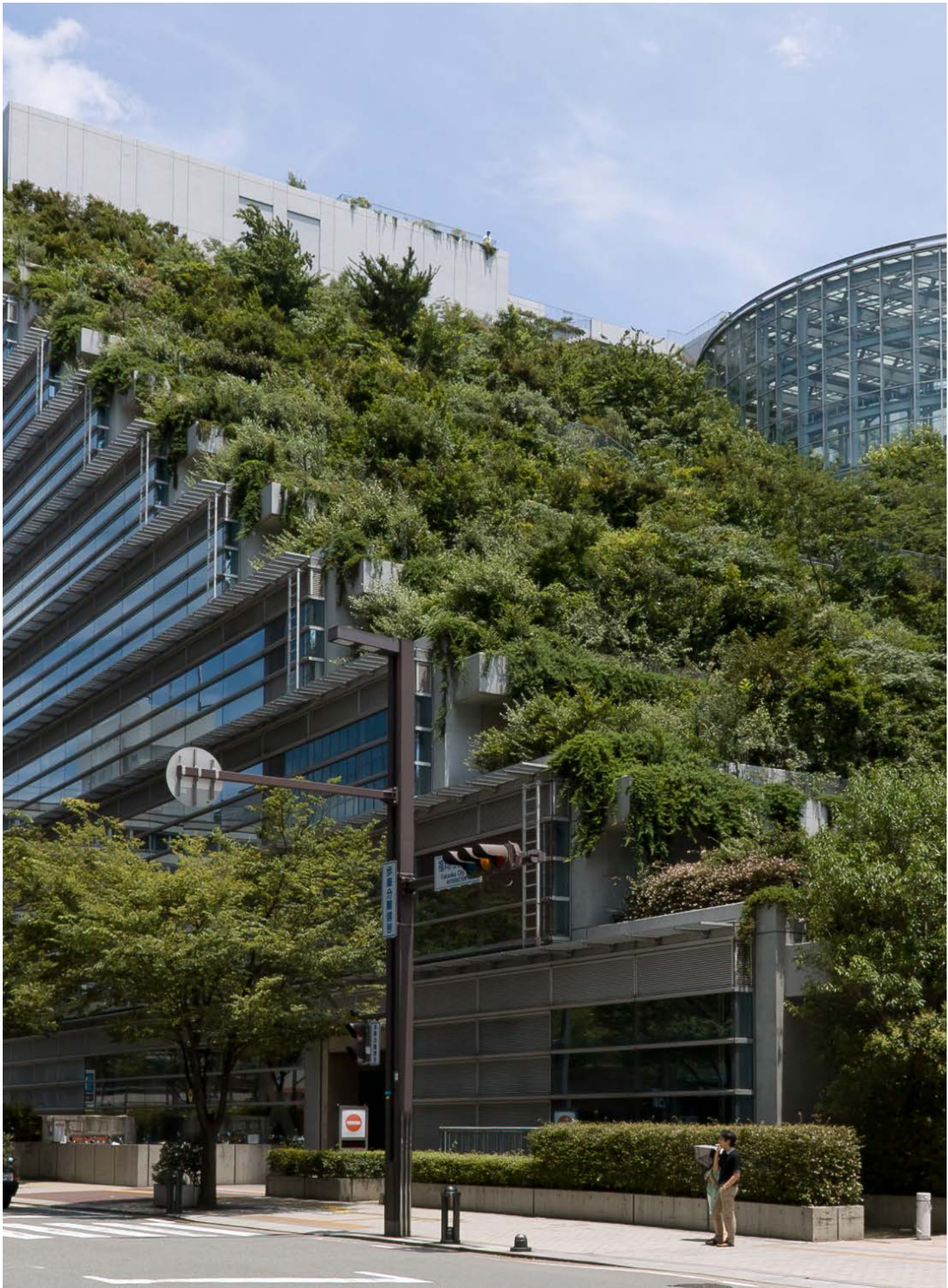


Green roofs manage stormwater by **absorbing rainwater**, reducing runoff, and promoting slow infiltration into the building's structure. They help **decrease the urban heat island effect**, improve drainage, and **enhance water quality** by **filtering pollutants** before they reach the ground.

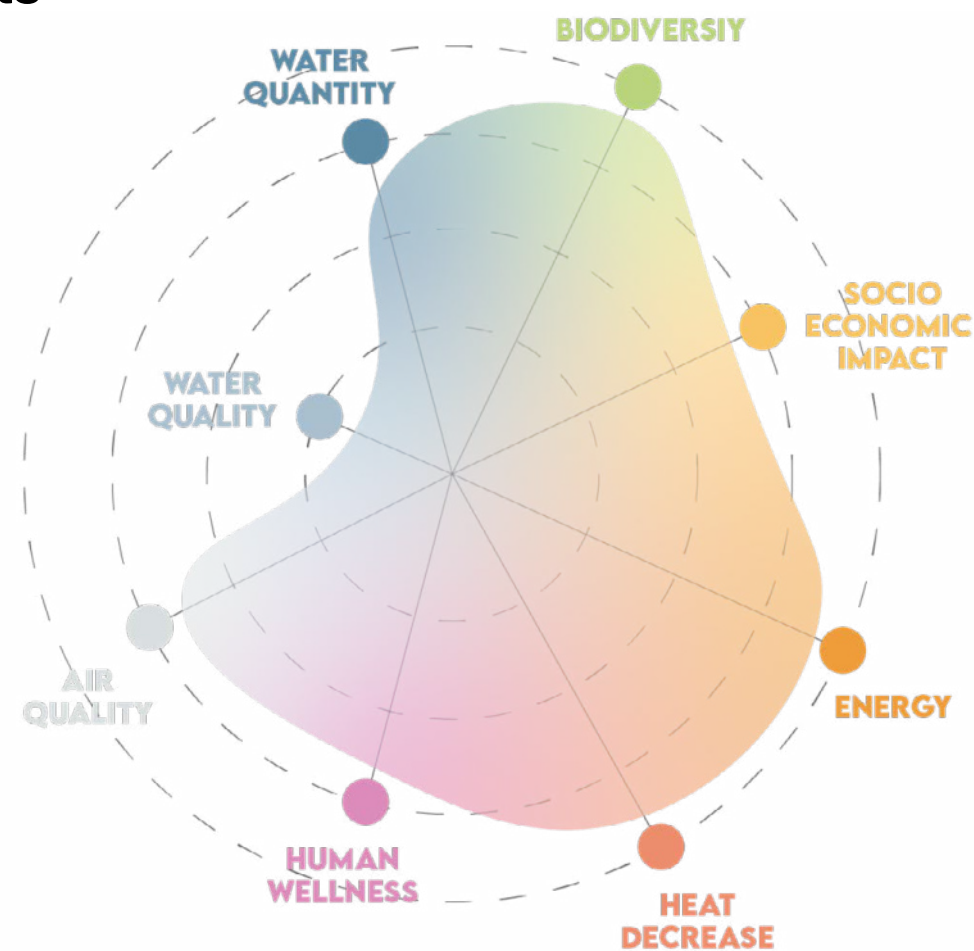


They support biodiversity by **providing habitat** for a variety of plant species, including sedums, grasses, and wildflowers. These spaces **attract pollinators**, such as bees and butterflies, and can also **support birds and insects**, contributing to urban ecosystem diversity.

↓ Acros building, Fukoka, Japan.
Pic source: Pinterest



Benefits



Water quantity and runoff control

Green roofs retain rainfall within the vegetation, substrate, and drainage layers, reducing runoff volumes and delaying peak flows to the sewer system. By storing part of the rainfall and releasing it gradually or through evapotranspiration, they help relieve pressure on urban drainage networks, especially during frequent rainfall events. (Berndtsson, 2010; EPA, 2015; Zhang et al., 2021).

Biodiversity

Green roofs create new habitats for plants, arthropods and birds, often supporting greater species richness than bare or gravel roofs and acting as ecological stepping stones in dense cities. Varied substrates and native species can still make a meaningful contribution to urban biodiversity conservation. (Madre et al., 2021; Williams et al., 2014)

Social interaction

Over their life cycle, green roofs can deliver net economic gains by reducing flood risk and stormwater fees, cutting energy bills, extending

roof membrane life and, in some contexts, increasing building value and tenant appeal. (Bianchini & Hewage, 2012; Kalantari et al., 2023)

Energy management

Green roofs shade the waterproofing layer, dampen temperature swings and add thermal resistance, reducing heat gains in summer and, to a lesser extent, heat losses in winter. Substantial cuts in cooling demand is noted, sometimes by tens of percent compared with bare roofs. (Castleton et al., 2010; Santamouris, 2014)

Heat decrease

Green roofs cool buildings by shading roof surfaces and enhancing evapotranspiration, which lowers surface temperatures and sensible heat flux to the air. Widespread roof greening can slightly reduce daytime urban air temperatures and contribute to mitigating the urban heat island. They are one of the most effective roof-level cooling measures, particularly in hot, dry climates. (Santamouris, 2014; Zölch et al., 2016)

Human wellness

Intensive, accessible green roofs add usable green space for rest, socialising, gardening and light recreation, extending everyday contact with nature in dense areas where parks are scarce. Regular exposure to such environments is linked to reduced stress, better mental health, higher physical activity and lower all-cause mortality—benefits that roof greenspaces can help provide when they are safe, attractive and easy to access. (Twohig-Bennett & Jones, 2018; Nieuwenhuijsen et al., 2024)

Air quality

Green-roof vegetation intercepts airborne particles and absorbs some gaseous pollutants, with annual removal of PM₁₀ and other contaminants, especially with species that have fine, rough or hairy foliage. Although their city-wide impact is modest unless deployed extensively,

meta-analyses indicate that green roofs usefully complement street-level vegetation in improving urban air quality and offsetting part of the emissions from building operation. (Speak et al., 2012; Jayasooriya et al., 2017)

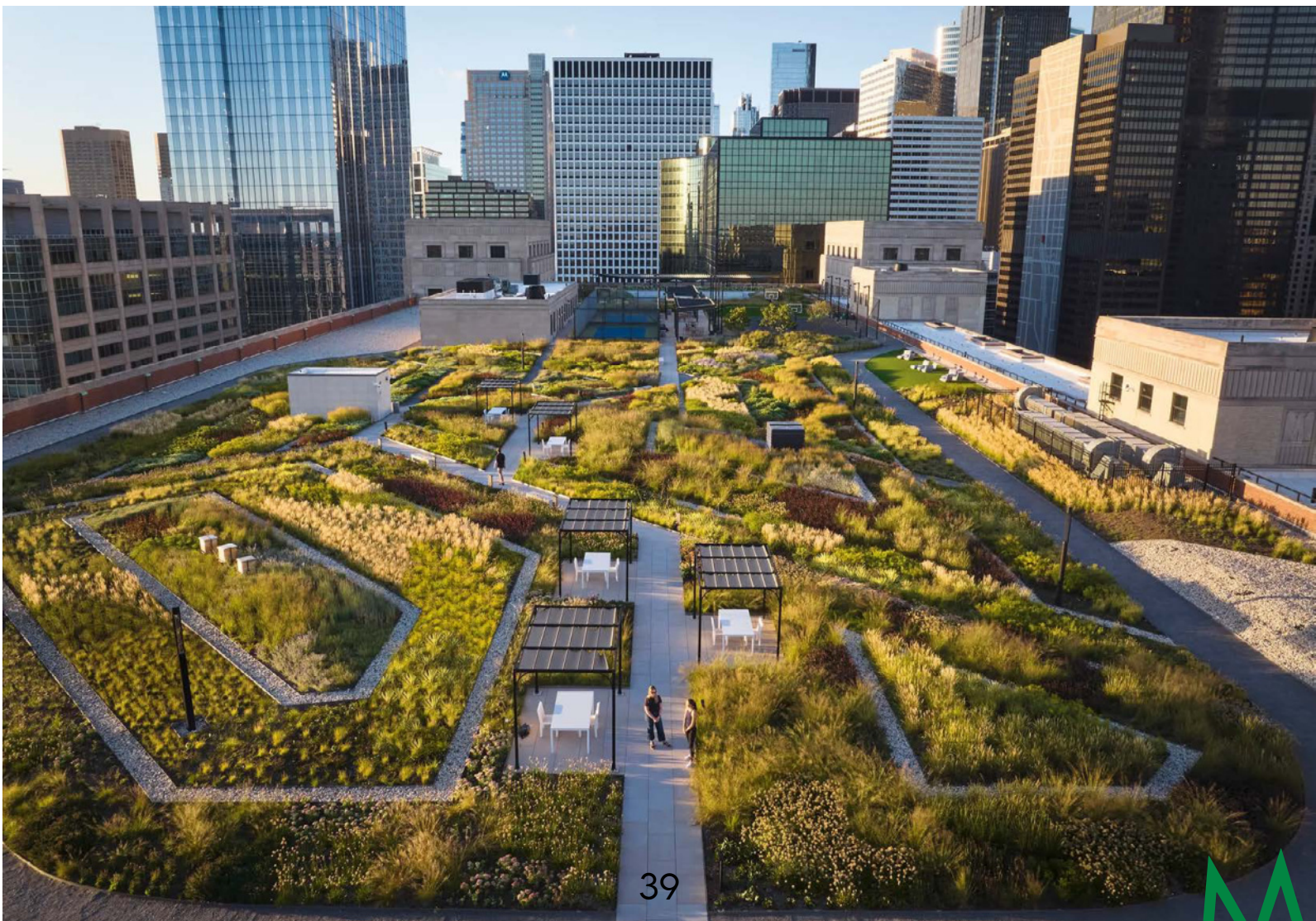
Water quality and sediment management

Green roofs may provide limited stormwater quality benefits by filtering rainfall through vegetation and substrate layers, retaining suspended solids and some atmospheric pollutants. However, this benefit is secondary and can vary significantly depending on substrate composition, vegetation, maintenance, and fertilisation, as some systems may release nutrients into runoff. (Berndtsson, 2010; Hachoumi et al., 2021; Vijayaraghavan, 2016).

← This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

↓
The Meadow at Old Chicago Post Office

Pic source: Hoerr Schaudt



Building-scale interventions

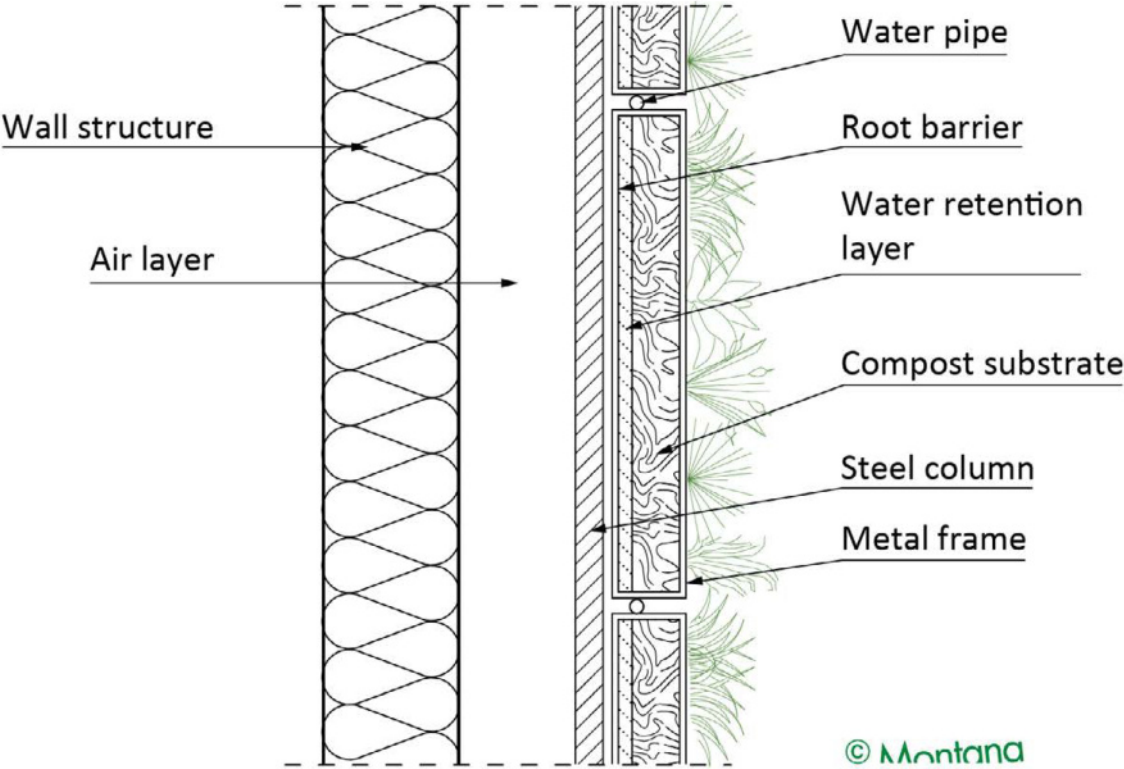
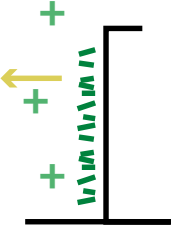
Green wall

A green wall, also known as a living or vegetated wall or vertical garden, is an **extension of the building envelope laminated with vegetation and a soil** or inorganic growing medium.

Vegetated walls are classified as passive or active systems. While **active systems** address **air quality**, **passive systems** address **water quality**, and thus are more applicable to LID.

Similar in application to vegetated roofs, vegetated walls harvest water to reduce stormwater runoff loads. Vegetated walls also regulate building temperature through additional thermal insulation, reducing heating and cooling loads.

Structural loads and proper moisture barriers must be carefully considered, as well as plant types suitable for the intended solar orientation.



© Montana

FUNCTIONS



SDGS GOALS



↗
Section of a green wall.

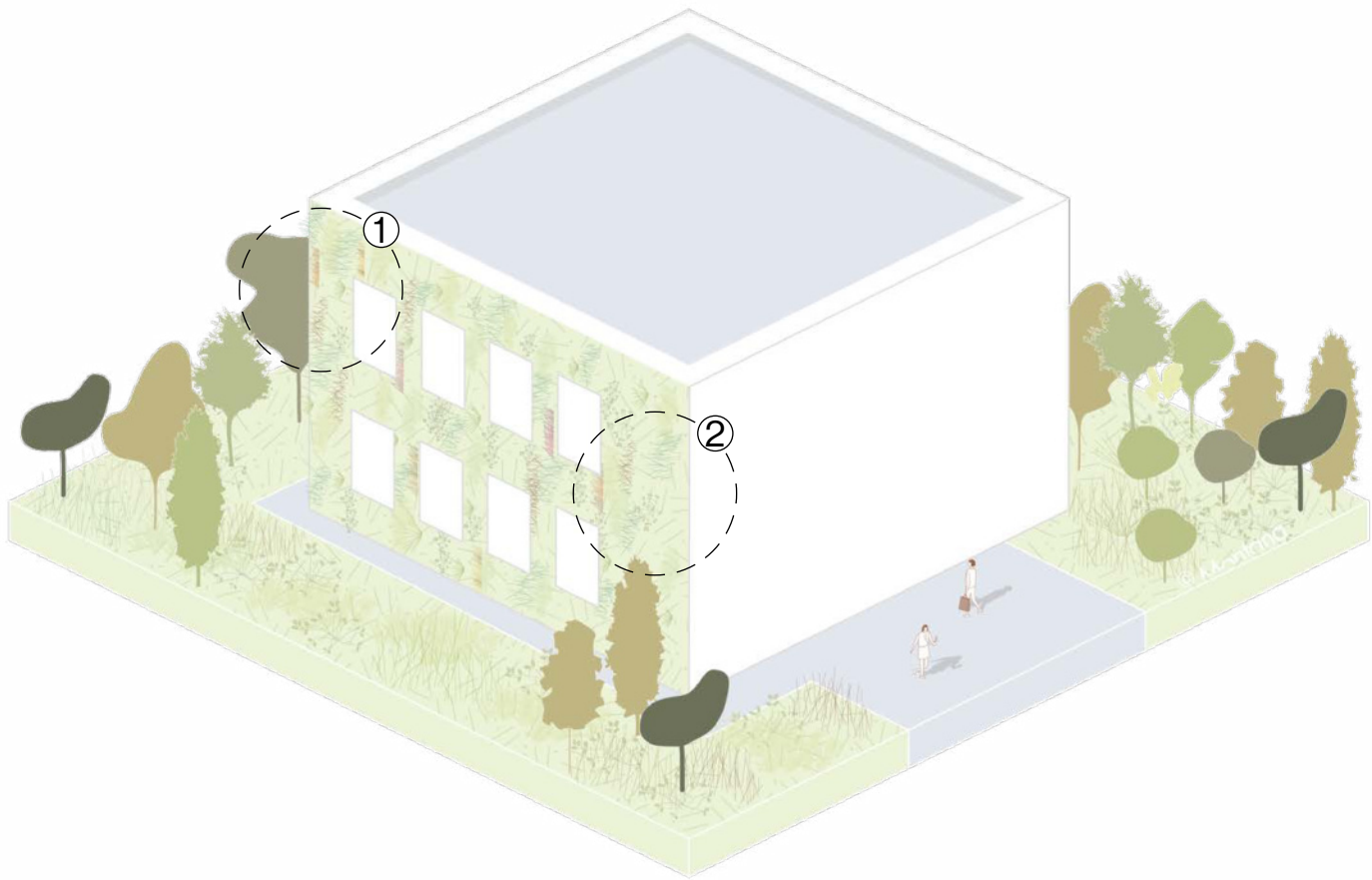
Drawing: Montana Sp.A.
Pic source: Montana Sp.A.

→
Musée du Quai Branly in Paris.
Pic source: Architizer



Visualization

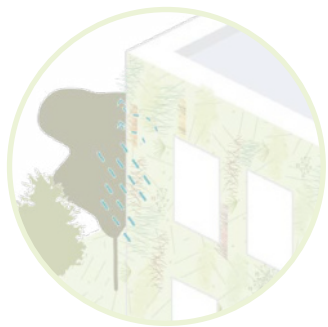
Visualization of green walls in an urban context



Jakob Saigon Factory in Saigon, Vietnam.

Pic source: Oki Hiroyuki

Details of increased benefits for the urban living environment



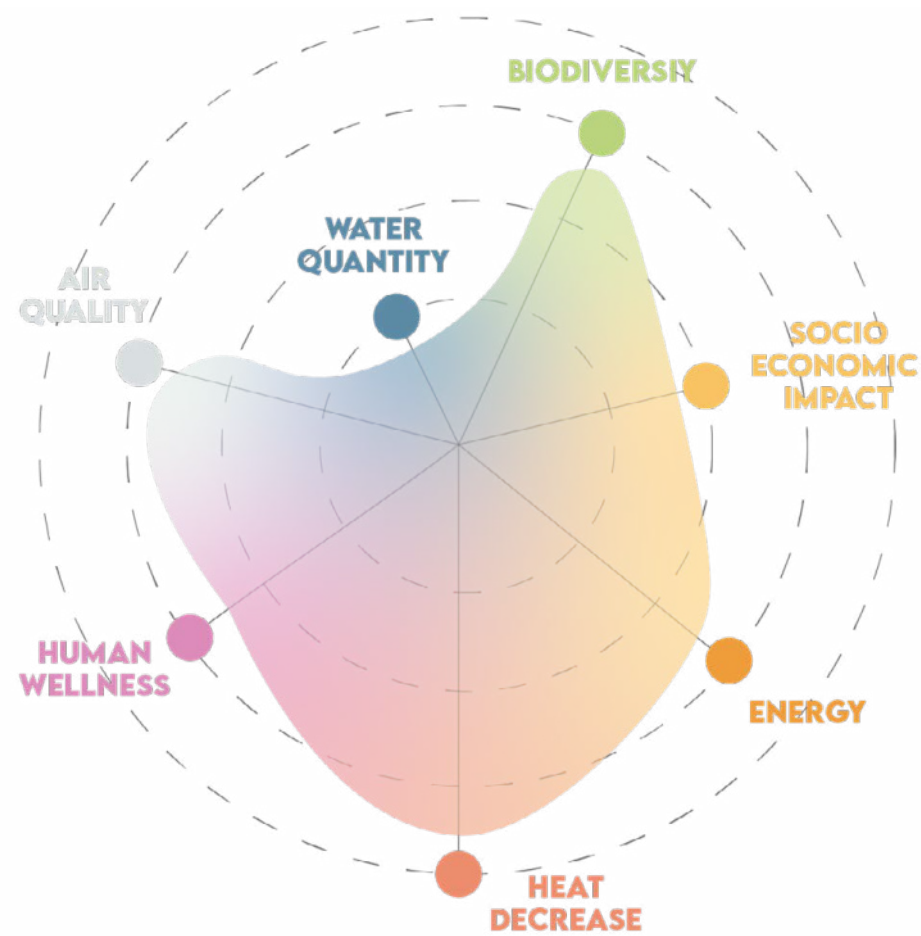
Green walls **absorb rainwater** and **reduce runoff**, while also **promoting evapotranspiration**. This process helps **regulate temperature**, reduce the urban heat island effect, and **improve air quality**, enhancing water management and environmental conditions in urban areas.



Green walls **promote vertical habitats** for a variety of **plant species**, including climbing plants, ferns, and mosses. These walls **attract pollinators**, such as bees and butterflies, and **offer shelter** to **small birds** and **insects**, enriching urban ecosystems.



Benefits



Water quality and sediment management

Green walls contribute to water management mainly by retaining part of the rainfall that hits façades and by treating greywater that is reused for flushing or irrigation, thereby reducing potable-water demand and loads to sewers. Case studies and reviews show that living walls can remove a large share of COD, nutrients and indicator bacteria from greywater while offering reliable reuse volumes in dense urban areas. (Masi et al., 2016; Pradhan et al., 2019; Pucher et al., 2019)

Biodiversity

Green walls add vertical habitat and microclimatic niches, supporting invertebrates, birds and other taxa and acting as “stepping stones” within fragmented urban landscapes. Plant-covered walls host richness and abundance of species, increasing where vegetation is denser and more structurally diverse, so well-designed living walls can make a real contribution to urban biodiversity and ecological connectivity. (Chiquet et al., 2018; Francis & Chadwick, 2012; Pallis et al., 2018; Xu et al., 2025; Vitali et al., 2018)

Social interaction

By enabling on-site greywater reuse and reducing stormwater runoff, green walls can lower water and drainage costs, defer infrastructure upgrades and add value through improved façade aesthetics and branding. Factsheets and project reports highlight that, although installation costs are relatively high, living walls can be economically viable when combined water savings, energy savings and marketing/amenity benefits are considered over the system’s lifetime. (Pucher et al., 2019; Pradhan et al., 2019; Turner, 2023)

Energy management

As vegetated cladding, green walls shade the building envelope, block wind and add an insulating layer, which reduces heat gains in summer and can modestly alter heating needs in winter. Studies report cooling-energy savings of a few to around 10% in educational and residential buildings with green walls, with higher benefits in warm climates and on poorly insulated façades. (Turhan et al., 2025; Mohammed, 2022; Manso & Castro-Gomes, 2015)

Heat decrease

Green walls help cool cities by lowering wall surface temperatures and cooling adjacent air through shading and evapotranspiration, thereby mitigating urban heat stress along streets and courtyards. Reviews and recent field/modelling studies show façade temperature drops of several degrees and local air-temperature reductions on the order of 1–3 °C near living walls under hot conditions. (Koch et al., 2020; Milosevic et al., 2023; Turhan et al., 2025)

Human wellness

Green walls add visible greenery in otherwise hardscaped streets and interiors, supporting stress reduction, visual restoration and improved comfort, even where access to parks is limited. An umbrella review of 30 studies finds consistent evidence that green walls mitigate environmental

stressors such as heat, air and noise pollution and provide restorative experiences, although direct health outcomes are still under-researched. (Cardinali et al., 2023; Tang et al., 2023)

Air quality

The foliage and rough surfaces of green walls act as vertical biofilters, capturing particulate matter and absorbing gaseous pollutants, with laboratory and field studies reporting substantial reductions in PM and VOCs, especially for active systems with forced airflow. Recent reviews conclude that, when suitably designed and maintained, green walls can significantly improve near-wall air quality and contribute to wider urban air-pollution mitigation strategies. (Tang, 2023; Vitaliano et al., 2024; Srbinovska et al., 2021)

← This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

↓ CaixaForum, Paseo del Prado, Madrid
Pic source: ArchDaily

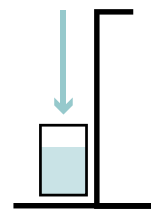


Rainwater harvesting

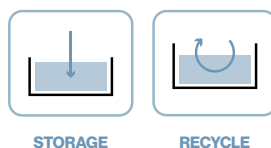
Rainwater harvesting **involves collection, storage and reuse of runoff from roofs.**

Rainwater harvesting **reduces runoff volume and peak flows.** Cisterns, bladder tanks, and precast ferrocement septic tanks are generally larger than rain barrels and slim tanks, and are **used for domestic water supply**, rather than **irrigation for landscaping.** Most rainwater harvesting devices are modulated and can be connected to provide increased storage. Consider that in areas with rainfall more than 0,60 m annually, a 90 square meter roof will produce a minimum of 57.000 lites of rainwater per year. To capture this water for irrigation during the peak months approximately 10 rain barrels or one 2000 liters cistern are needed.

Maintenance needs are moderate compared to other driver Low Impact Developments technologies, however, water must be used periodically between rain events to maximize storage capacity, minimize runoff, and avoid odors. Gutter screens prevent the accumulation of debris in runoff. Filtration and purification equipment must be incorporated when using stormwater runoff for potable uses.



FUNCTIONS



SDGS GOALS



Example of a pumped rainwater harvesting system.

Pic source: Xoli Outdoor



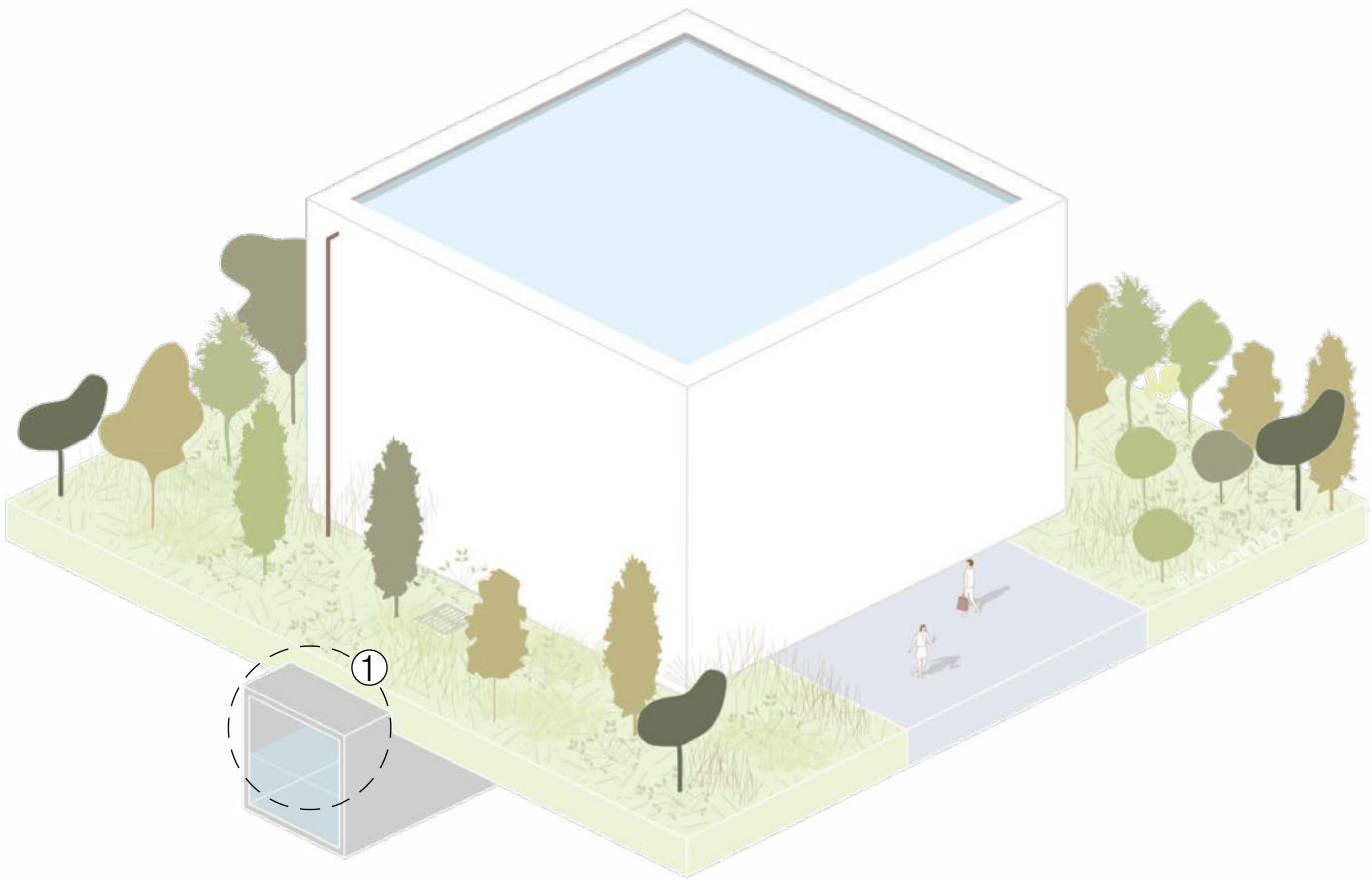
Example of a gravity rainwater harvesting system.

Pic source: Rainwater Management Solutions

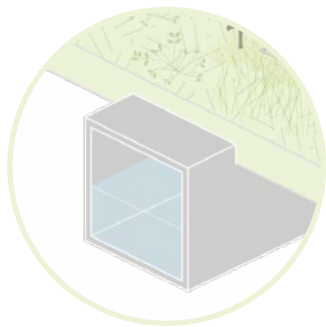


Visualization

Visualization of rainwater harvesting in an urban context



Details of increased benefits for the urban living environment

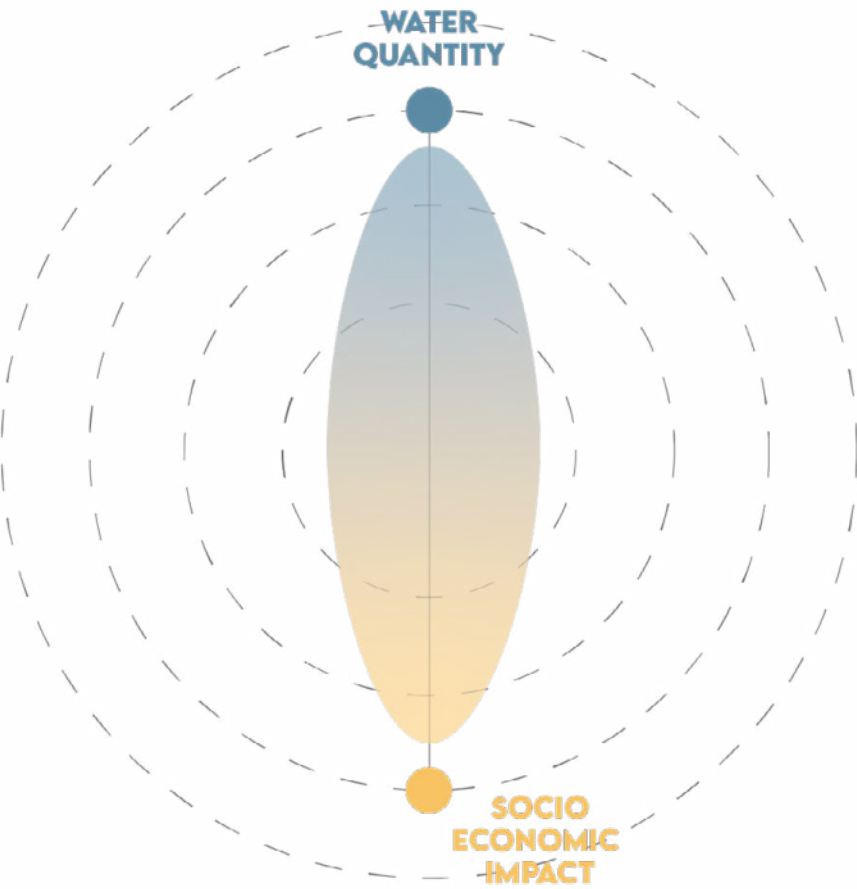


Collected rainwater can be filtered and **used for** various purposes, such as **irrigation** or **non-potable water needs**, improving water efficiency and **reducing dependence on municipal water supplies.**

→
Example of reuse of harvested water.
Pic source: Pinterest



Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

This solution reduces pressure on drinking-water sources and sewer networks, lowers combined sewer overflows, and helps mitigate urban flooding by cutting peak flows and runoff volumes. When designed with appropriate first-flush diversion and basic treatment, harvested rainwater can meet quality targets for many non-potable uses while improving the overall performance of urban water-management systems. (Campisano et al., 2020; Pacheco & Alves, 2025; Santos et al., 2023; Silva et al., 2023)

public spaces can also support green jobs, local innovation and public engagement around sustainable water use. (Silva et al., 2023; de Gois et al., 2021; da Costa et al., 2022; Sigma Earth, 2024)

Socio-economic impact

Rainwater harvesting can improve water security and climate resilience for households, industries and cities, particularly in regions facing scarcity or service interruptions. Economic assessments highlight reduced water bills, deferred investments in centralised supply and drainage infrastructure, and avoided flood damages as key benefits, while policy analyses point to the role of incentives and supportive regulation in unlocking these gains. At community scale, visible systems integrated into buildings and

→
Example of a rainwater harvesting project.
Pic source: Pinterest



Site selection

Rainwater harvesting can be used in residential, commercial or industrial development for new or retrofit projects for water conservation and surface water management. Careful consideration should be given to the likely contaminants present in the runoff, and thus the suitability of the runoff for harvesting; for example, runoff from roofing materials containing copper or zinc, or treated with fungicides or herbicides, may not be suitable, depending on the purpose for which the water is to be used.

Treatment design

Rainwater harvesting systems **should deliver a water quality** that is suitable for applications such as toilet flushing, washing machines and garden watering. Runoff that contains a high pollutant loading (eg sediments or heavy metals) may only be appropriate for use after treatment. Water-quality treatment measures for rainwater harvesting include: **pre-treatment, filtration, biological treatment** and **disinfection**. Storing the water below ground can reduce the need for water quality treatment by keeping the water cool. Cool water has higher oxygen concentrations and prevents bacteria growth, and the lack of light prevents algal growth. Filters can be implemented pre or post storage.

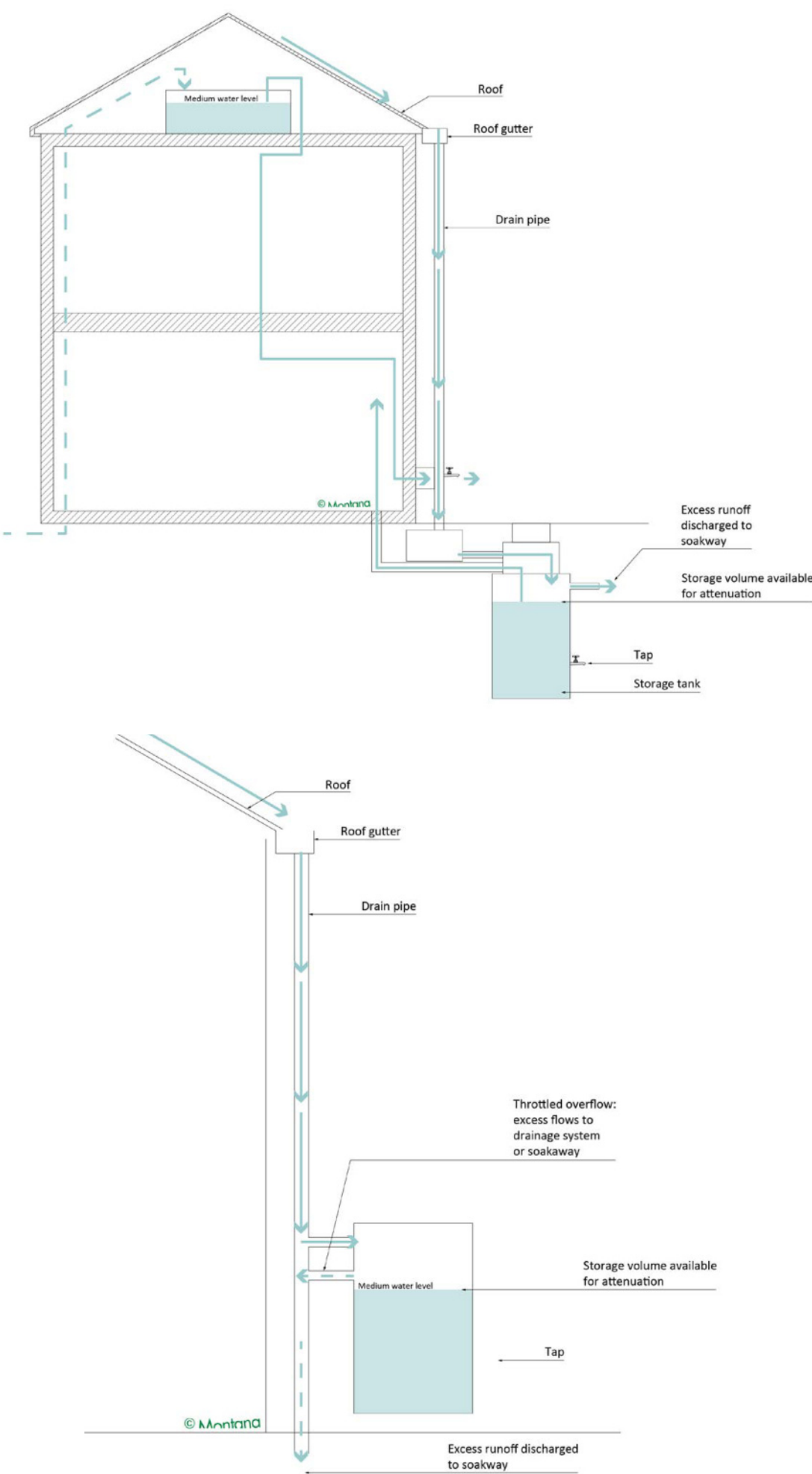
Gravity systems

Gravity systems are designed so that the **rainwater is collected by gravity and stored at elevation** so that it can also be supplied by gravity. Rainfall runoff can be collected from standard domestic or commercial property pitched roofs and stored in the roof space or on the roof. In other designs, the storage is supported at a high level on the wall just below gutter level. In low elevation buildings, above-ground storage tanks can be used to serve ground floor appliances and irrigation demands. The key design constraints are:

- the structural capacity of the building to store the water at an elevated location;
- the collection of sufficient water from the roof, at sufficient height, that will allow subsequent supply based on a gravity-only process;
- limiting operating pressure;
- temperature of stored water.

Pumped systems

The most common type of rainwater harvesting systems tend to **store water underground or at ground level and then pump it out** for supply purposes. There are two types of pumped systems: those that pump to a header tank and those that pump directly to the units in the buildings.



Sections of a pumped system and a gravity system for rainwater harvesting.
Sections: Montana S.p.A.
Pic source: Montana S.p.A.

02. Public and urban spaces interventions

- 56 Bioretention area
- 66 Bioswale
- 78 Detention pond
- 86 Detention tank
- 90 Filter strip
- 96 Floodable park
- 102 Infiltration systems
- 112 Pervious paving
- 120 Rain garden
- 128 Trees
- 132 Tree filter box
- 138 Underground detention

→
*Benjakitti Forest Park, Khlong
Toei, Thailand, 2022*
Pic source: Turenscape



Public and urban scale interventions

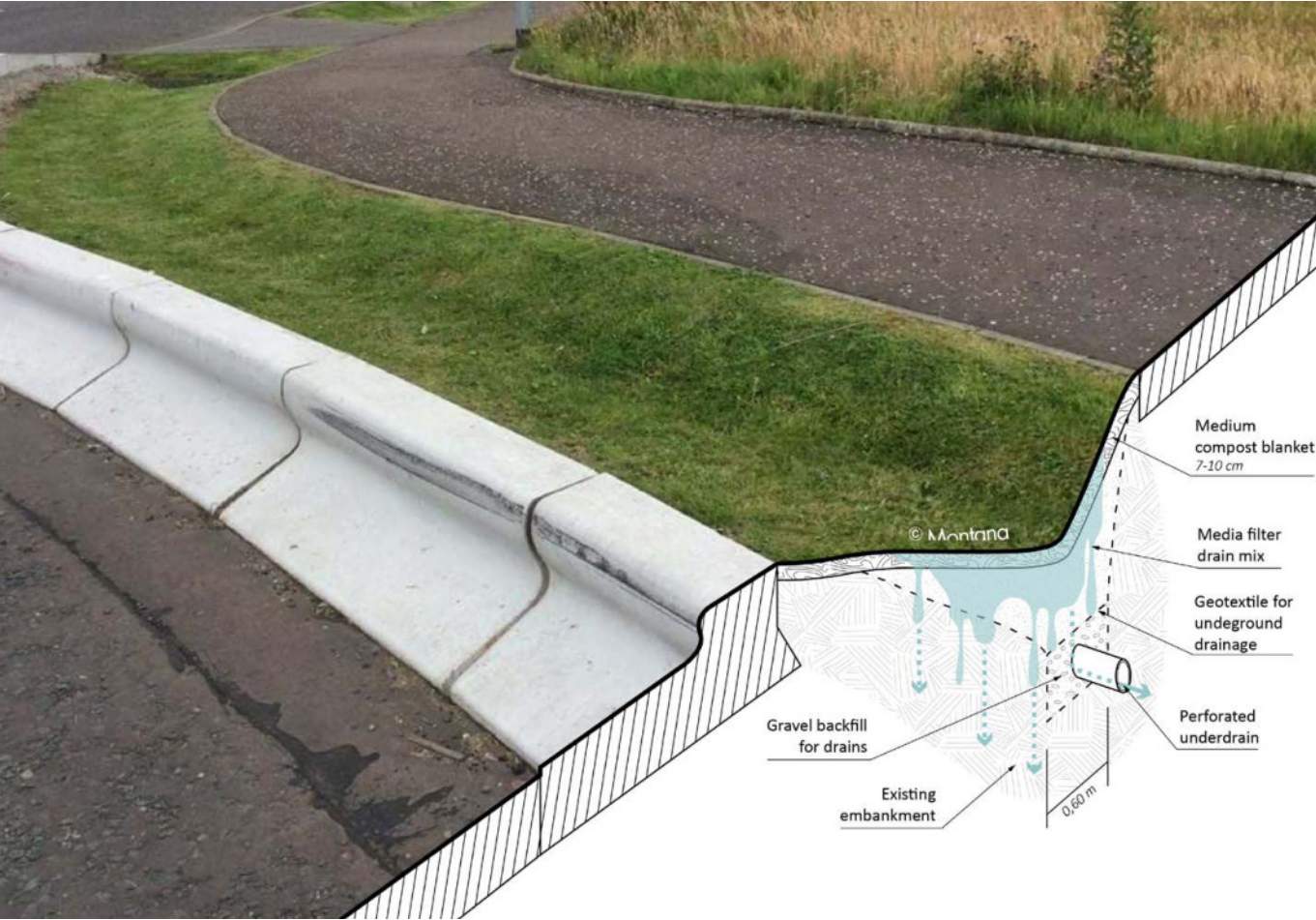
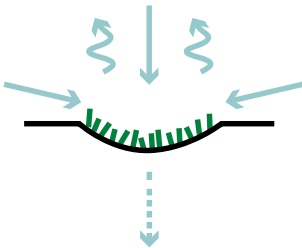
Bioretention area

Bioretention areas are **shallow trenches filled with stone/gravel** that create temporary subsurface storage for the **attenuation, conveyance** and **filtration** of surface water runoff.

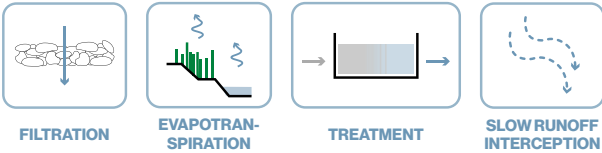
The stone may be contained in a simple trench lined with a geotextile or other permeable liner, or within a more structural facility such as a concrete trough.

Bioretention areas can help **reduce pollutant levels in runoff** by filtering out fine sediments, metals, hydrocarbons and other pollutants. They can also encourage adsorption and biodegradation processes.

Bioretention areas **can replace conventional pipework** as conveyance systems, and the use of adjacent filter strips or flow spreaders can remove the need for kerbs and gullies when systems are located adjacent to roads or highways.



FUNCTIONS



SDGS GOALS



↗
 Infographic: Montana S.p.A.
 Pic source: Abertay University

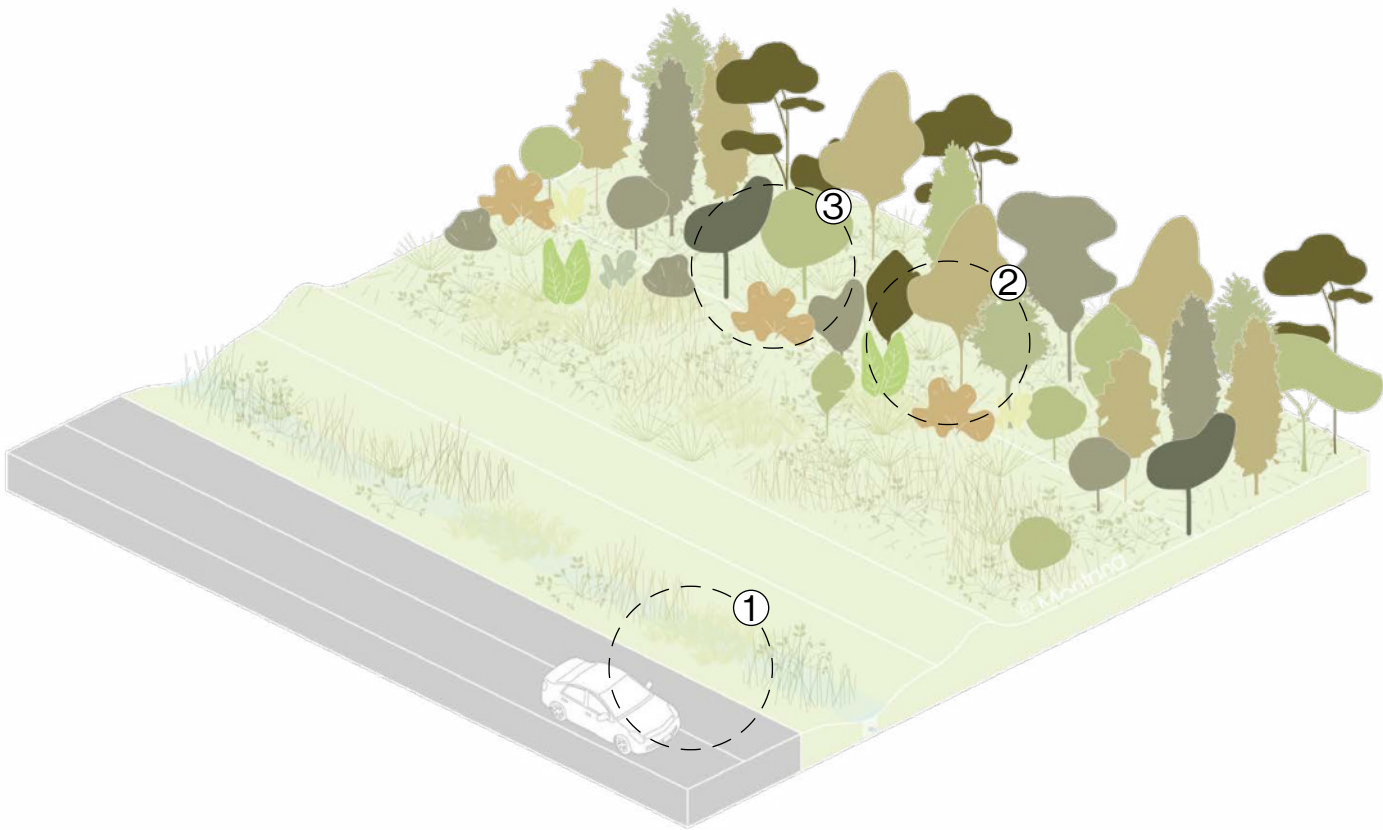
→
 Bioretention pockets between parking lots in the HDI-Gerling Industry, Hannover, Germany.
 Pic source: Bruun & Möllers Landscape Architects

→ 2
 Bioretention pockets between parking lots, Quartier de la Morinais, Saint-Jacques-de-la-Lande, France.
 Pic source: Atelier de paysages Bruel Delmar

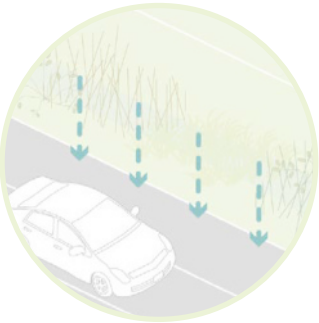


Visualization

Visualization of bioretention areas in an urban context



Details of increased benefits for the urban living environment



Bioretention areas **remove pollutants** by filtration, adsorption and biological uptake. Filtered water carries fewer sediments, nutrients, and toxic substances into downstream rivers, lakes, and coastal areas, helping **improve aquatic habitats** and recreational **water quality**.



Vegetated bioretention areas provide **evapotranspiration and shading**, which reduce local surface and air temperatures, contributing to **mitigation of the urban heat island effect**.

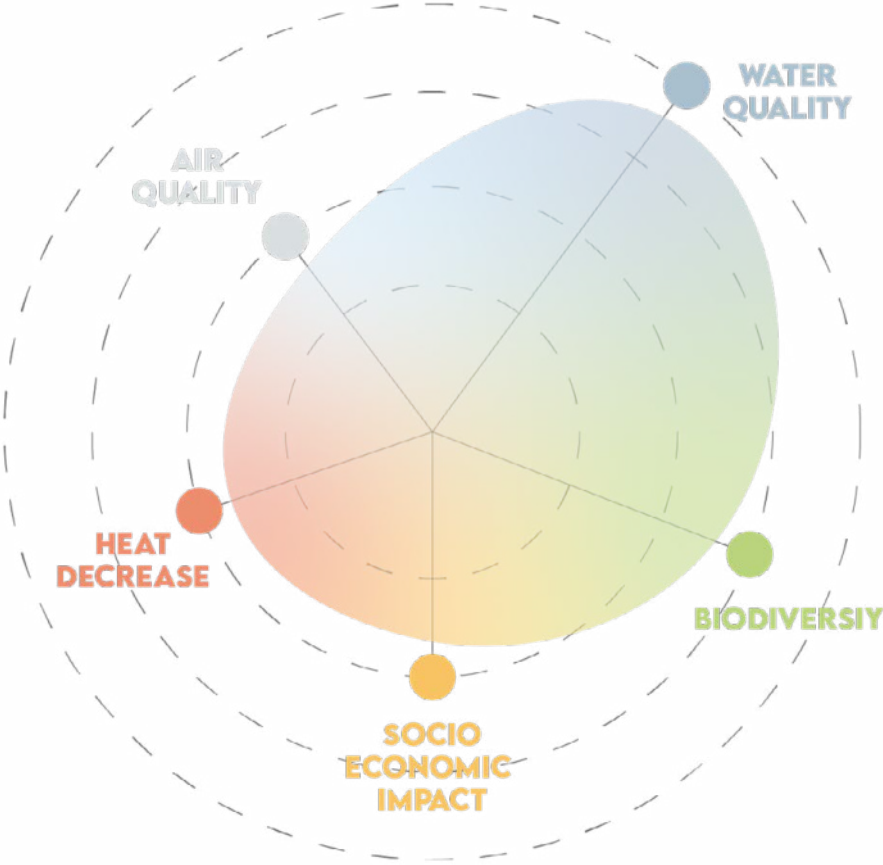


Bioretention systems can be planted with diverse native shrubs, grasses and trees, creating micro-habitats that support birds, pollinators and beneficial insects. Bioretention is **enhancing urban biodiversity and ecological connectivity** as part of wider green-blue infrastructure networks.



Grønningen-Bispeparken in Copenhagen, Denmark
Sections: Montana S.p.A.
Pic source: Montana S.p.A.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Bioretention areas are typically designed to capture and treat the first flush of stormwater runoff—the initial wave of runoff that carries the highest amount of pollutants. While effectiveness varies, some bioretention areas have been shown to remove up to 90% of heavy metals from stormwater, organic pollutants, and nitrogen contamination (*Kennen and Kirkwood 2015*).

Biodiversity

Bioretention areas provide important habitats; support biodiversity by improving ecological connectivity, providing food and pollination, preserving terrestrial and semiaquatic habitats, and linking the urban environment to the surrounding countryside (*Kim and Song 2019*).

Social interaction

Bioretention areas provide benefits to improve quality of life. They also create opportunities for recreation in public spaces and create informal social gathering spaces (*Kim and Song 2019*). These systems can be used to engage the public in their planning and maintenance to build

stronger community cohesion. Designs can combine bioretention areas with traffic control and regulation measures, which can improve the safety and spontaneous use of public spaces.

Heat decrease

Bioretention areas cool their surroundings by replacing dark, impervious surfaces with moist soil and dense vegetation whose evapotranspiration and shading lower surface and near-ground air temperatures, helping to mitigate local urban heat island effects. (*Bonciarelli et al., 2025*)

Air quality improvement

The planting in bioretention cells acts as a near-ground “green filter” that captures particulate matter on leaves and stems and supports deposition and transformation of traffic-related pollutants (*Bonciarelli et al., 2025*).

→
Plan and section of a bioretention area next to a road.
Sections: Montana S.p.A.
Pic source: Montana S.p.A.



Site selection

Bioretention areas are best located **adjacent to impermeable surfaces** such as car parks or roads/highways with upstream pre-treatment systems. They can be used for draining residential and non-residential runoff and, when lined, can be used to manage surface water runoff from areas with high groundwater pollution risks. Unless effective pre-treatment of sediments is included within the design, they are applicable primarily to impervious areas where there are **not high levels of particulates in the runoff**.

Dimension

Bioretention areas **depths** should generally be **1–2 m**. The minimum depth of filter medium beneath any inflow distribution pipework and outfall collection systems should be 0,5 m to ensure reasonable levels of pollutant removal. Where infiltration is allowed, the **maximum groundwater level** should be at least **1 m below the base of the trench**.

Hydraulic design

There are three elements to the design of bioretention areas:

- Design of the **filter material for adequate percolation of water** (the rate of percolation is a compromise between pollutant removal and the need to restrict the risk of flooding in the catchment for the design storm event, and to act as an appropriate trickling filter for small events, contact time with the aggregate should be maximised);
- Design of the **filter material to store water** (the greater the void ratio, the more storage is available in the trench, and the level of storage available will depend on the throttle at the outlet);
- Design of the **pipe system to convey water**.

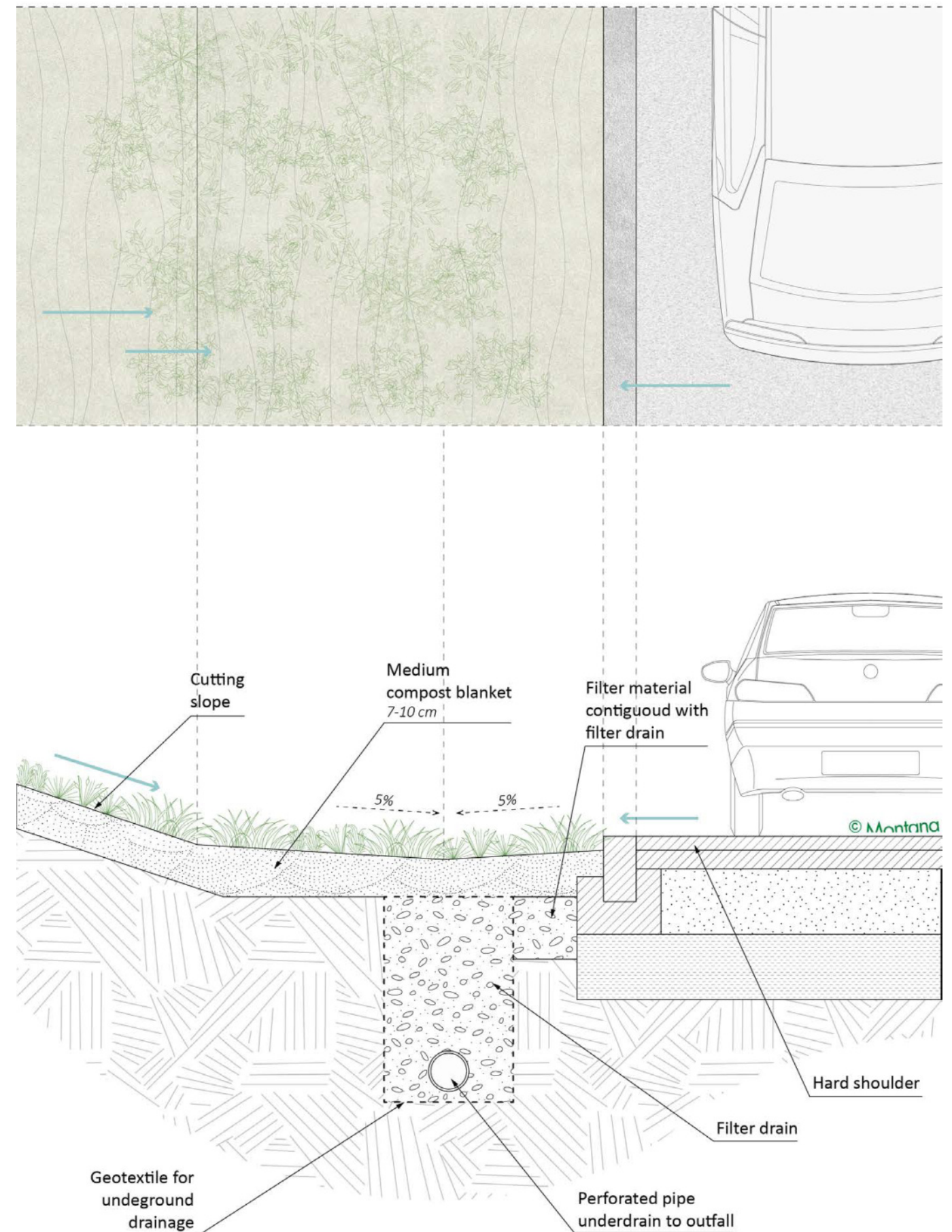
Interception design

Bioretention areas can only deliver a **small contribution to interception** (the prevention of runoff for the majority of small events) where they do not allow infiltration. Some water will soak into the filter medium and will also be removed by evapotranspiration and infiltration (where allowed) even if permeability levels are very low.

Treatment design

Unless infiltration is allowed, **filter drains will not provide a significant reduction in contaminant loads to surface waters via volumetric runoff control**, as they can only provide limited Interception.

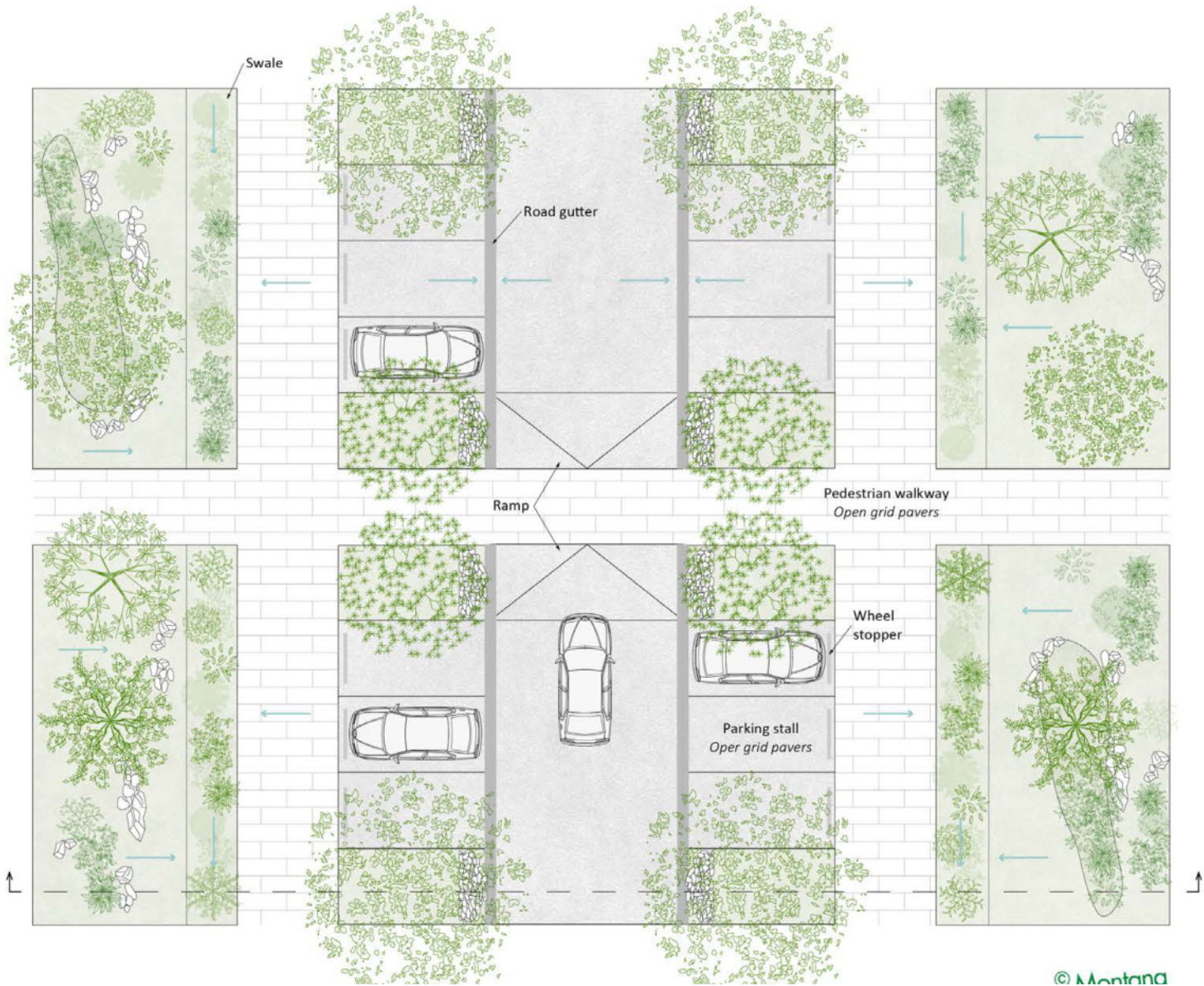
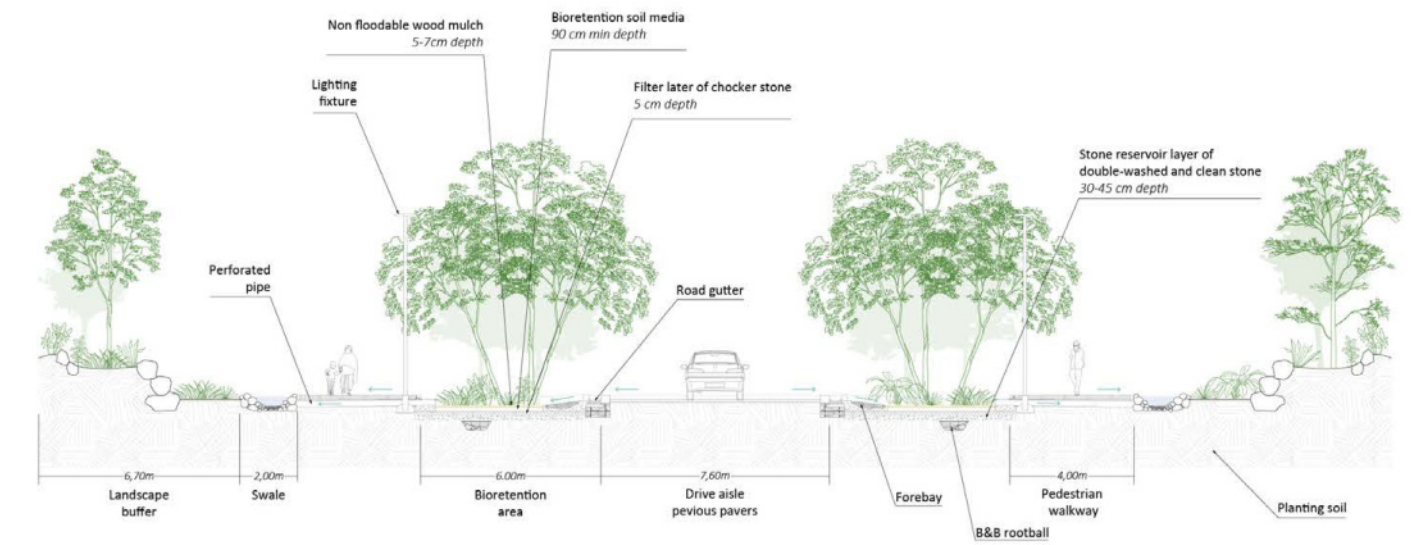
The acceptability of allowing infiltration from the bioretention areas will depend on the extent of the likely runoff contamination and site characteristics.



→

Plan and section of a bioretention area next to a road.

Sections: Montana S.p.A.
Pic source: Montana S.p.A.



↑ →
Al Urubah Park, KSA.

Water design by Montana S.p.A.
Pic credit: LAND

←
Detailed plan and section of the bioretention pockets between the parking stall, the permeable pedestrian walkway and the swall.
Al Urubah Park, KSA.

Project: Montana S.p.A.



Bioswale

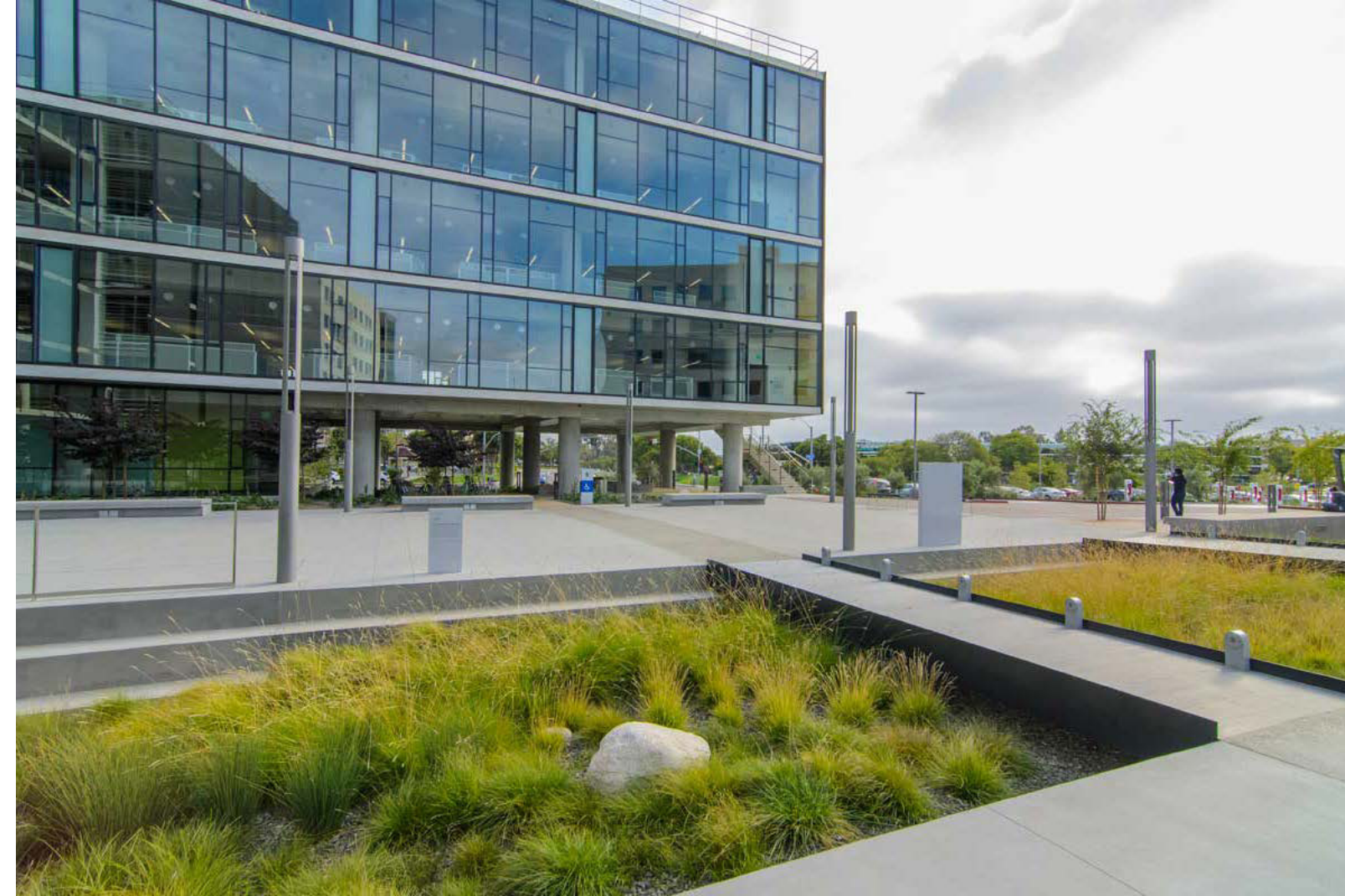
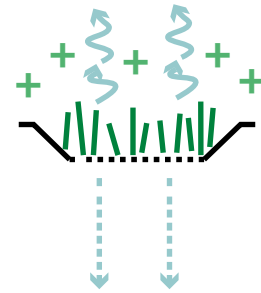
A bioswale is an **open, gently sloped, vegetated channel** designed for **treatment, store and conveyance of stormwater runoff**.

Bioswales are a **bioretention device** in which pollutant mitigation occurs through phytoremediation by facultative vegetation.

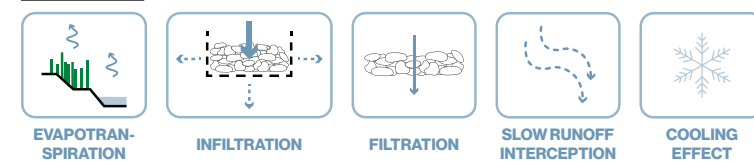
Bioswales **combine treatment and conveyance services**, reducing land development costs by eliminating the need for costly conventional conveyance systems.

The main function of a bioswale is to treat stormwater runoff as it is conveyed, whereas the main function of a rain garden is to treat stormwater runoff as it is infiltrated. Bioswales are usually **located along roads, drives, or parking lots** where the contributing acreage is less than five acres.

Bioswales require curb cuts, gutters or other devices that direct flow to them. They may require an underdrain where soil permeability is limited, as well as an overflow grate for larger storm events.



FUNCTIONS



SDGS GOALS

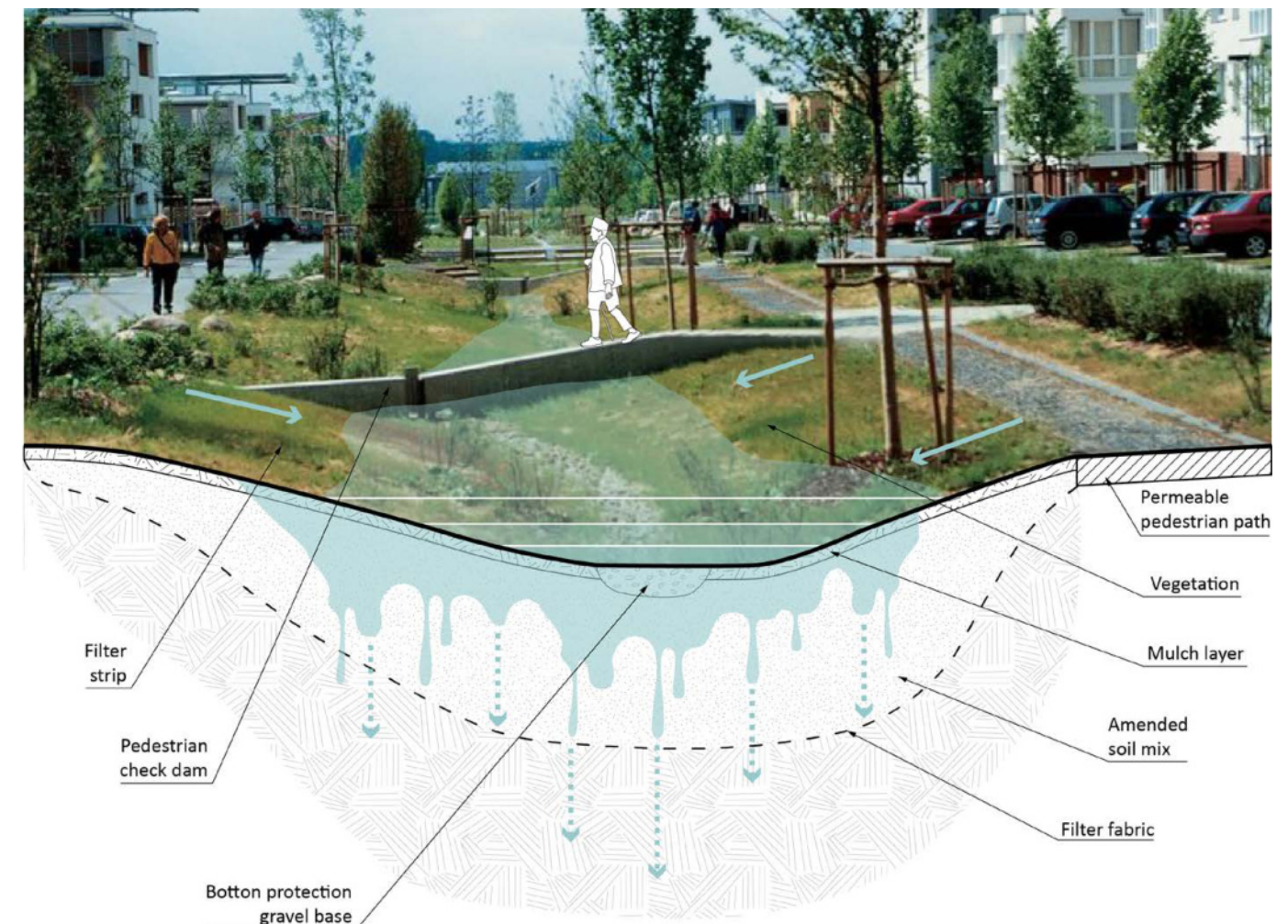


Qualcomm Pacific Center Campus / San Diego, California.

Pic source: mooool

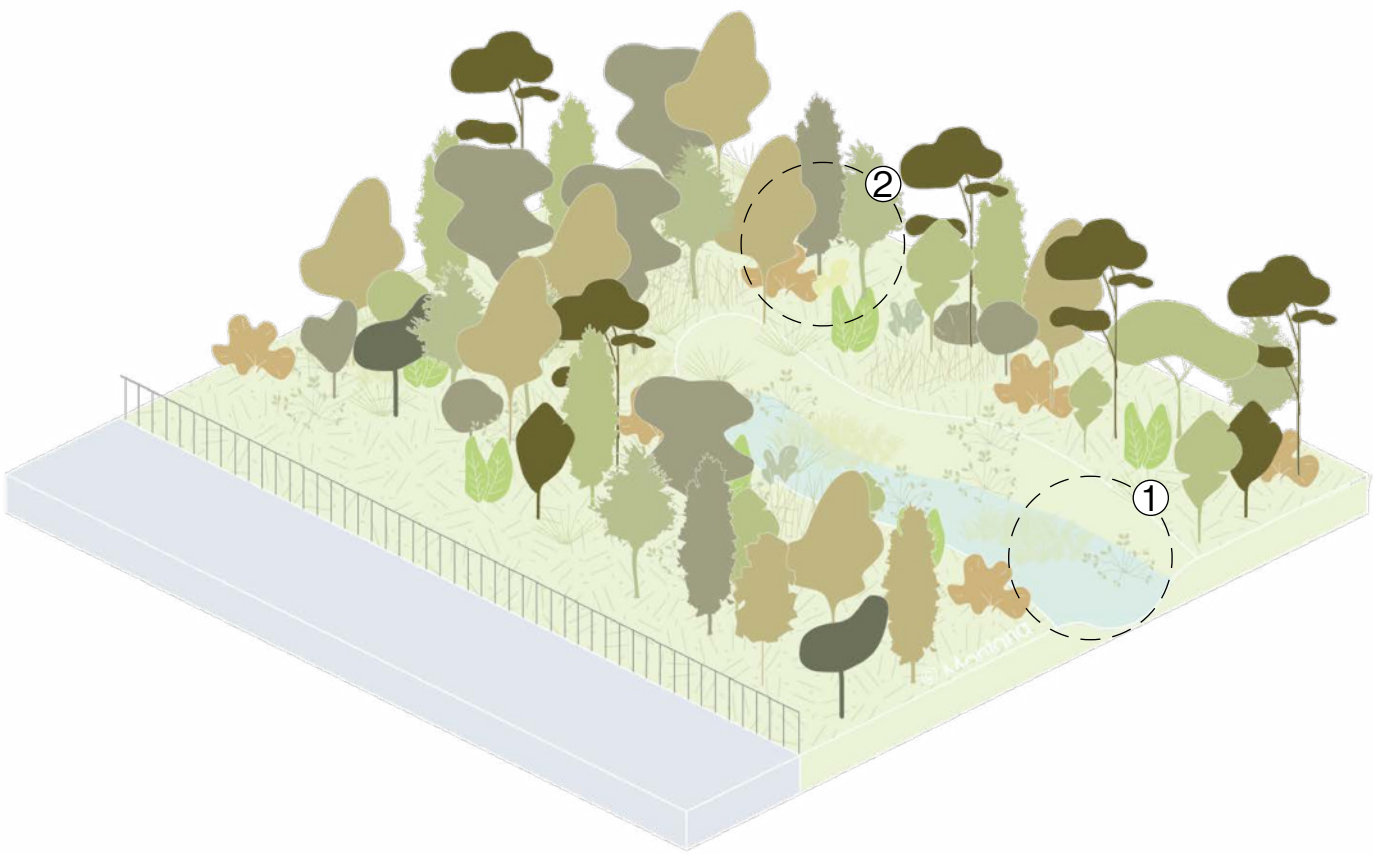
Infographic: Montana S.p.A.

Pic source: Urban Green Blue Grids



Visualization

Visualization of bioswales in an urban context



Details of increased benefits for the urban living environment



Bioswales **convey stormwater runoff** and promote **pollutant removal** through phytoremediation by facultative vegetation, with subsequent **filtration** occurring during infiltration through the underlying soil profile.

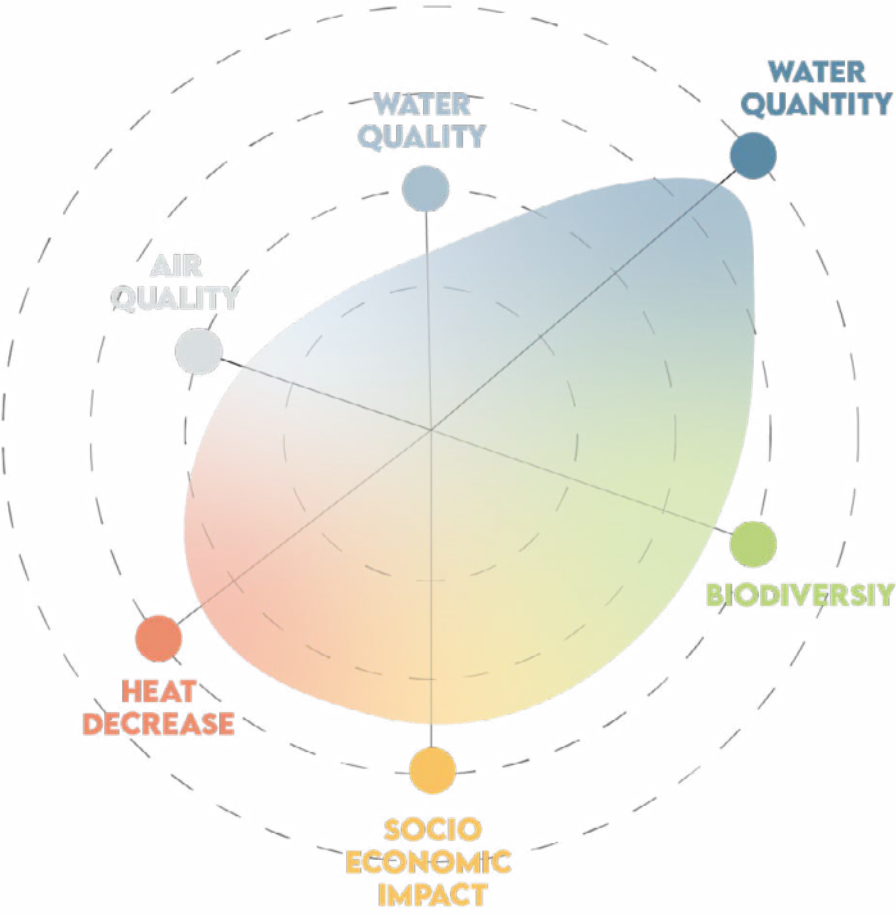


If well vegetated, bioswales foster heterogeneous **habitats**. Common plant species such as sedges, rushes, and wildflowers provide **resources for pollinators** and herbivores, while also promoting soil stabilization and attracting a **variety of fauna**, maintaining **ecological balance**.

Swale on Yale, Seattle, Washington
Pic source: Kpf



Benefits



→ Jaktgatan and Lövängsgatan, Stockholm, Sweden.
Pic source: Landezine
←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Bioswales help improve the urban water system, buffering rainwater allowing it to infiltrate, minimising overflow, improving the quality of surface water and preventing the ground from drying out.
(BioSwales | Urban Green-Blue Grids, n.d.).

Water quantity and runoff control

Bioswales slow, convey, and temporarily store stormwater runoff within shallow vegetated channels, promoting infiltration and delaying discharge to the drainage network. By reducing runoff volumes and attenuating peak flows, they help limit sewer overload and support urban flood mitigation during rainfall events.
(EPA, 2022; Zeng et al., 2024; Rizzo et al., 2023).

Biodiversity

Planting suited vegetation can enhance both biodiversity and the aesthetic appeal of urban areas. Bioswales serve as ecological corridors, providing shelter for small mammals, amphibians, and insects.
(BioSwales | Urban Green-Blue Grids, n.d.).

Social interaction

Resident engagement can increase acceptance of bioswales and raise awareness of how everyday pollutants affect water quality. Where inflow connections cross private property, collaboration with residents is essential to ensure long-term functionality and shared community benefits.
(BioSwales | Urban Green-Blue Grids, n.d.).

Heat decrease

Vegetated swales can help moderate local temperatures by increasing surface albedo, reducing heat storage in paved areas, and improving the street-level microclimate, especially when placed along sidewalks or traffic lanes.
(BioSwales | Urban Green-Blue Grids, n.d.).

Air quality improvement

Vegetation and water surfaces in bioswales can provide a small positive contribution to air quality by helping capture particulate matter. When used as buffers or traffic-calming elements, bioswales may also indirectly support emission reduction by lowering vehicle speeds and encouraging walking and cycling.
(BioSwales | Urban Green-Blue Grids, n.d.).



Site selection

Bioretention systems are applicable to most types of development, and can be used in both residential and non-residential areas to mitigate polluted runoff from roads. Bioswales should be at least **3 m above ground water**, or 1,2 m above seasonal high water table, to allow adequate infiltration and drainage.

Dimension

Swales should typically be designed with a trapezoidal or parabolic cross-section, as these configurations are the most straightforward to construct and maintain, while also providing excellent hydraulic performance. Grass swales are generally designed with a bottom width of 0.5 to 2.0 meters; however, narrower or wider swales may be utilized if a suitable assessment has been conducted. The standard maximum depth for swales is 400–600 mm. This depth may be increased if deemed acceptable following a health and safety risk assessment. The swale depth may also be influenced by the required depth of inflow pipework, such as that from a permeable pavement sub-base or other upstream components.

Slope gradient

Longitudinal **slopes** should be maintained **between 0.5% and 6%**. For slopes exceeding 3%, check dams should be incorporated, potentially allowing slopes to increase up to 10%. In cases where flow velocities surpass the recommended limits for standard designs, the use of permanent reinforcement matting should be considered. For conveyance swales with slopes less than 1.5%, underdrains are required, or alternatively, wet swales can be considered for such conditions.

Side slopes should be as flat as possible to facilitate the pre-treatment of lateral inflows by maximizing the swale’s filtering surface, enhancing safety, and ensuring easy access for mowing. Steeper side slopes are prone to erosion channelling from incoming lateral flows. A maximum slope of 1 in 3 (33%) is recommended, with a preferred slope of 1 in 4 (25%) where space allows, to simplify mowing. Side slopes may be increased if all technical and safety implications have been thoroughly evaluated.

Treatment design

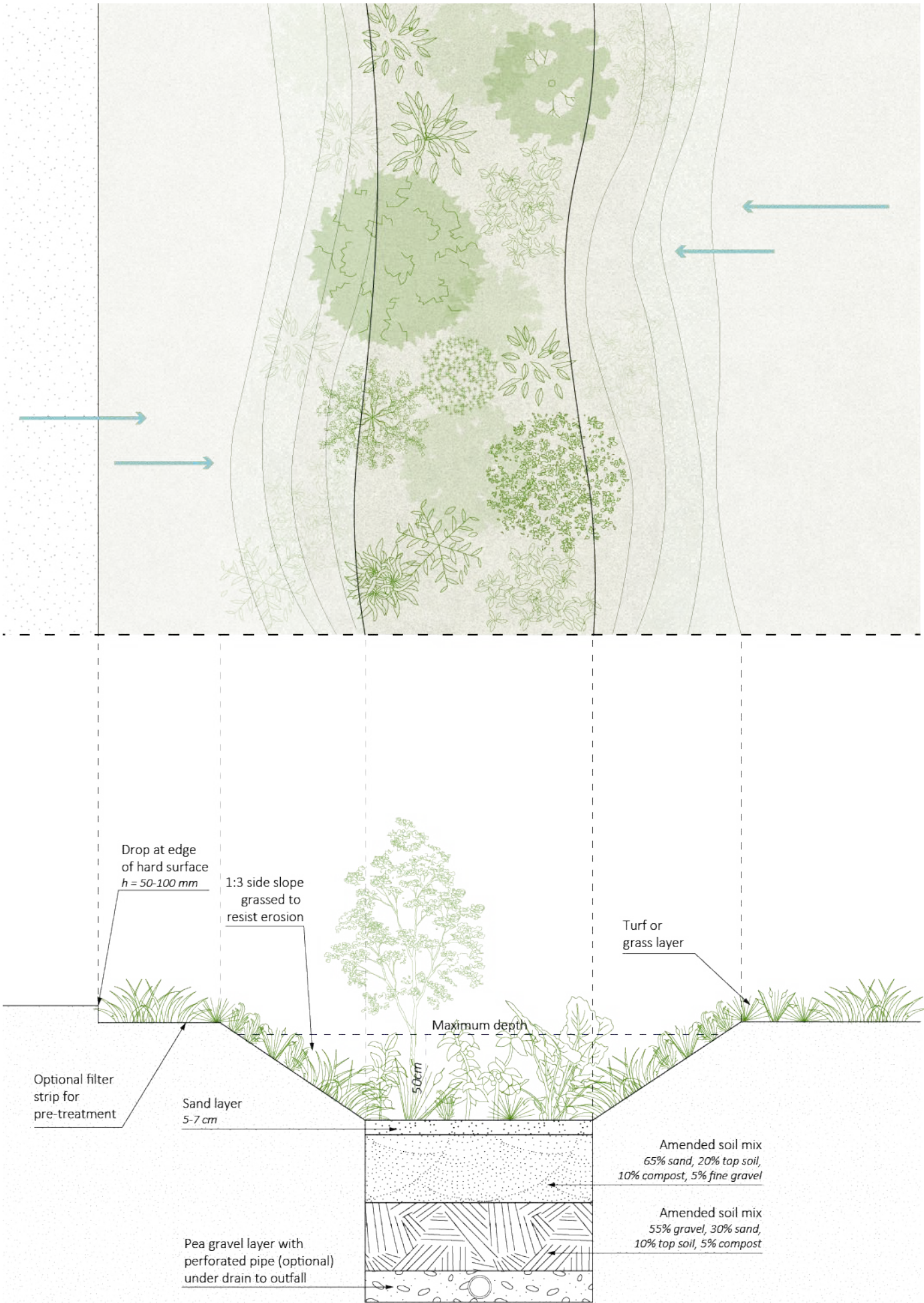
Swales can retain runoff from minor events on-site, thereby reducing the contaminant load discharged to surface waters through volumetric control. Additionally, they can treat residual runoff through various methods. The acceptability of allowing infiltration from the swale will depend on the anticipated level of runoff contamination and specific site characteristics.

Maintenance

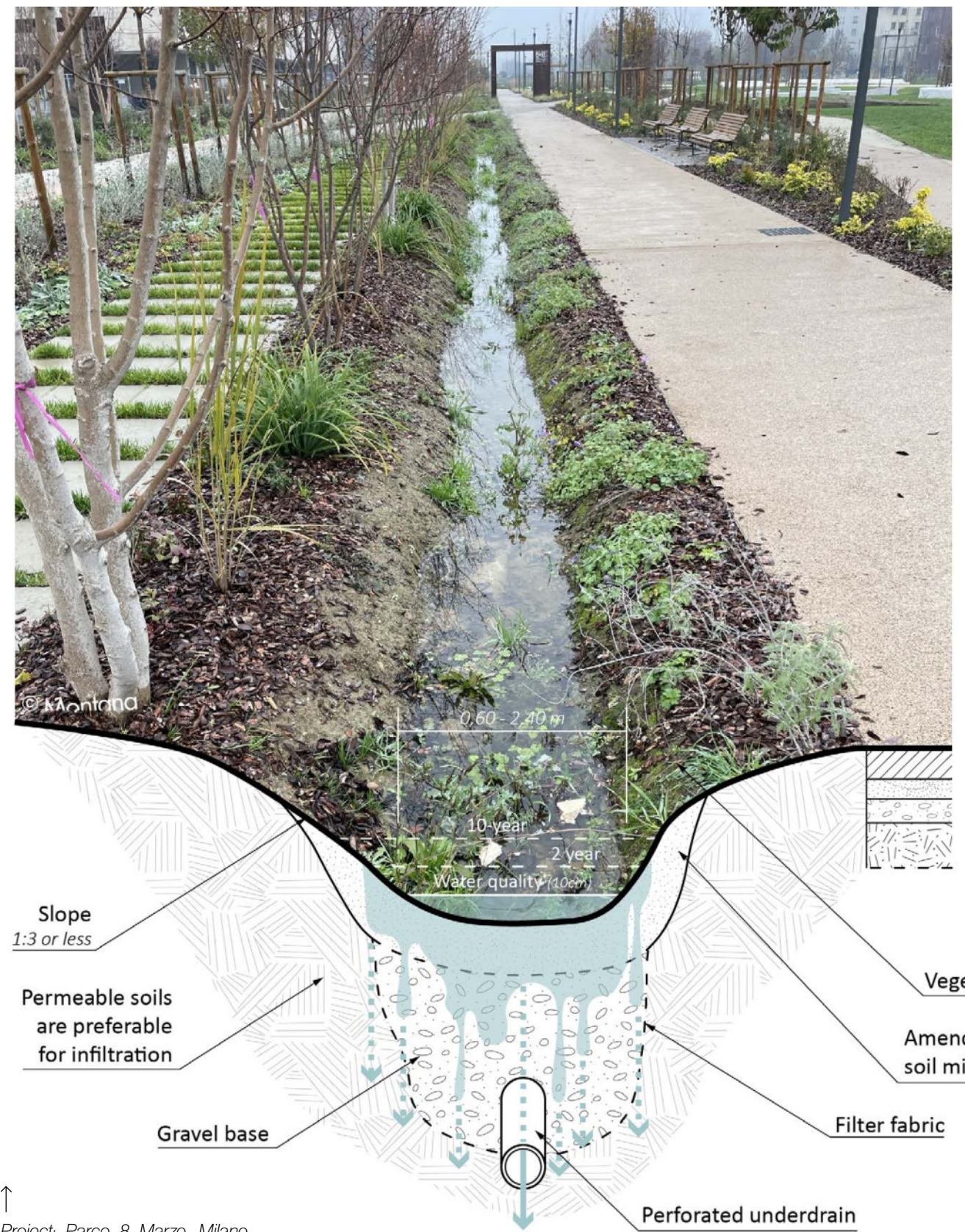
It’s important that the storage capacity and functional integrity of the bioswale be maintained through regular monitoring and maintenance of vegetation, infiltration capacity and structures. Regular inspection of bioswale should be conducted to identify signs of erosion, accumulation of debris around structures and sign of excessive sedimentation. Soil infiltration capacity should be tested annually to determine if soil are becoming clogged.

Materials

Bioswales consist of an **underdrain system, filter media, vegetation** and a **pre-treatment forebay**. It’s also possible to place berms, check dams or weirs to promote settling and infiltration. The perforated pipe should have a diameter of 0,10m. Aggregate gravel or equivalent filter material as the underdrain system. It’s important to place a permeable nonwoven **geotextile filter** fabric between the gravel and the overlaying permeable filter media. The filter media for bioswales consists of a permeable layer that is a minimum of 0,60 m deep.



→
Plan and section of a bioswale.
Sections: Montana S.p.A.
Pic source: Montana S.p.A.



↑
Project: Parco 8 Marzo, Milano
by Montana Sp.A., Studio Laura
Gatti, Studio Fabio Nonis.
Bioswale after a storm event.

Infographic: Montana Sp.A.
Pic source: Montana Sp.A.

←
Qualcomm Pacific Center
Campus / San Diego, California.
Pic source: mooool

Swale's types

Conveyance and attenuation swale

The conveyance swale is a shallow vegetated channel. These are particularly effective ways of **collecting and conveying runoff from the drained area** to another stage of the system. Vegetation in the swale should typically be maintained at a height of 75–150 mm to prevent flattening during flow events. **Good pollutant removal** performance is required for all runoff events up to and including events which occur, on average, about once a year. Check dams and appropriate pre-treatment systems can be used to improve both hydraulic and water quality performance of a swale system by reducing velocities, increasing residence time and increasing infiltration or storage.

Dry swale

The dry swale is a **vegetated conveyance channel**, designed to **include a filter bed** of prepared soil that overlays an underdrain system. This underdrain provides additional treatment and conveyance capacity beneath the base of the swale, and prevents waterlogging. The enhanced drainage beneath the swale can **provide increased flow and storage capacity**, extra interception performance, a reduced risk of localised ponding and marshy areas developing where gradients are at, and improved conditions for infiltration. Dry swales that are served by an underdrain need not have an above-ground outfall and can therefore act as a connected length of detention basins.

Wet swale

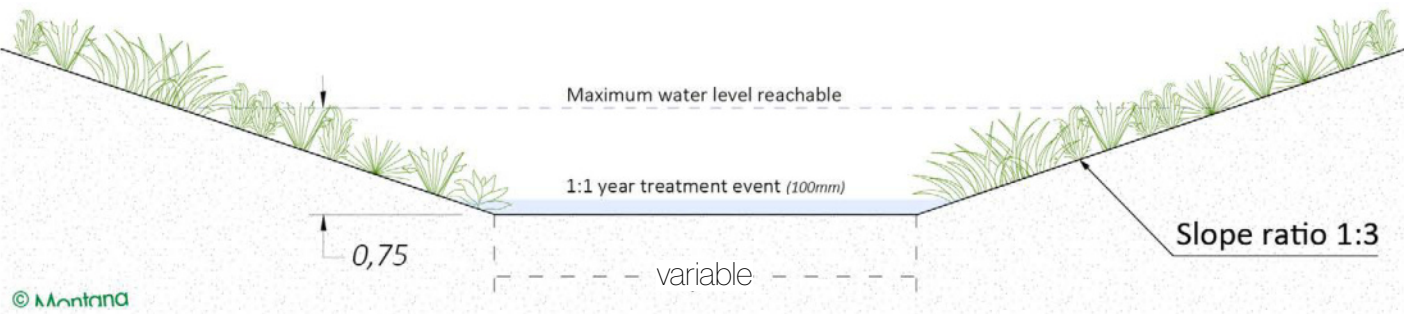
This system is equivalent to the conveyance swale, but is **designed specifically to deliver wet and/or marshy conditions** in the base. They can be used where sites and soils are poorly drained and/or to deliver the functionality or amenity or biodiversity requirements of a longitudinal pond/wetland component. For this kind of swale are required some specific wetland planting. A permanently wet swale base can provide different zones for the removal of fine particles, acting as small linear pond/wetland systems. Wet swales are usually appropriate where sites are very flat and soils are poorly drained, but can be designed for more permeable sites using impermeable liners to deliver specific treatment performance or amenity or biodiversity requirements.



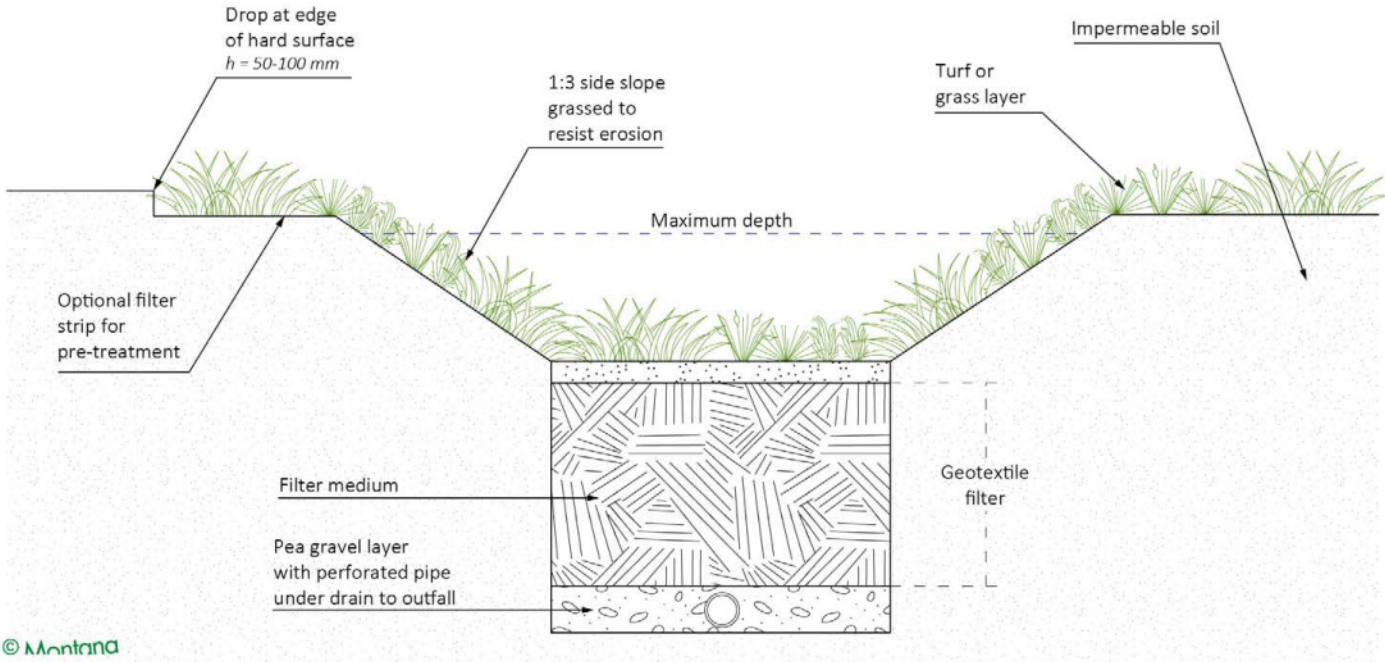
↑
Bioswale, Durando Campus, Milan, Italy.
Water design: Montana S.p.A.
Pic source: Montana S.p.A.

→
Sections of a conveyance swale, a dry swale and a wet swale.
Sections: Montana S.p.A.
Pic source: Montana S.p.A.

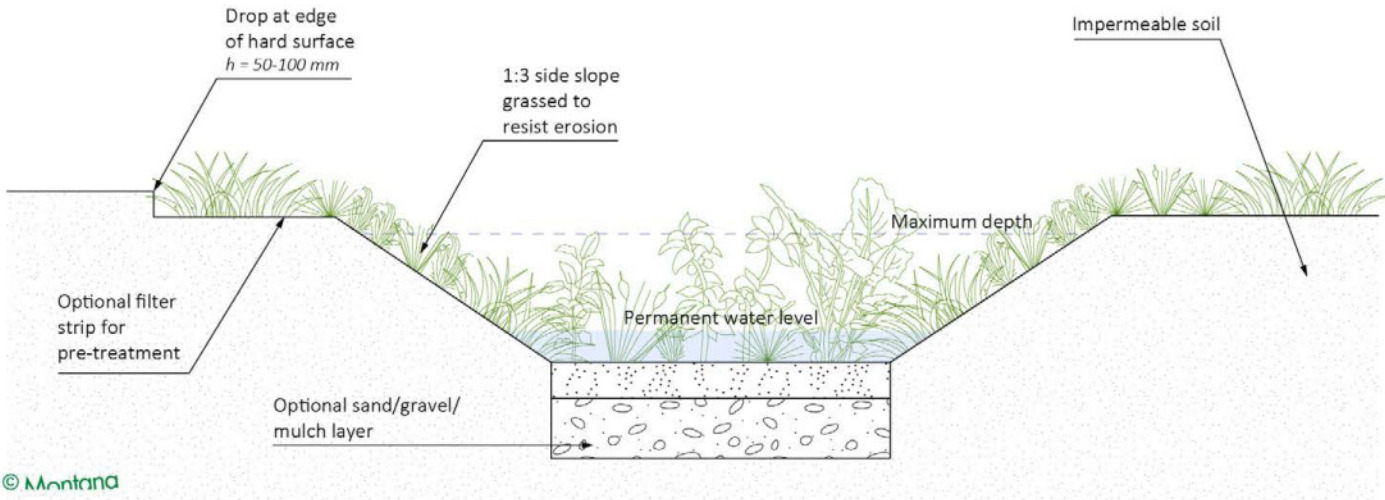
Conveyance swale



Dry swale



Wet swale



Public and urban scale interventions

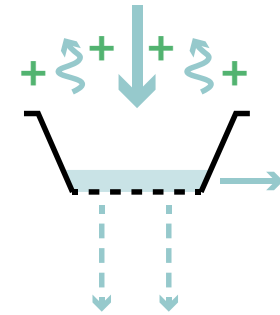
Detention pond

Detention ponds, or dry ponds, are stormwater basins designed to intercept stormwater runoff for temporary impoundment and metered discharge to a conveyance system or a receiving waterbody.

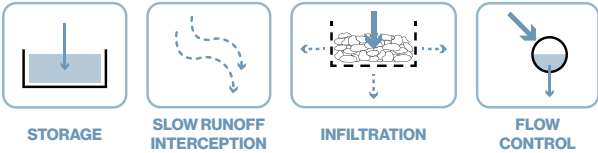
They can be **on-line components** where surface runoff from regular events is routed through the basin and when the flows rise, because the outlet is restricted, the basin fills and provides storage of runoff and flow attenuation.

They can also be **off-line components** into which runoff is diverted once flows reach a specified threshold.

Detention basins can be **vegetated depressions** or **hard landscaped storage areas**. Where the basin is vegetated, the soil surface can absorb some runoff, so can be used to support the prevention of runoff from the site for small rainfall events (Interception), provided that small amounts of infiltration would not pose a risk to groundwater.



FUNCTIONS



SDGS GOALS



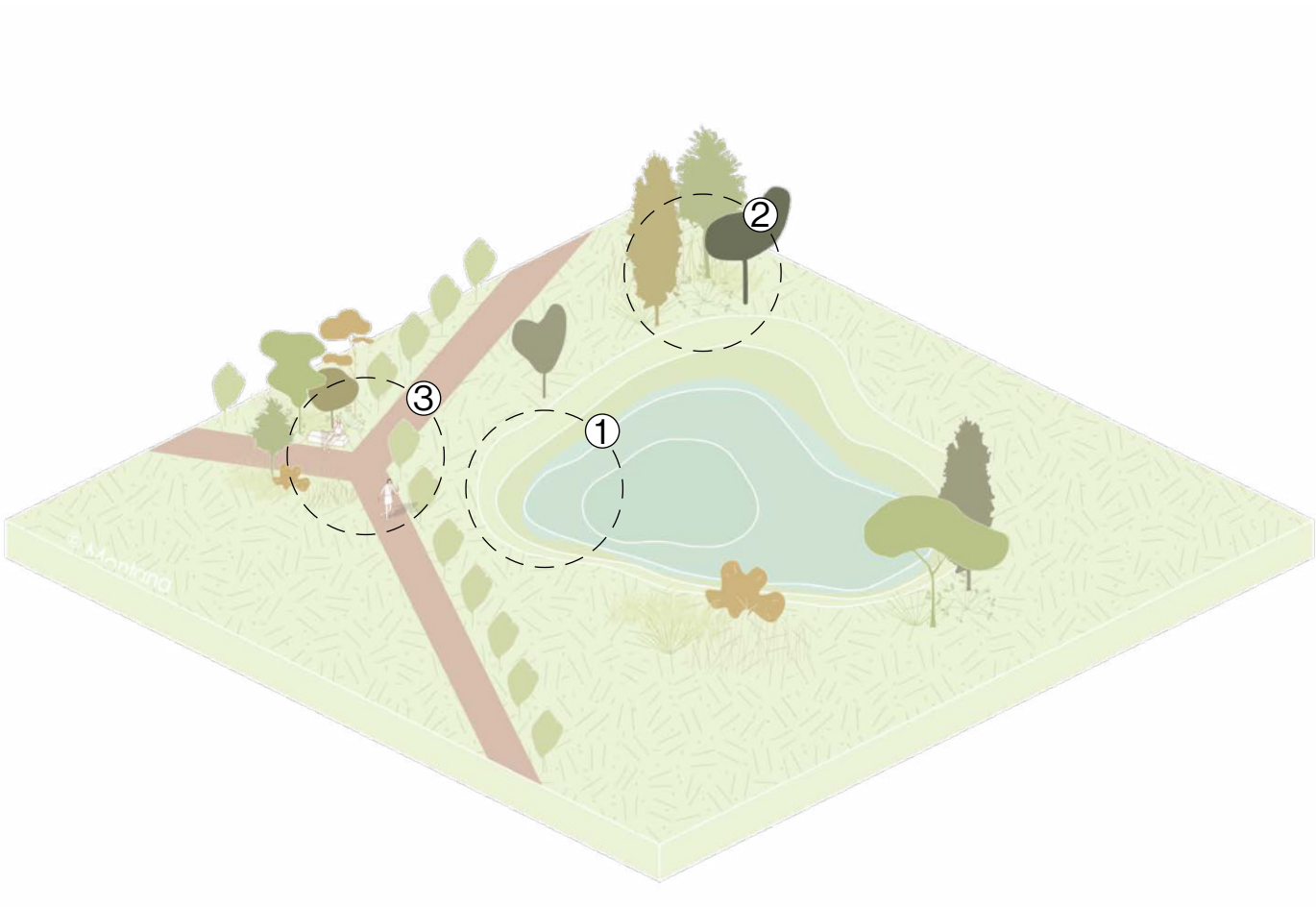
↗
Elsa Eschelsson's Park, Uppsalla, Sweden.
Pic source: Landezine

→
Rotterdam's public water square to manage the water drainage.
Pic source: Archdaily



Visualization

Visualization of detention ponds in an urban context



Details of increased benefits for the urban living environment



A detention pond temporarily stores runoff and gradually releases it, helping **control water flow, mitigate erosion, and promote sedimentation**, allowing pollutants to settle before the water is released systems.



If vegetated, a detention pond supports biodiversity by **providing habitats for a range of plant and animal species**. Aquatic plants, grasses, and shrubs offer food and shelter, while the pond attracts insects, birds, and small mammals, contributing to local ecological balance.

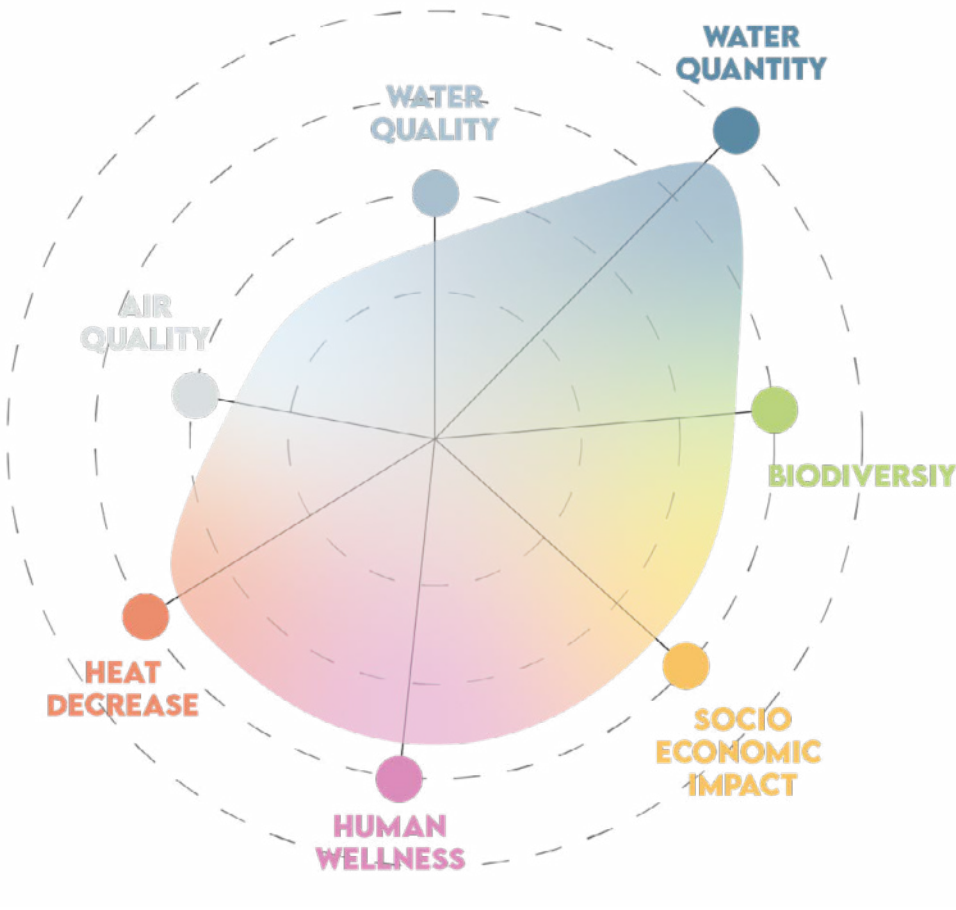


This solution can offer **recreational benefits**, providing spaces for passive activities such as walking or birdwatching if the pond is designed as vegetated, or active activities if the pond is designed to sport facilities when not used to store water



Boughton House Garden, UK.
Pic source: Gardenvisit

Benefits



← This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Heat decrease

Detention ponds contribute to urban cooling through evaporative heat loss and by replacing heat-absorbing sealed surfaces. Appropriately sized and configured water bodies can lower local air and surface temperatures. (Ampatzidis et al., 2023).

Air quality

Detention ponds influence air quality mainly indirectly: cooler, more humid microclimates, can slightly reduce local ozone formation and dust resuspension, while vegetation captures some particulate matter and gaseous pollutants on leaf surfaces. (Hassall & Anderson, 2015; Marselle et al., 2020; World Health Organization, 2021).

→ Example of a detention basin with multifunctional use.

Pic source: Pinterest

↓ BasketBar, Utrecht, The Netherlands

Pic source: NL Architects



Water quality and sediment management

Substantial reductions in total suspended solids and notable, though variable, removal of nitrogen, phosphorus and some pathogens, with performance strongly influenced by pond design, soil and vegetation management (Jeon et al., 2021; Moghadam et al., 2023; Marques & Mandrak, 2024.).

Water quantity and runoff control

Detention ponds temporarily store stormwater runoff during rainfall events and release it gradually through controlled outlets. By delaying discharge and attenuating peak flows, they help reduce pressure on drainage networks, limit downstream flooding, and improve overall stormwater management at site or catchment scale. Their performance depends on available storage volume, inlet and outlet design, contributing drainage area, rainfall intensity, and maintenance of the basin. (EPA, 2021; CIRIA, 2015; Susdrain, n.d.; Nature Scientific Reports, 2023)

Biodiversity

When designed with aquatic vegetation, detention ponds function as small urban wetlands that host macrophytes, invertebrates, amphibians and waterfowl, often reaching species richness comparable to natural or unmanaged ponds in cities (Hassall & Anderson, 2015; Hill et al., 2017; Marques & Mandrak, 2024).

Social interaction

This solution can increase nearby property values, create attractive public spaces and support education and citizen engagement when paths and viewing areas are integrated into the design. (Irwin et al., 2017; Ghermandi & Fichtman, 2015; Johansson, 2025).

Human wellness

Access to water features has been linked to reduced stress, better self-reported general health and improved mental well-being, especially when they are clean, biodiverse and easy to reach on foot or by bike (World Health Organization, 2021; Marselle et al., 2020; Smith et al., 2021; Sani et al., 2025).



Dimension

The recommended **length/width ratio** for on-line vegetated detention basins is **between 3:1 and 5:1**.

Site selection

Detention basins are generally **applicable to most types of development**, and can be used in both residential and non-residential areas. They are also **appropriate for use in retrofit situations**.

They can often be designed as **multi-functional spaces**, creating an open area within a development, part of which can be made available for recreational purposes. **Roundabouts can also often provide suitable space** that is redundant within the existing or proposed development landscape.

Slope gradient

Side slopes of any vegetated basin should not usually exceed 1 in 3 unless special site and/or safety arrangements allow for steeper slopes (eg steeper slopes may be acceptable for very shallow basins).

Slopes should be no steeper than 1 in 3 wherever mowing is required, to reduce the risks associated with maintenance activities.

Water depth

The maximum depth of water in the basin should not normally exceed **2 m** in the most extreme design event. However, many authorities will require a much lower maximum depth, for safety reasons.

Hydraulic design

Detention basins can be sized to provide **flood attenuation** for all events to meet the site standards of service (up to the 1:10, 1:30 or 1:100 year events), if required, with discharges being constrained to the equivalent greenfield (or other agreed) rates.

On-line/Off-line design

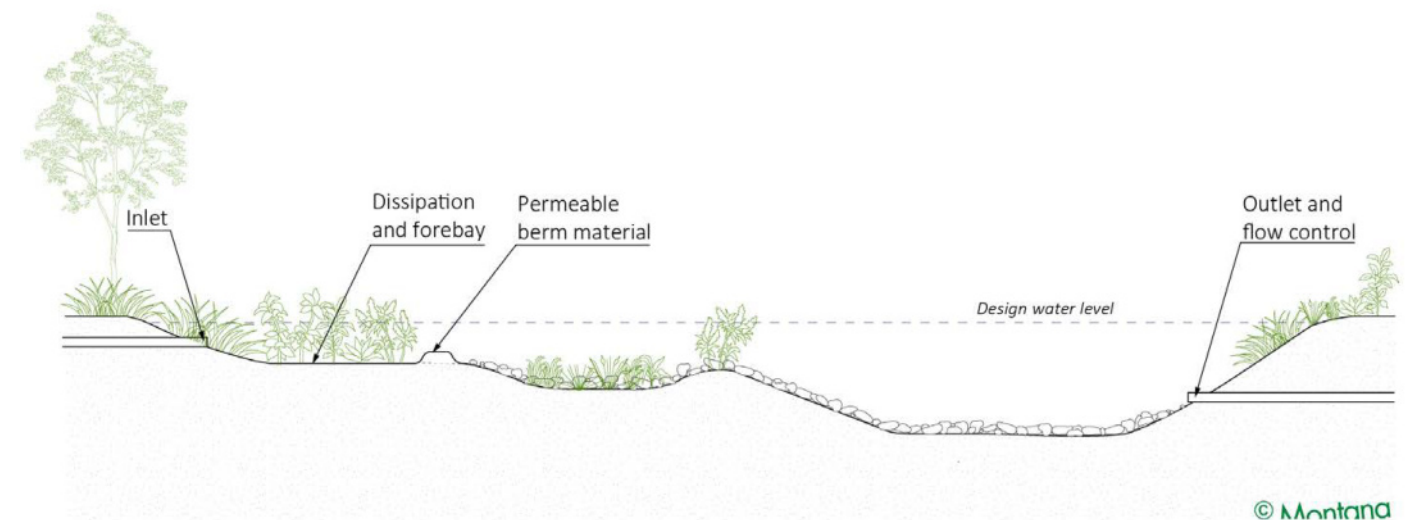
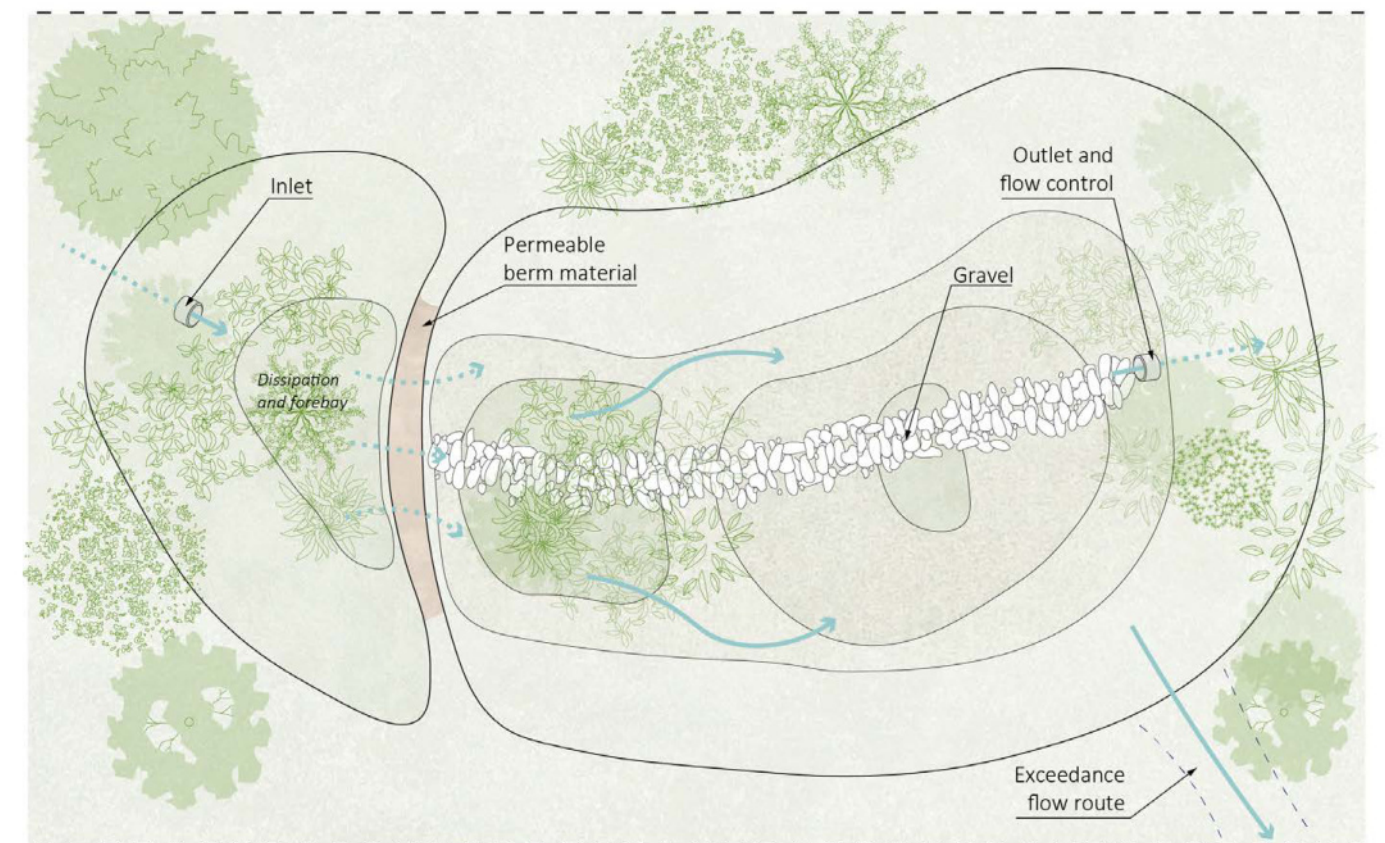
Detention basins may be constructed as **on-line or off-line facilities**.

On-line facilities have surface runoff routed through them during storm events. They have a restricted outflow that allows the basin to fill, thus attenuating flows.

Off-line facilities usually receive runoff via a flow diverter or overflow, by which flows in excess of a threshold value are diverted from the main flow path into the detention basin and temporarily stored. The water from the detention basin is passed back into the main system when the inflow falls below the diversion threshold. Off-line detention basins should be avoided where treatment of the runoff is important, because it is the lower flows that will generally pose the highest pollution risk.

Interception design

Vegetated detention basins can deliver some Interception because there tends to be no runoff from them for the majority of small rainfall events. The water soaks into the basin topsoil layer and is removed by evapotranspiration and even very small amounts of infiltration.



Plan and section of a detention pond.

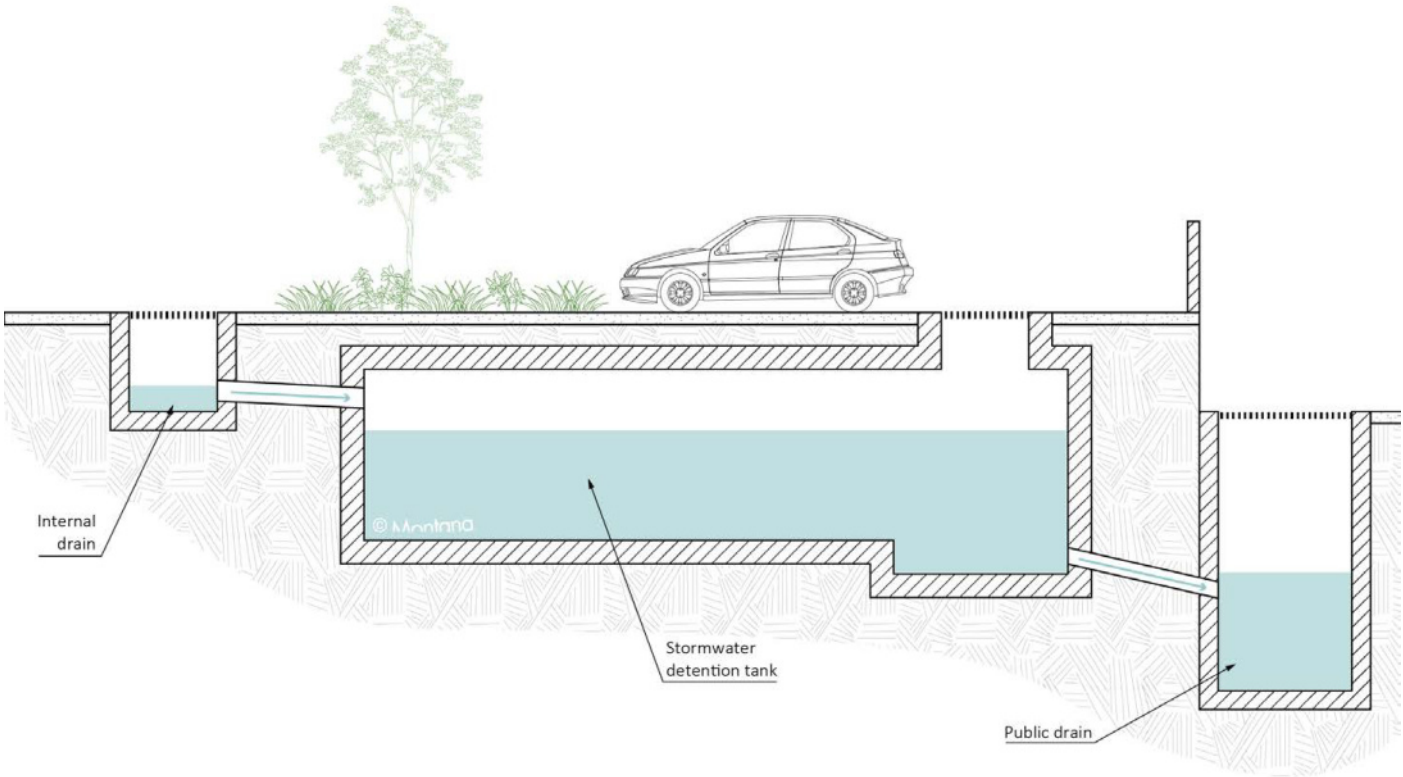
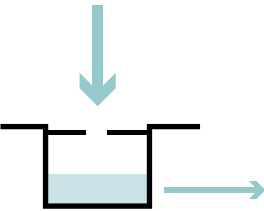
Sections: Montana S.p.A.

Public and urban scale interventions

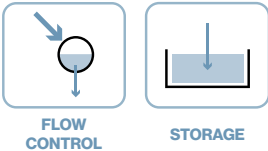
Detention tank

Detention tanks are **underground structures for stormwater runoff retention** where a **permanent pool is maintained**. Detention tanks contribute to stormwater flow attenuation, as well as minor treatment. As a result of permanent water retention, wet vaults are **able to remove more sediment** than other subterranean storage devices, which drain completely. Detention tanks do not empty in between storm events, but do slowly discharge storage into other stormwater facilities. This facility provides runoff volume control, peak discharge reduction, sediment control, and harvesting potential. Detention tanks are typically used where there is limited surface area for LID facilities.

Minimal maintenance is required. Periodic inspection of in-flow areas is needed along with removal of large debris, sediment, and settled pollutants.



FUNCTIONS



SDGS GOALS



↗
Plan and section of a detention tank under a parking.

Section: Montana S.p.A.

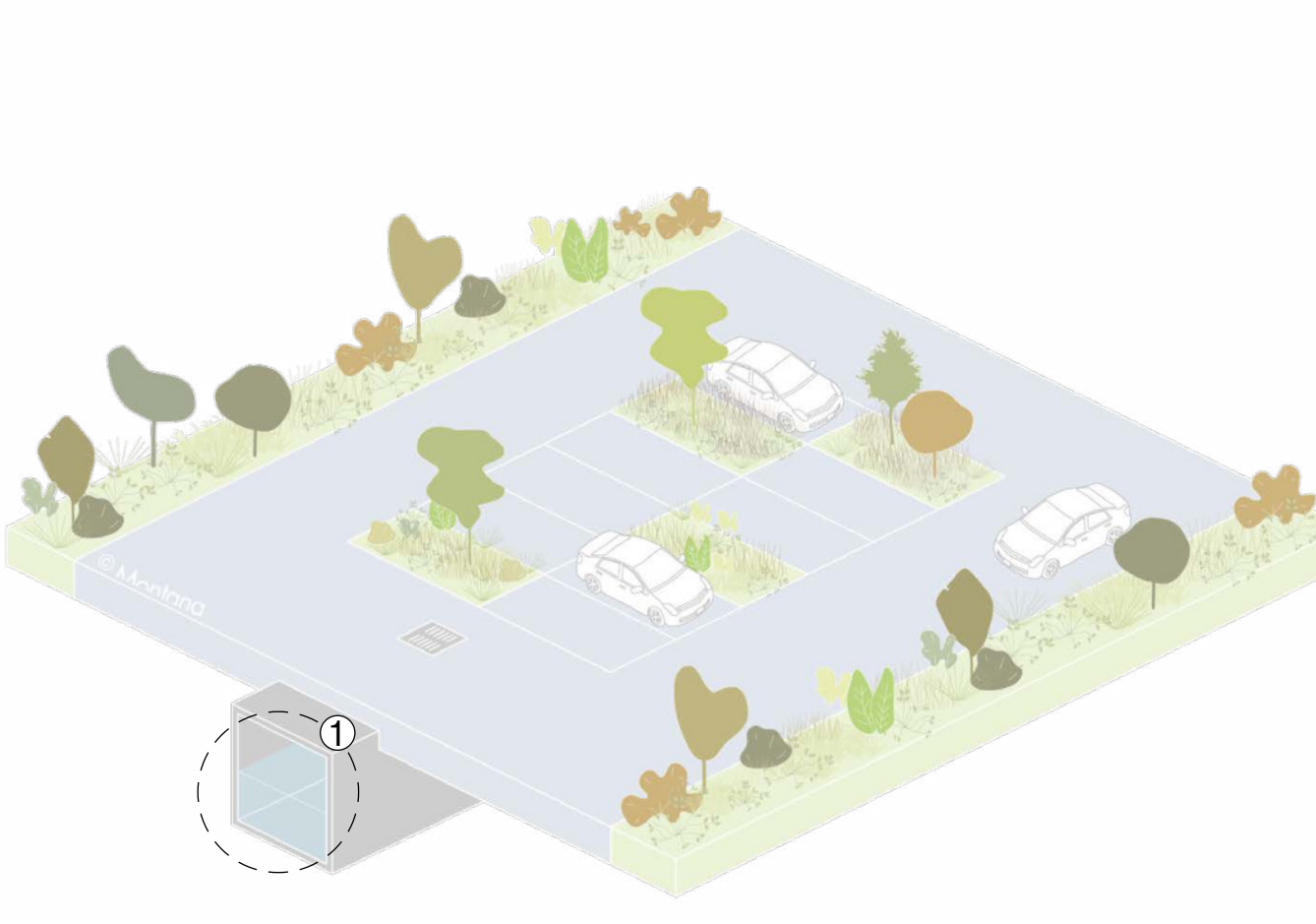
→
Example of an underground detention tank.

Source: Foley Products

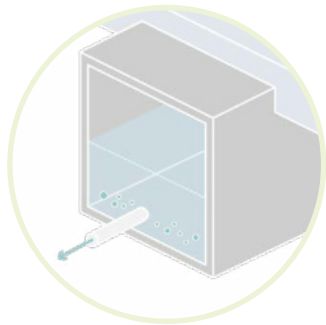


Visualization

Visualization of detention tanks in an urban context

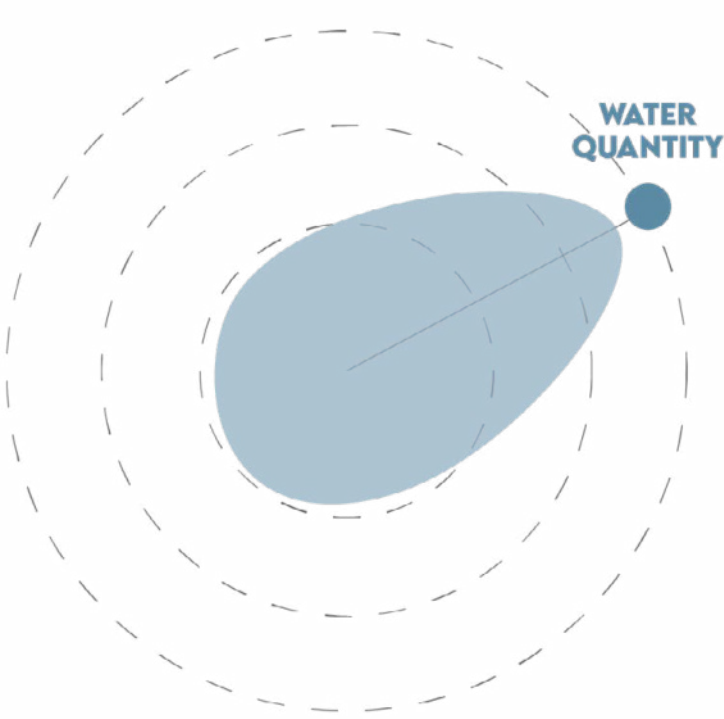


Details of increased benefits for the urban living environment



Detention tanks store stormwater runoff releasing it at a controlled rate. This prevents overwhelming the sewer system, **reduces flood risks**, and improves drainage. The system also helps minimize erosion and water pollution by providing **time for sediment and contaminants to settle before discharge**.

Benefits



↑
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water management

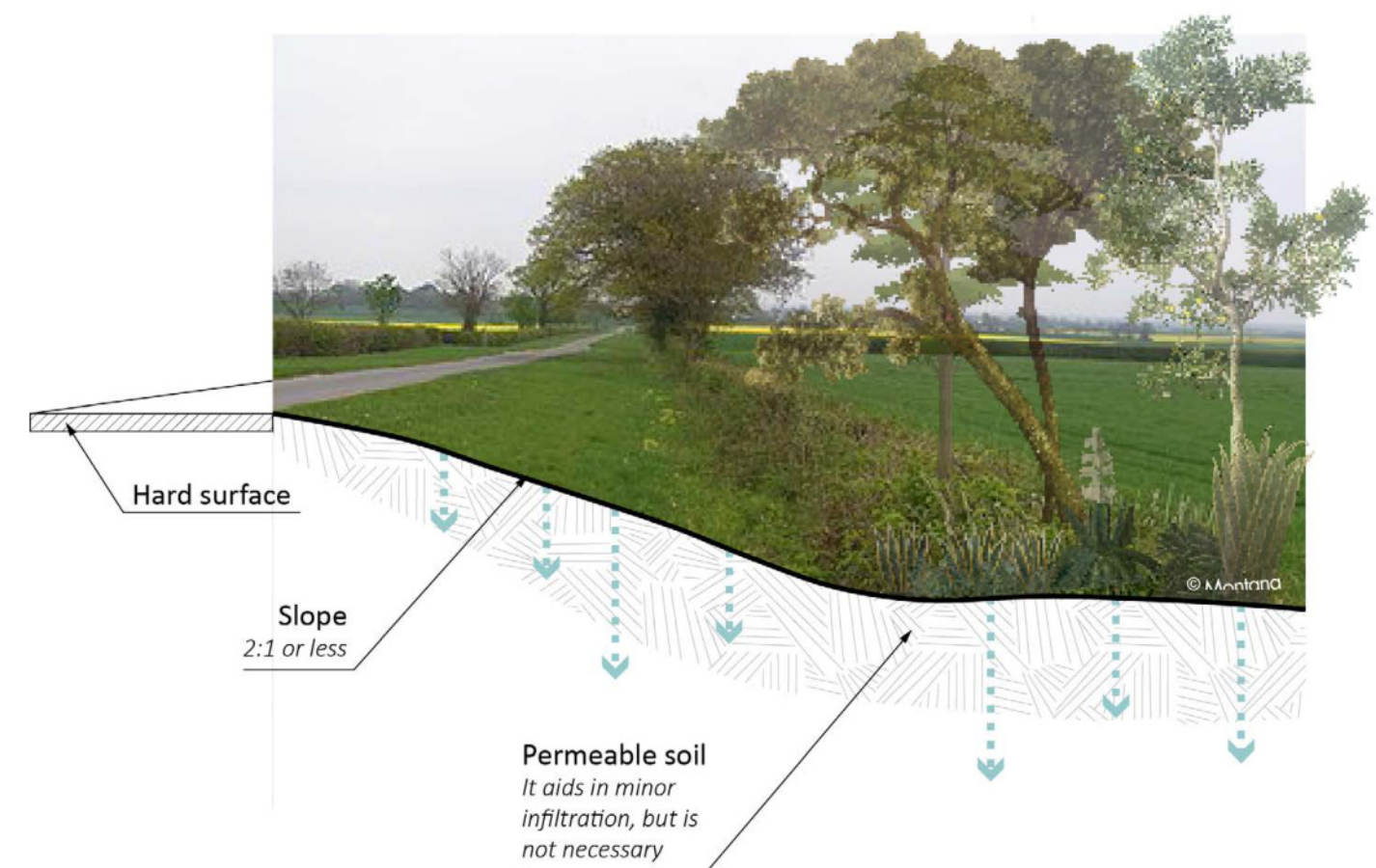
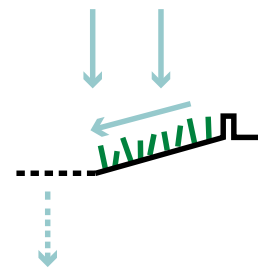
Detention temporarily store stormwater during rainfall events and release it in a controlled way, flattening hydrographs, reducing local flooding and combined sewer overflows, and helping drainage systems meet design and regulatory criteria. When combined with low-impact development measures and operated under multi-objective or real-time control strategies, they can simultaneously enhance downstream water quality, support rainwater harvesting and improve overall system resilience, making them an efficient and space-saving option for sustainable stormwater management in dense urban areas. (Barros et al., 2025; Li et al., 2019; Wang et al., 2023).

Filter strip

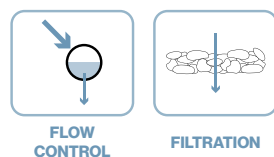
Filter strips are uniformly graded and **gently sloping strips of grass** or other dense vegetation that are designed to **treat runoff from adjacent impermeable areas** by promoting **sedimentation, filtration** and **infiltration**.

At low to moderate velocities, filter strips effectively reduce particulate pollutant levels by removing sediments, organic materials and heavy metals.

Filter strip design requirements are principally aimed at delivering water quality benefits and the filter strip performance will be dependent on its length.



FUNCTIONS



SDGS GOALS



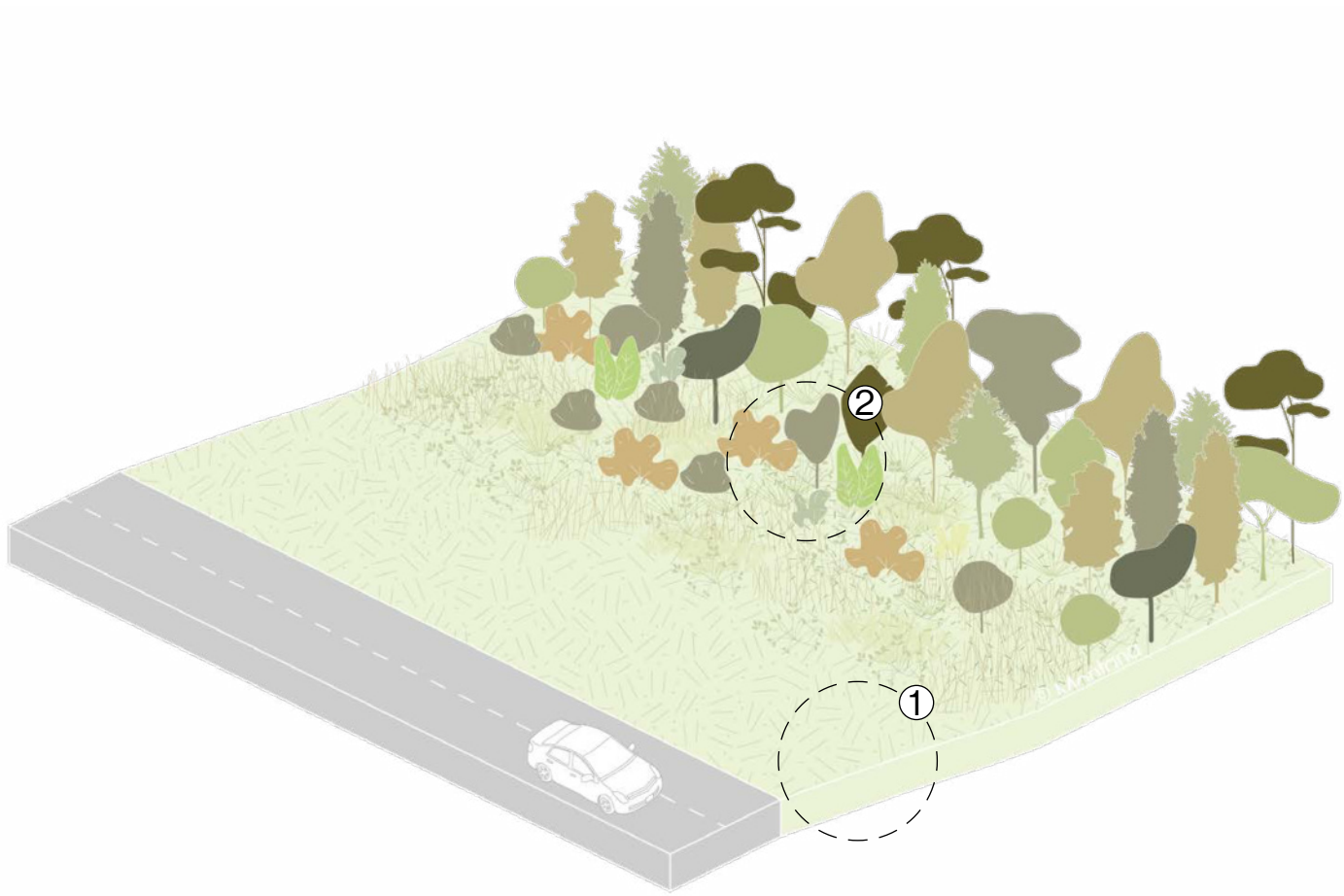
↗
Infographic: Montana S.p.A.
Pic source: Sustainable Technology

→
Example of a filter strip.
Pic source: Belfast City Council

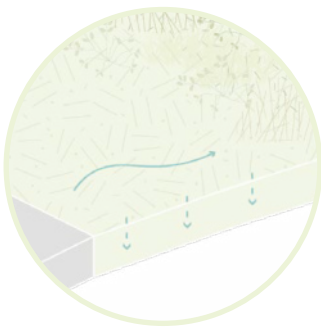


Visualization

Visualization of filter strips in an urban context



Details of increased benefits for the urban living environment

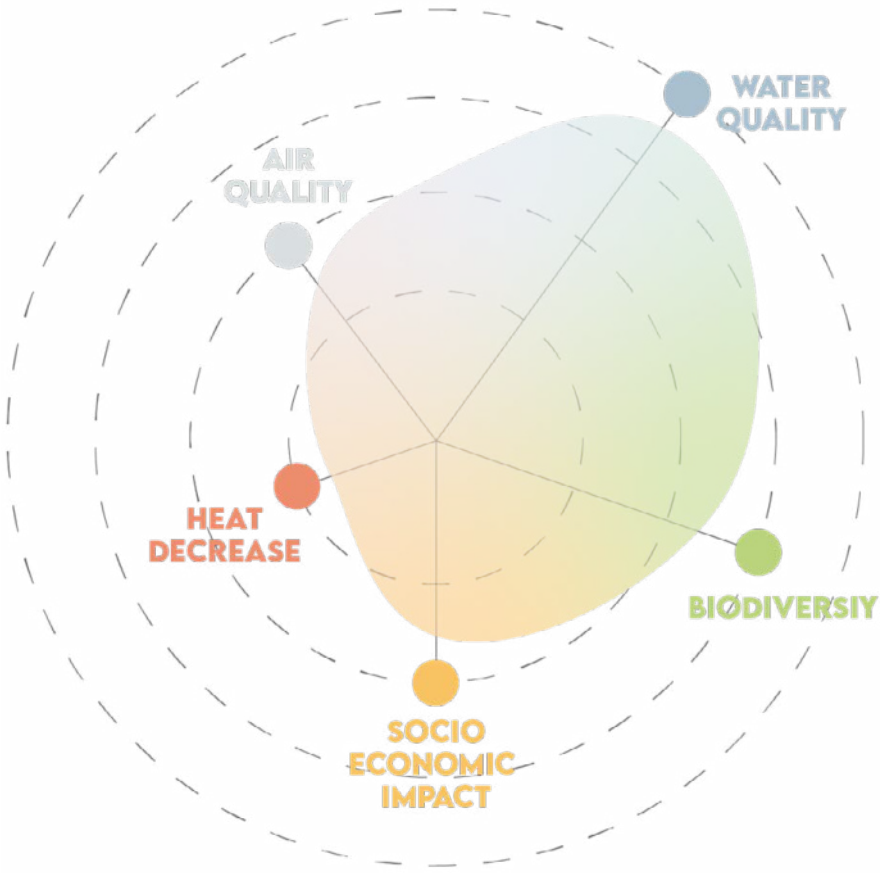


A filter strip captures runoff from impermeable surfaces allowing it to **infiltrate the soil**. These strips reduce pollutant levels, control erosion, and promote natural filtration, **improving water quality** before it reaches water bodies.



A well-vegetated filter strip enhances biodiversity by **supporting a variety of plant species**, including grasses, wildflowers, and shrubs, which **provide food** and shelter for **insects, birds, and small mammals**.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Filter strips slow and spread surface runoff so that sediments, nutrients and pesticides settle out or are taken up by vegetation before reaching drains and streams. (Smyth et al., 2016; Li et al., 2024)

Biodiversity

When planted with diverse native grasses, forbs and shrubs, filter strips act as semi-natural habitat and movement corridors in simplified agricultural or roadside landscapes. They support higher plant and invertebrate richness and help maintain connectivity for birds and other fauna across fragmented farmland. (Haddaway et al., 2018; Marshall & Moonen, 2002)

Social interaction

Filter strips along fields, road verges or in public spaces act as visible, easy-to-understand examples of nature-based management, improving how people perceive infrastructure, especially when they are flower-rich and wildlife-friendly. (Haddaway et al., 2018; Health Canada, 2023; Kent Wildlife Trust, 2018)

Heat decrease

Filter strips create shaded, moist micro-environments and increase evapotranspiration, which can modestly cool near-surface air and soil along fields, roadsides and stream banks. Evidence from riparian and urban-vegetation studies shows that densely vegetated strips reduce local peak temperatures, particularly near small water bodies, by limiting solar radiation and enhancing microclimate cooling. (Moore, Spittlehouse, & Story, 2005; Bowler et al., 2012)

Air quality

Along roads or dusty field edges, filter strips act as near-ground “green filters”: dense foliage captures traffic-related and wind-blown particulates on leaf surfaces and slows polluted air flows. Road-verge studies show substantial fine-particle deposition on shrub and herb layers and measurable reductions in near-road PM behind vegetated barriers, indicating a real contribution to local air-quality improvement. (Sillars-Powell et al., 2020; Greenwald et al., 2024)

Site selection

Filter strips can be used in a variety of situations but are particularly well suited for **managing runoff from roads** because they are a linear feature and easily incorporated into roadside space.

They are also suitable for managing runoff **from car parks and other impermeable and permeable areas**.

Filter strips **should be effectively incorporated into landscaping and public open spaces**, so that their function is not compromised by activity in the area.

They are **useful on industrial sites** because any visible pollution can be identified, the source traced, the contamination removed as far as possible and the strip rehabilitated relatively easily.

Dimension

Filter drain **depths** should generally be **1–2m**.

The minimum depth of filter medium beneath any inflow distribution pipework and outfall collection systems should be 0,5 m to ensure reasonable levels of pollutant removal.

Where infiltration is allowed, the maximum groundwater level should be at least 1 m below the base of the trench.

Hydraulic design

Filter strips should be designed with a **minimum longitudinal slope of 1%** (to prevent ponding) and a maximum slope of 5% to prevent flow channelling.

The top and bottom of the slope should be at the lower end of the allowable slope range to reduce flow velocities and thereby reduce the risk of erosion.

Where filter strip slopes are > 5%, a series of level spreaders can be used to maintain sheet flow as runoff flows over the strip.

Interception design

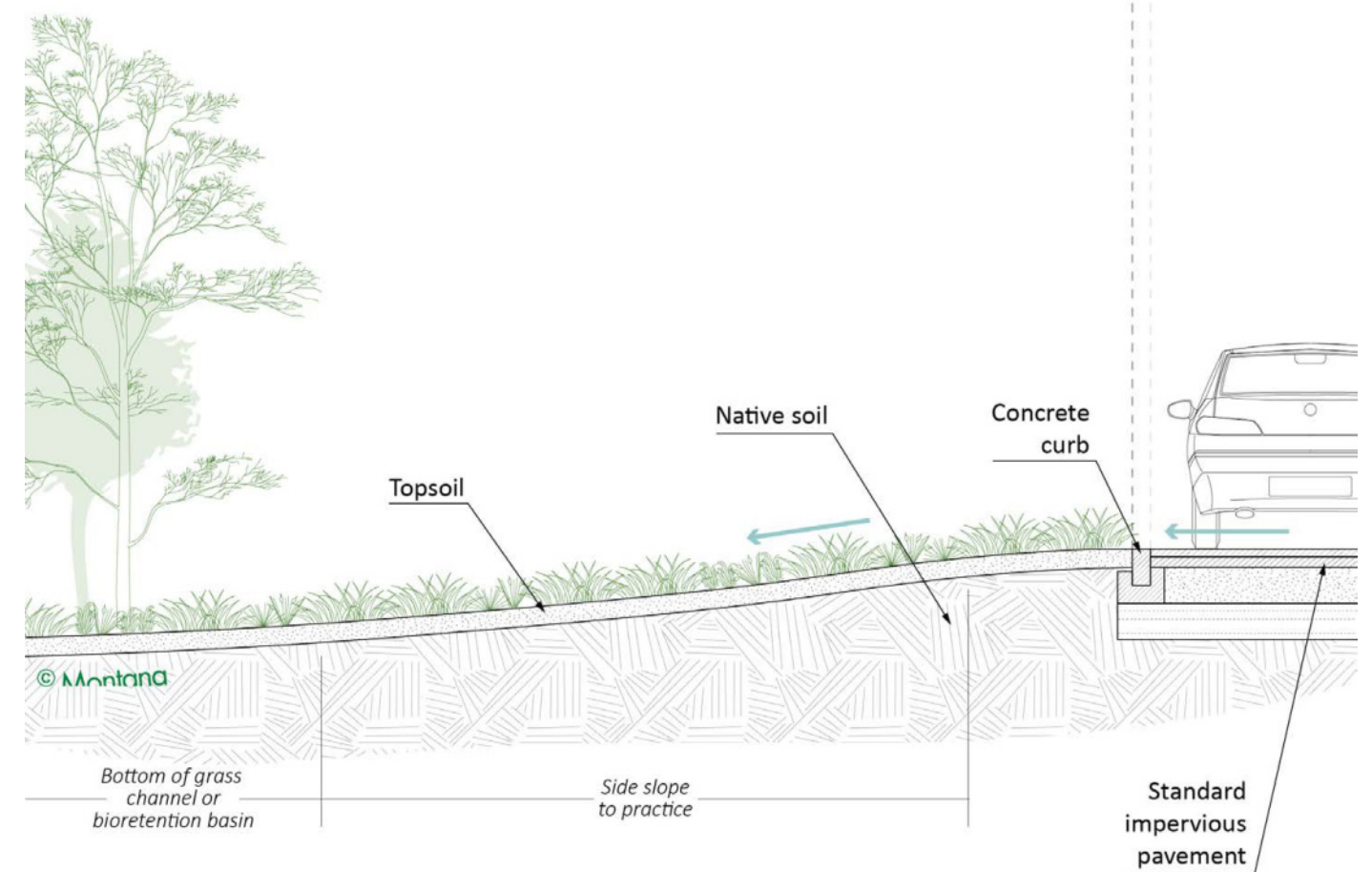
Where topsoils are suitably permeable, and underlying soils have some capacity to store and/or infiltrate runoff, then filter strips with very shallow slopes can be designed to deliver Interception (ie reduce or prevent runoff during small rainfall events). The extent of Interception delivered will be strongly dependent on filter strip length, which also influences designing for treatment.

Where there is infiltration capacity, infiltration is acceptable and the strip is designed to facilitate even limited infiltration, then a check should be made to determine whether the strip is able to dispose of 5 mm rainfall depth over the contributing catchment area.

Treatment design

Filter strips **can help retain runoff from small events on site**, helping to **reduce the contaminant load discharged to surface waters via volumetric control**.

They can also treat the residual runoff by facilitating sedimentation and filtration.



Plan and section of a filter strip next to a road.

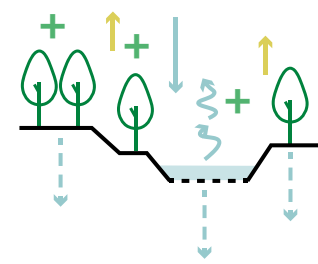
Drawing: Montana S.p.A.
Pic source: Montana S.p.A.

Public and urban scale interventions

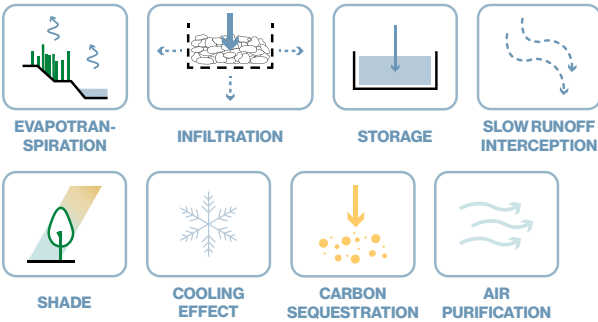
Floodable park

Floodable parks can be designed to **control flow rates and decrease flow peaks** by **storing excess floodwater and releasing it slowly** once the risk of flooding has passed. They are innovative sustainable urban drainage systems that can play a particularly important role in **mitigating potential impacts caused by surface run-off** water from rain, flash floods, or from small and medium sized water courses. Floodable park could be composed by different blue infrastructures such as water retention ponds, constructed wetlands, infiltration ponds, bioswales.

Floodable parks are best located in areas subject to heavy rainfall. For other cases, rainfall intensity and potential impacts on the drainage system must be assessed.



FUNCTIONS



SDGS GOALS



↗
Corktown Common Park,
Toronto, Canada.

Pic source: Net Zero Cities

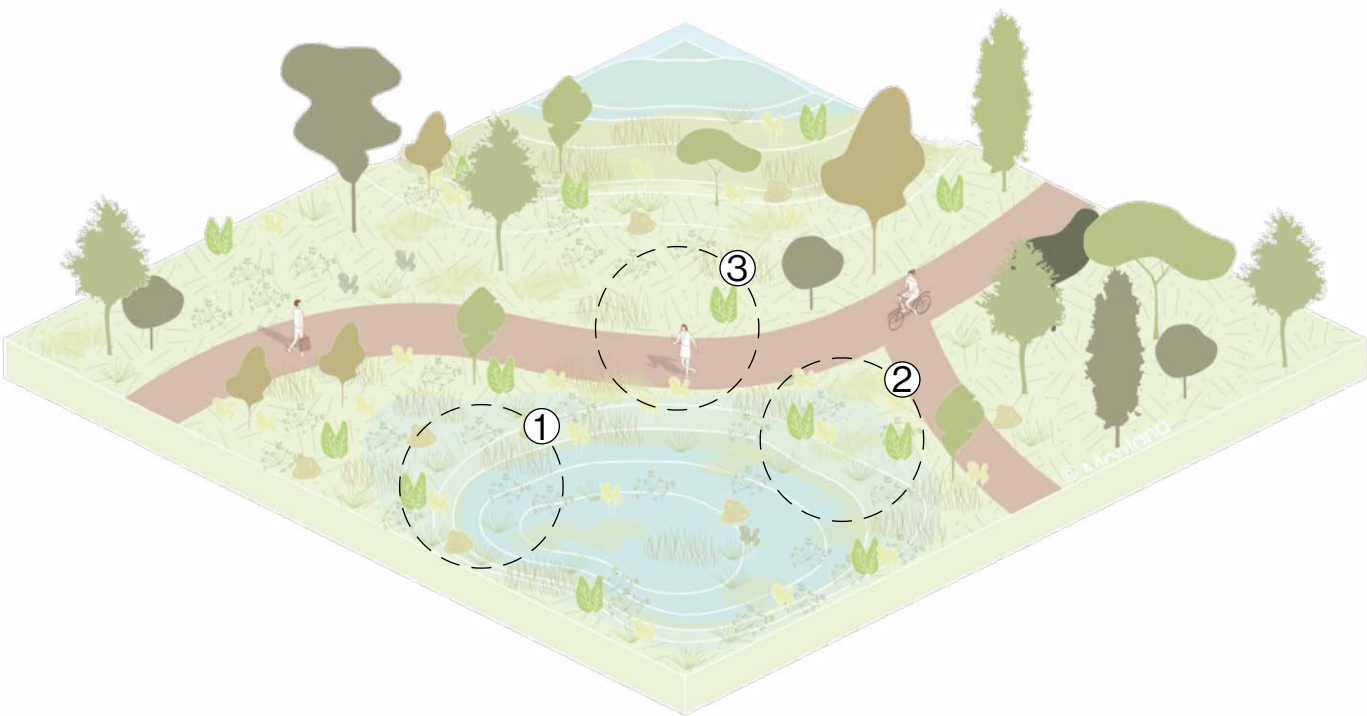
→
Al-Urubah Park, Riyadh, KSA.
Team: LAND Italia Lead
Consultant, Montana Sp.A,
Schiattarella Associati, Manens
Tifs, Drees & Sommer, Cannata
e Partners, IKON, AR&P, Kamel
Louafi, Leftloft.

Pic source: LAND



Visualization

Visualization of a floodable park in an urban context



Bishan Park, Singapore.

Pic source: Landezine

Details of increased benefits for the urban living environment



Floodable parks **temporarily hold excess runoff** during heavy rain, reducing flood risks and allowing water to **slowly infiltrate the ground**. These parks improve drainage, **enhance water quality**, and provide natural flood control while integrating green spaces into urban areas.



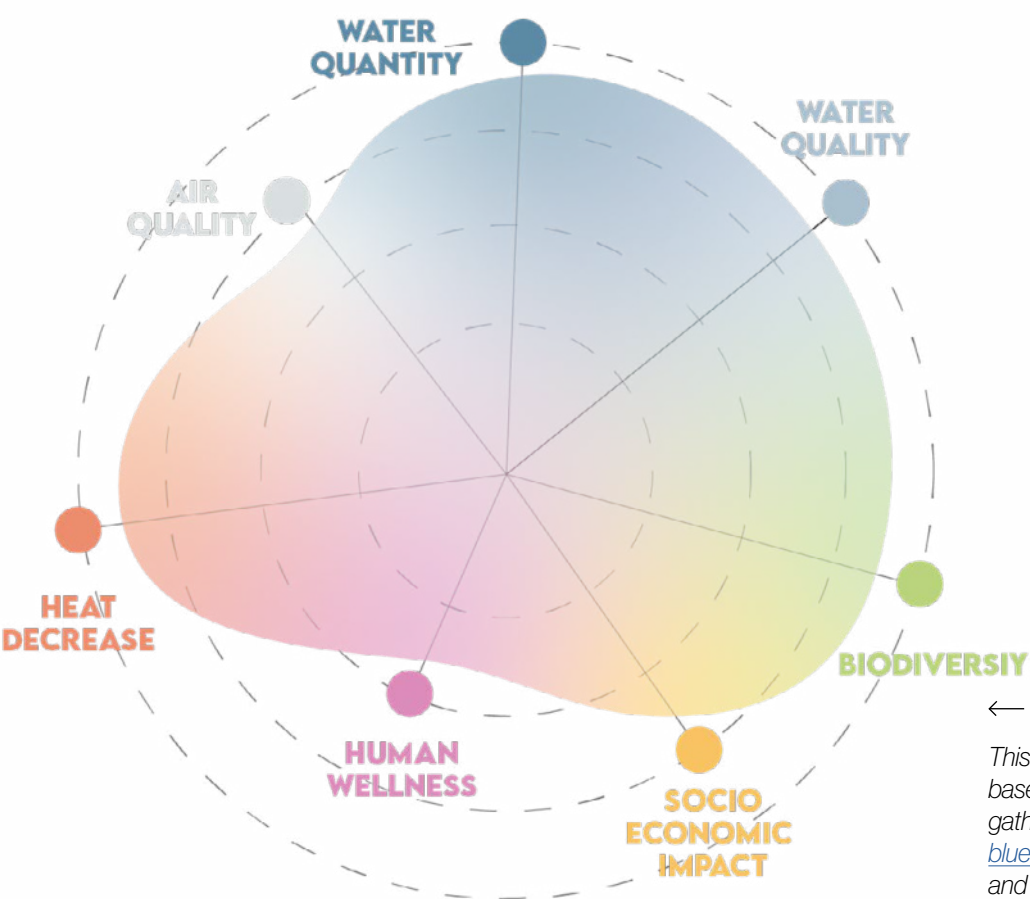
Floodable parks promote biodiversity by **creating diverse habitats** with native plants, wetlands, and grasslands. These spaces support various animal species, including insects, birds, and amphibians, while helping to maintain ecological balance and **enhance urban green spaces**.



Floodable parks offer **recreational opportunities** by providing spaces for walking, cycling, and nature observation. Their design integrates green areas with water management, allowing **visitors to enjoy outdoor activities while also benefiting from the park's ecological functions**.



Benefits



This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Floodable parks are landscaped retention basins that temporarily store stormwater, reducing peak runoff and combined sewer overflows while allowing slow infiltration or controlled discharge to treatment systems. As water moves through soils and vegetated zones, sedimentation, filtration, plant uptake and microbial degradation help remove pollutants, improving downstream water quality and increasing urban flood resilience (Martín Muñoz et al., 2024; Khiabani, 2024; Arian et al., 2025).

Water quantity and runoff control

Floodable parks temporarily accommodate excess stormwater within multifunctional open spaces such as lawns, plazas, or depressed landscape areas. During heavy rainfall events, these areas can store, slow down, and safely convey runoff, reducing peak flows to the drainage network and helping to mitigate local flooding. Once the event has passed, the stored water is gradually drained, infiltrated, or released, allowing the space to return to its everyday recreational or ecological function. (CIRIA, 2015; García et al., 2024; NBS Hub, n.d.).

Biodiversity

By recreating wetland and riparian conditions with permanent or periodic water bodies, native trees and emergent vegetation, floodable parks provide habitat for aquatic organisms, birds, amphibians and pollinators within dense urban areas. Examples such as La Marjal in Alicante show that these parks can act as refuges and stepping-stones that enhance local species richness and ecological connectivity at city scale (Martín Muñoz et al., 2024; Interreg Europe, 2023; Water Action Hub, 2023).

Social interaction

Floodable parks reduce economic losses by limiting flood damage to buildings, infrastructure and business activities, while also providing attractive public spaces that support recreation, environmental education and, in some contexts, higher nearby property values. Combining hydraulic safety with leisure facilities can turn a technical asset into a civic landmark that supports tourism, local identity and urban regeneration (Fundación Aquae, 2024; Gorjian, 2025)

Human wellness

Floodable parks function as blue-green health settings that encourage physical activity, social interaction and psychological restoration. Large reviews of green and blue spaces link such exposure to lower stress, improved mental health, higher physical activity and reduced all-cause mortality, especially when these spaces are accessible to disadvantaged neighbourhoods (Wang et al., 2025; Gascon et al., 2017; WHO Regional Office for Europe, 2023; Huang et al., 2022).

Heat decrease

Floodable parks help cool cities by combining tree shade, evapotranspiration from vegetation and water surfaces, and more reflective, permeable ground, creating “park cool islands” that lower air and surface temperatures around them. Empirical studies and systematic reviews show that larger parks with integrated water bodies—such as La Marjal—can meaningfully

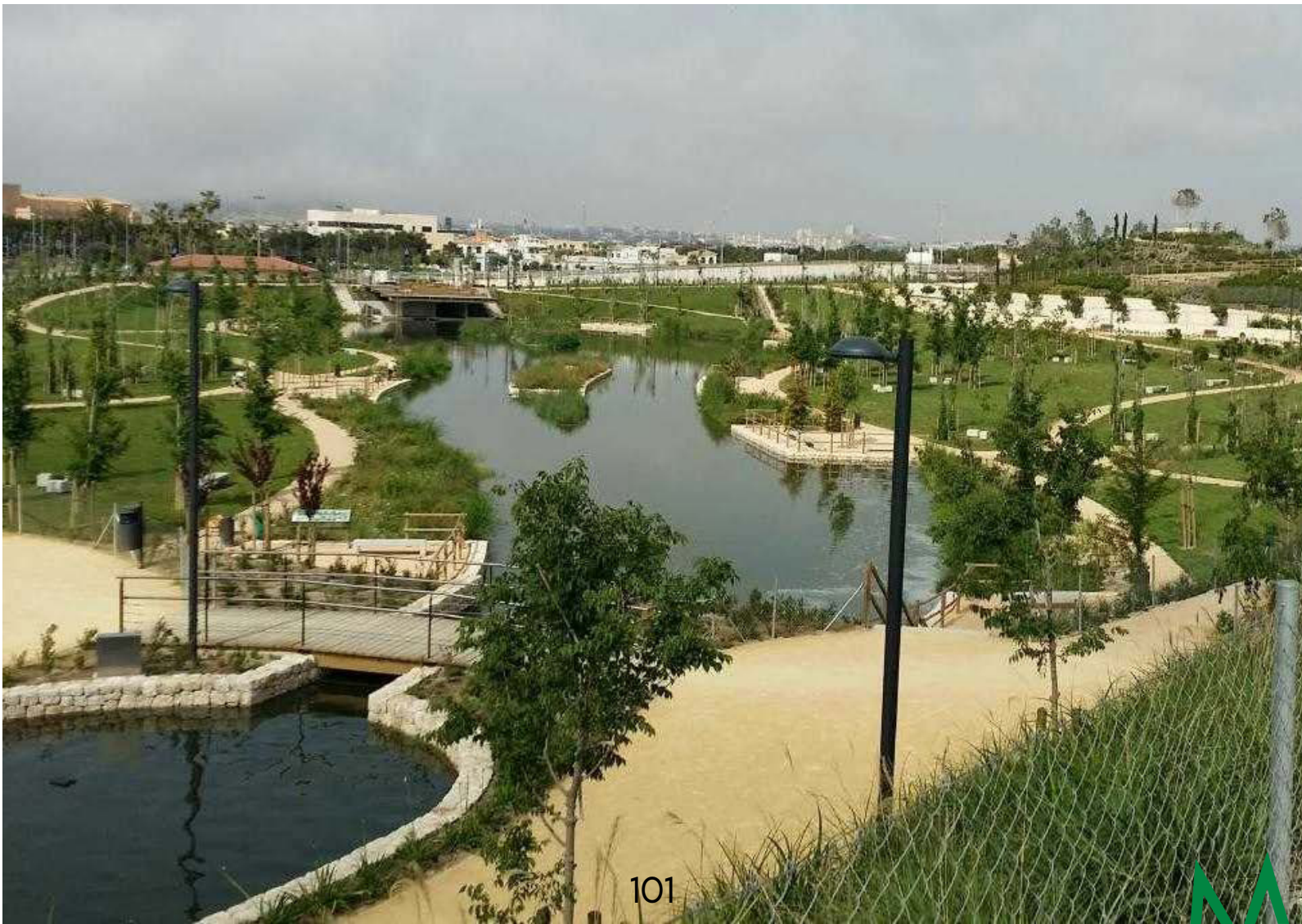
reduce local urban-heat-island intensity and improve thermal comfort during heatwaves (Cai et al., 2023; Lin & Li, 2024; CARDIMED, 2024; Zhang et al., 2024).

Air quality

Although primarily designed for flood control, floodable parks act as urban green infrastructure whose trees and shrubs capture particulate matter on leaf surfaces and absorb gaseous pollutants, yielding modest but relevant improvements in local air quality and exposure for nearby residents. Reviews and field studies on urban parks report measurable reductions in PM₁₀ and other pollutants where vegetation is sufficiently extensive and well designed (Marino, 2022; Moftakhar Juybari et al., 2025; Daraojimba, 2024; Jain, 2024).

↓ La Marjal, Alicante, Spain

Pic source: Comunita Valenciana



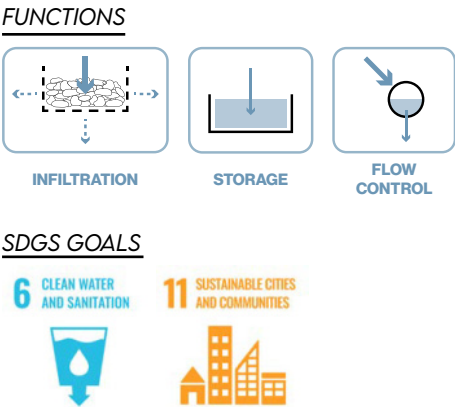
Public and urban scale interventions

Infiltration systems

An infiltration system is an area designed to enable, or **enhance**, the **infiltration of surface water run-off** into the ground.

Infiltration can contribute to reducing runoff rates and volumes while supporting baseflow and groundwater recharge processes. Infiltration systems facilitate the discharge of surface water runoff to the ground and ultimately into groundwater. It is therefore crucial that any runoff is suitably clean before entering the infiltration component so that the groundwater is not put at risk of contamination.

There are many different types of drainage component that can be used to facilitate infiltration. These include **soakaways, infiltration trenches, infiltration blankets, drainage pipes** and **infiltration basins**.



↗
Infiltration basin on Airport Road in Middleton, Wis.

Pic source: Upper Midwest Water Science Center

→
An example of a drainage pipe.

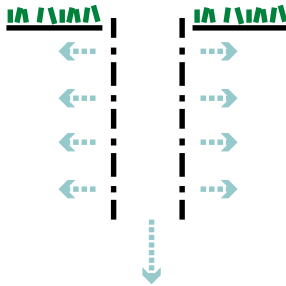
Pic source: My Gravel Monkey



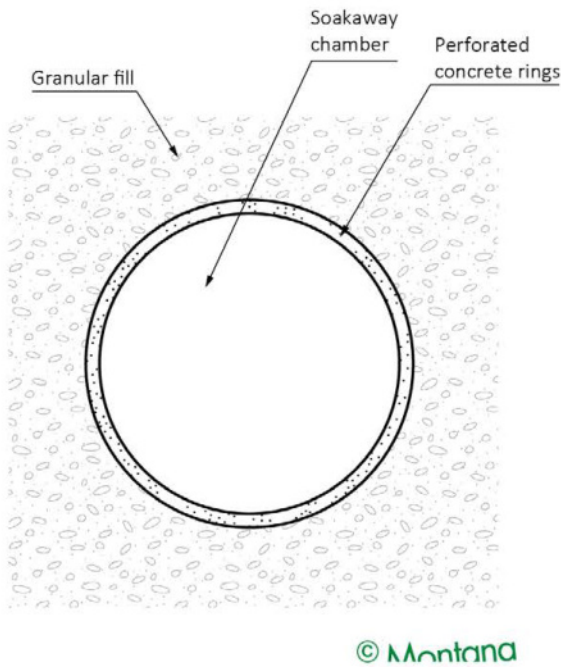
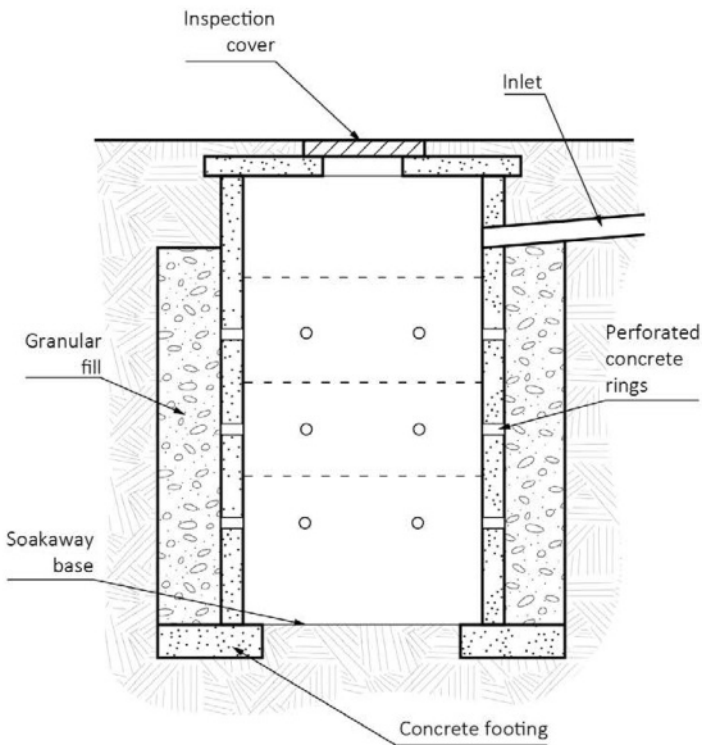
Soakaways

Soakaways are **square or circular excavations, filled with rubble or lined with brick, pre-cast concrete, or perforated polyethylene rings.** They are surrounded by granular backfill and can be grouped and connected to drain large areas, such as highways.

Many small soakaways are now constructed with geocellular units pre-wrapped in geotextile. The geocellular units provide good overall storage capacity compared to the rubble fill used historically, and they allow the size of the structure required for any application to be minimised.



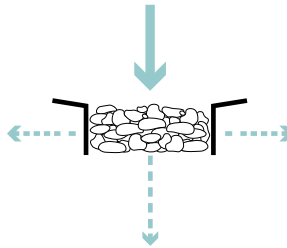
↓
Plan and section of a soakaway.
Drawing: Montana Sp.A.
Pic source: Montana Sp.A.



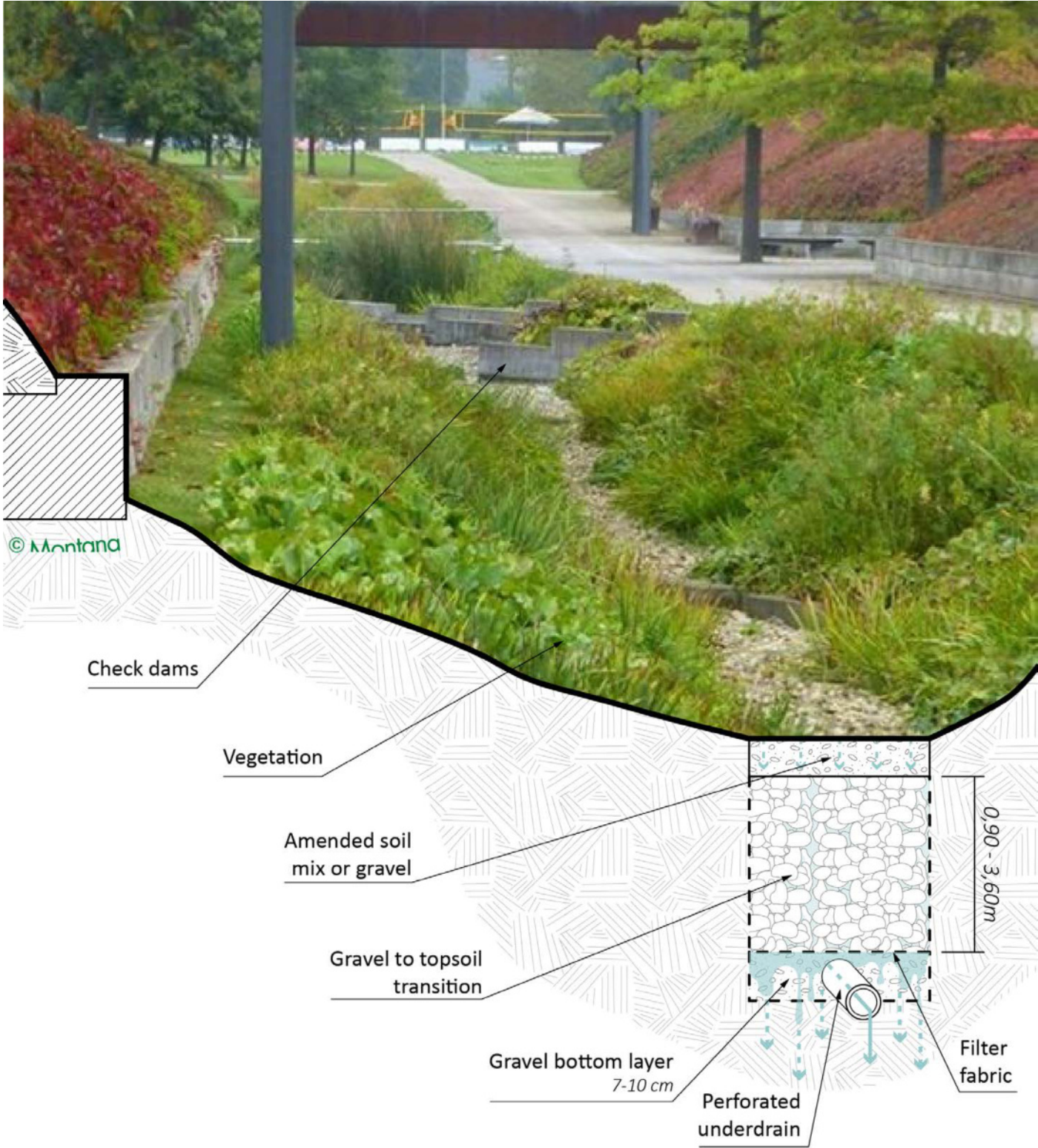
Infiltration trenches

Infiltration trenches are shallow excavations with stone that create temporary subsurface storage of stormwater runoff, enhancing the natural storage capacity of the ground.

Infiltration trenches **allow water to exfiltrate into the surrounding soils** from the bottom and sides of the trench.

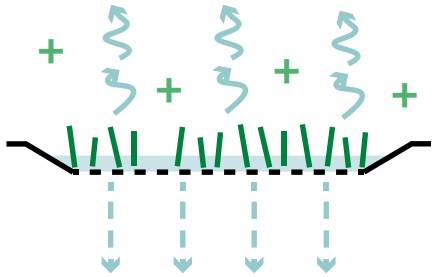


↓
Infographic: Montana Sp.A.
Pic source: Jethro Jeff

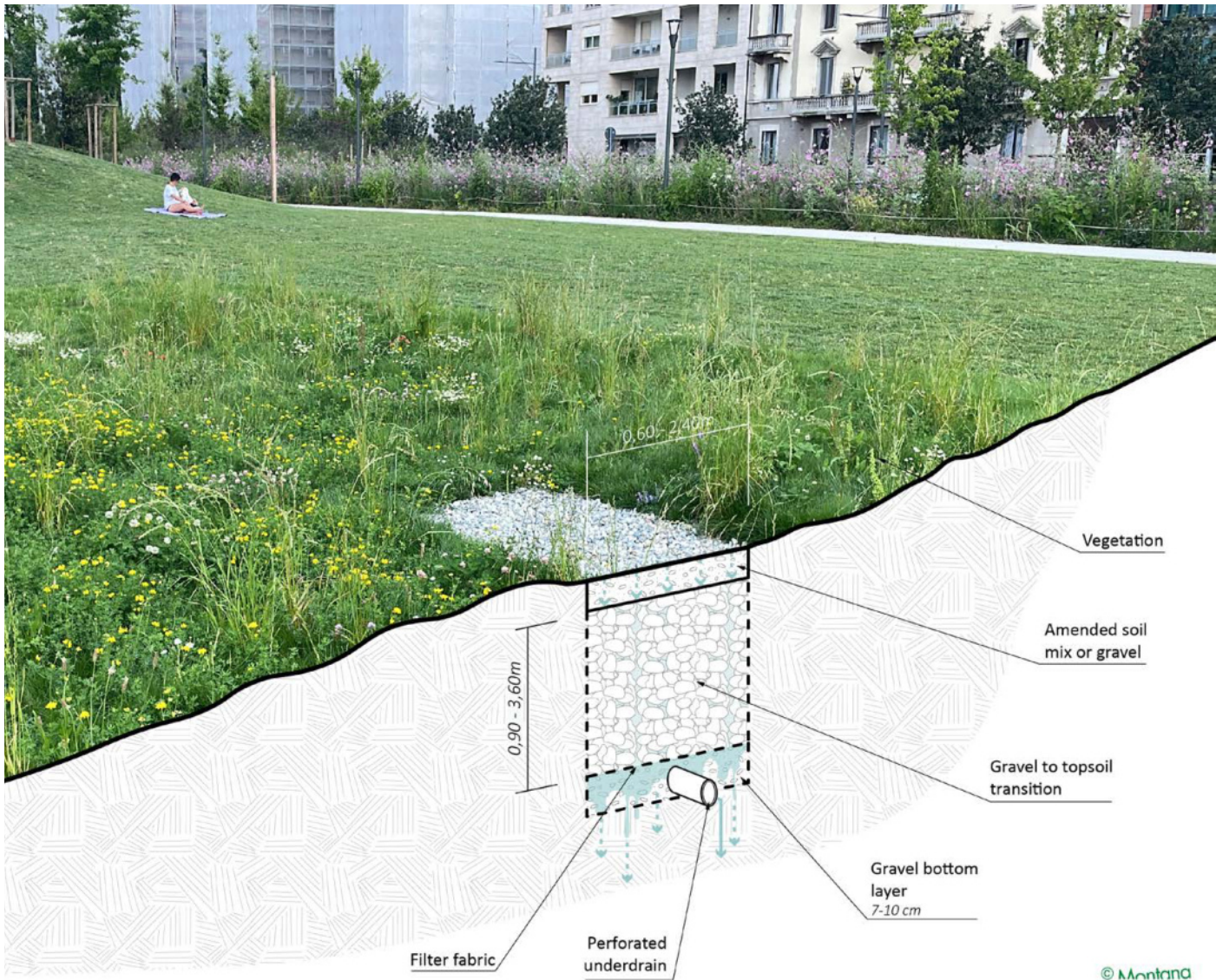


Infiltration basins

Infiltration basins are **flat-bottomed, shallow landscape depressions** that store runoff (allowing pollutants to settle and filter out) before infiltration into the subsurface soils. They can include a stone layer to increase storage capacity.



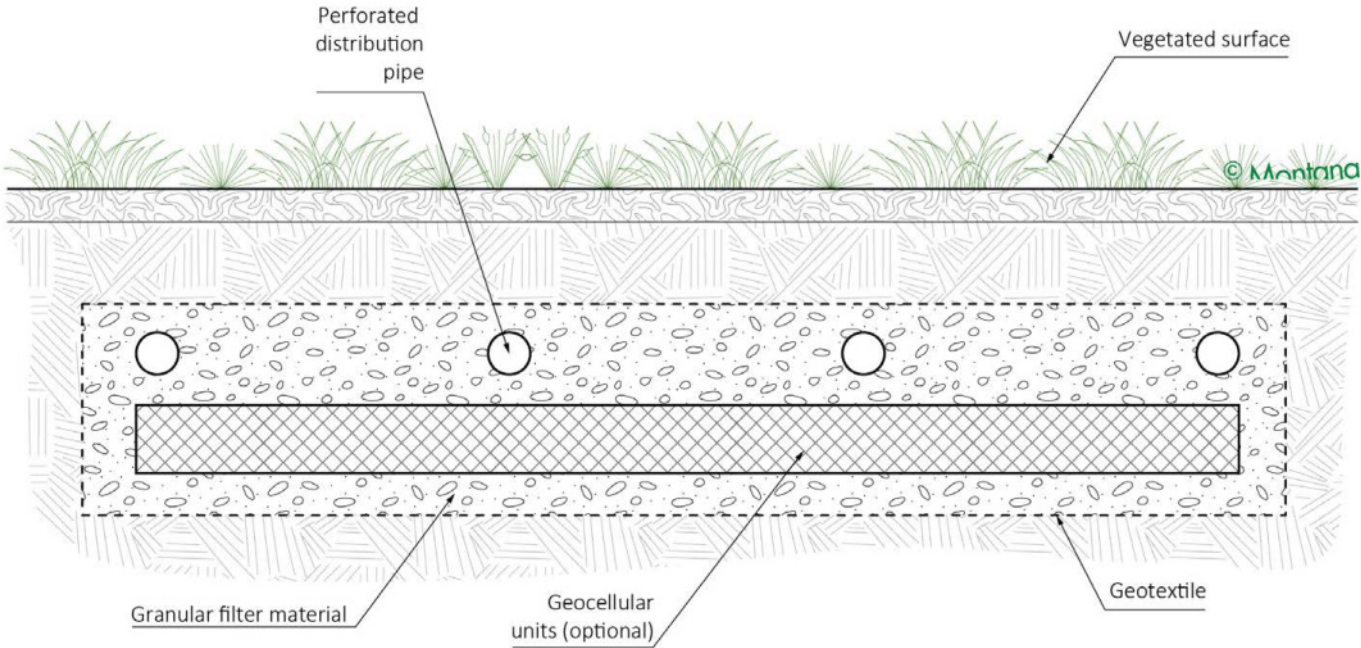
↓
Project: Parco 8 Marzo, Milano by Montana Sp.A.
Infographic: Montana Sp.A.
Pic source: Montana Sp.A.



Infiltration blankets

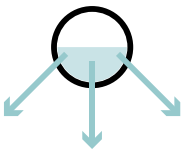
Infiltration blankets are **large shallow systems** that are typically constructed using permeable aggregate or geocellular units that act as extensive soakaway systems. Examples include below car parks where the storage layer is part of the car park pavement construction, below playgrounds or below sports pitches.

↓
Section of an infiltration blanket.
Drawing: Montana Sp.A.
Pic source: Montana Sp.A.

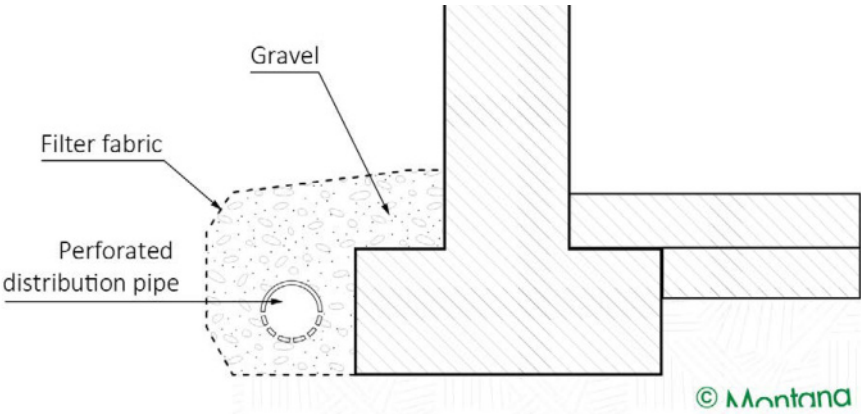


Drainage pipes

A drainage pipe is a tool that use underground sand filters or other devices to treat hotspot runoff.

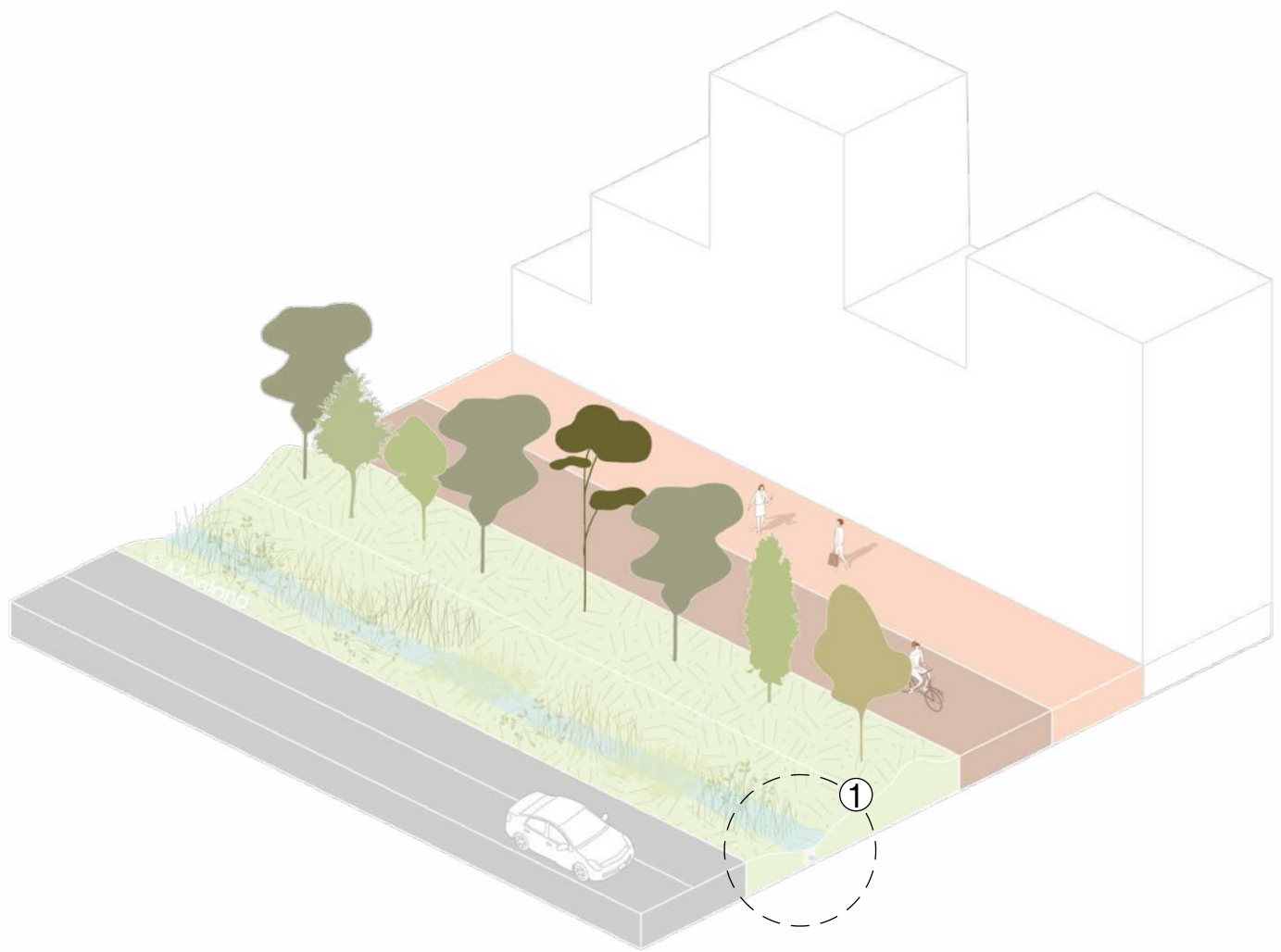


↓
Section of a drainage pipe.
Drawing: Montana Sp.A.
Pic source: Montana Sp.A.



Visualization

Visualization of infiltration systems in an urban context

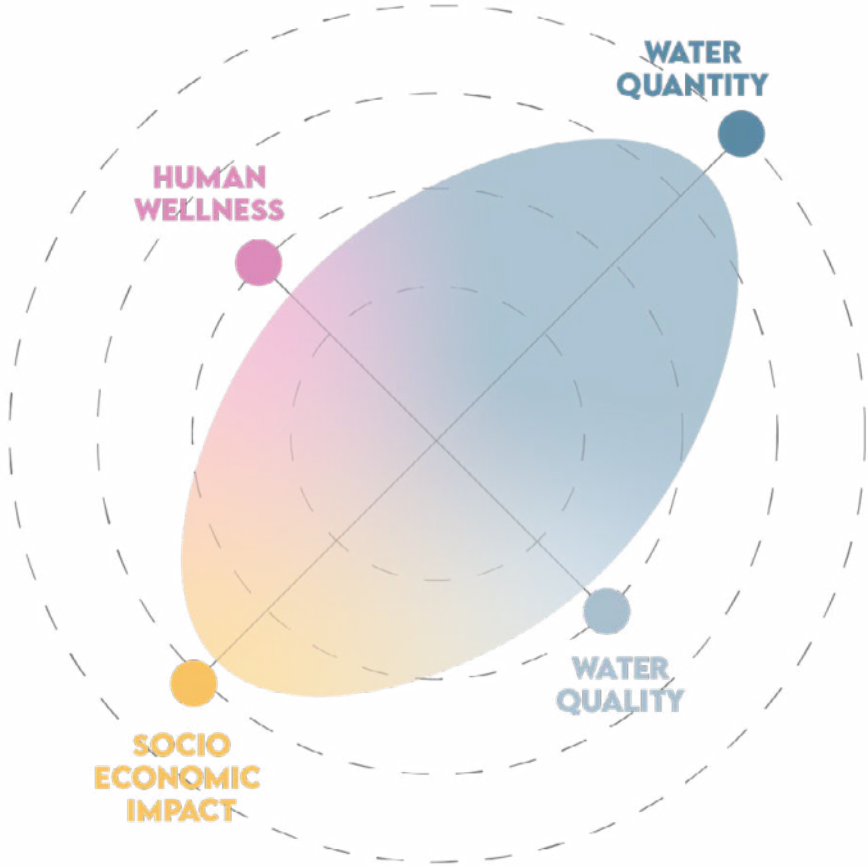


Details of increased benefits for the urban living environment



Infiltration systems such as trenches, **capture stormwater** allowing it to soak into the ground rather than running off, reducing runoff volumes. As water infiltrates through the soil, part of it contributes to **groundwater recharge**, helping to restore a more **natural urban water balance**.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quantity and runoff control

Infiltration systems collect and temporarily store stormwater runoff, allowing water to soak into the ground rather than being directly discharged to the drainage network. By promoting infiltration, they reduce runoff volumes, delay discharge, and help attenuate peak flows, supporting groundwater recharge and reducing downstream flood risk. Their performance depends on soil permeability, groundwater level, available storage capacity, contributing drainage area, rainfall intensity, and regular maintenance to prevent clogging. (CIRIA, 2015; EPA, n.d.; Susdrain, n.d.).

Water quality and sediment management

Infiltration-based solutions (such as infiltration trenches, soakaways, and basins) significantly reduce surface runoff, promote water infiltration into the ground, and contribute to aquifer recharge. Additionally, they improve water quality by naturally filtering pollutants through the soil (NWRM, 2023).

Social interaction

Sustainable urban drainage systems (SuDS), including infiltration-based solutions, are generally more cost-effective to construct and maintain compared to conventional infrastructure like traditional sewer systems. Additionally, they help reduce costs associated with flooding and wastewater treatment (Forest Research, 2021).

Human wellness

While not directly offering benefits for human wellness in terms of green spaces, these solutions indirectly contribute to improving environmental quality and reducing flood risks, with positive effects on urban health and comfort when integrated with urban green infrastructure (Forest Research, 2021).

Diagram based on:
Garbanzos & Maniquiz-Redillas, 2022;
Hatt et al, 2009;
U.S. EPA, 2021;
Deng et al, 2024;
Höglund & Nilsson, 2024

Slope gradient

The side slopes of infiltration basins should normally be **no steeper than 1 in 3** to allow for vegetative stabilisation, mowing, access and for public safety reasons. However, this requirement may be relaxed if a basin is very shallow (eg less than 500 mm deep).

Stepped or benched slopes also offer a range of habitats that can survive fluctuating water levels and wet to dry soil conditions.

General consideration

The performance of infiltration systems is dependent on the **infiltration capacity** of the surrounding soils and the depth to groundwater. Effective upstream pre-treatment is required to remove sediment and silt loads to prevent long-term clogging and subsequent failure of the system. Construction best practice is also crucial to preventing damage to the subsoil structure (and permeability) before commissioning of the system.

A minimum **distance of 1 m** between the **base of the infiltration system** and the maximum likely **groundwater level** should always be adopted. This is to minimise the risk of groundwater rising into the infiltration component and reducing the available storage volume, to protect the functionality of the infiltration process by ensuring a sufficient depth of unsaturated material and to protect the groundwater from any contamination in the runoff.

The bottom of any infiltration system **should be flat** to provide uniform ponding and infiltration of the runoff across the surface. The tolerance on the base levels should be a maximum level difference of 10 mm in 3 m.

Hydraulic design

Infiltration systems should be designed to manage storms up to the design standard of service required for the contributing catchment area: this could be the 1:10 or 1:30 year storm, or larger.

As discharge criteria from a development site are usually based on a 1:100 year event plus an allowance for climate change, the performance of infiltration systems under such conditions needs to be known.

The infiltration component should discharge from full to half-full within a reasonable time so that the risk of it not being able to manage a subsequent rainfall event is minimised. Where components are designed to manage the 1:10 year or 1:30 year event, it is usual to specify that half emptying occurs within 24 hours.

Interception design

Infiltration can play an important role in providing Interception – the capture and retention of the first 5 mm of any rainfall event, even on sites with low infiltration rates.

Treatment design

The acceptability of infiltration design will depend on the extent of the likely runoff contamination and site and ground characteristics.

Sedimentation tends to occur within the temporary storage area, it's important to consider to put in place upstream SuDS components to remove sediment.

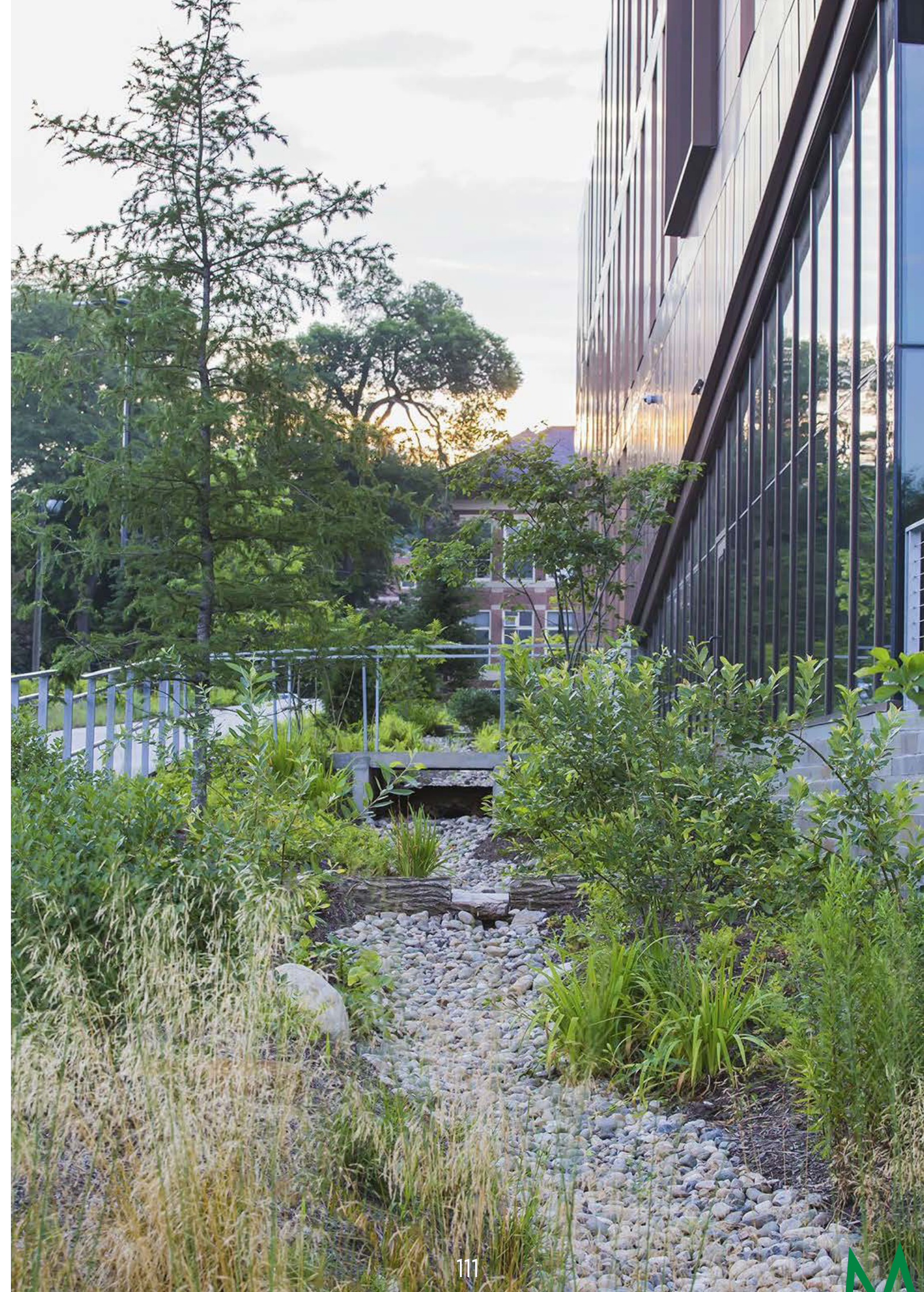
The deeper an infiltration system is, the greater the risk of bypassing the protective upper soil layers and decreasing the distance to the water table. This can lead to an increased risk of groundwater pollution.

In this respect shallow and dispersed systems are usually best. Geotextile layers can be used within infiltration components for additional trapping of surface water runoff particulates and hydrocarbons.

→

Infiltration trench in the "New Quad" at Williams College, Williamstown, Massachusetts

Pic source: Moooool



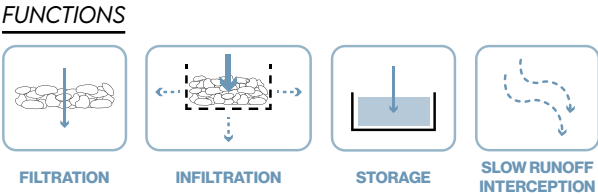
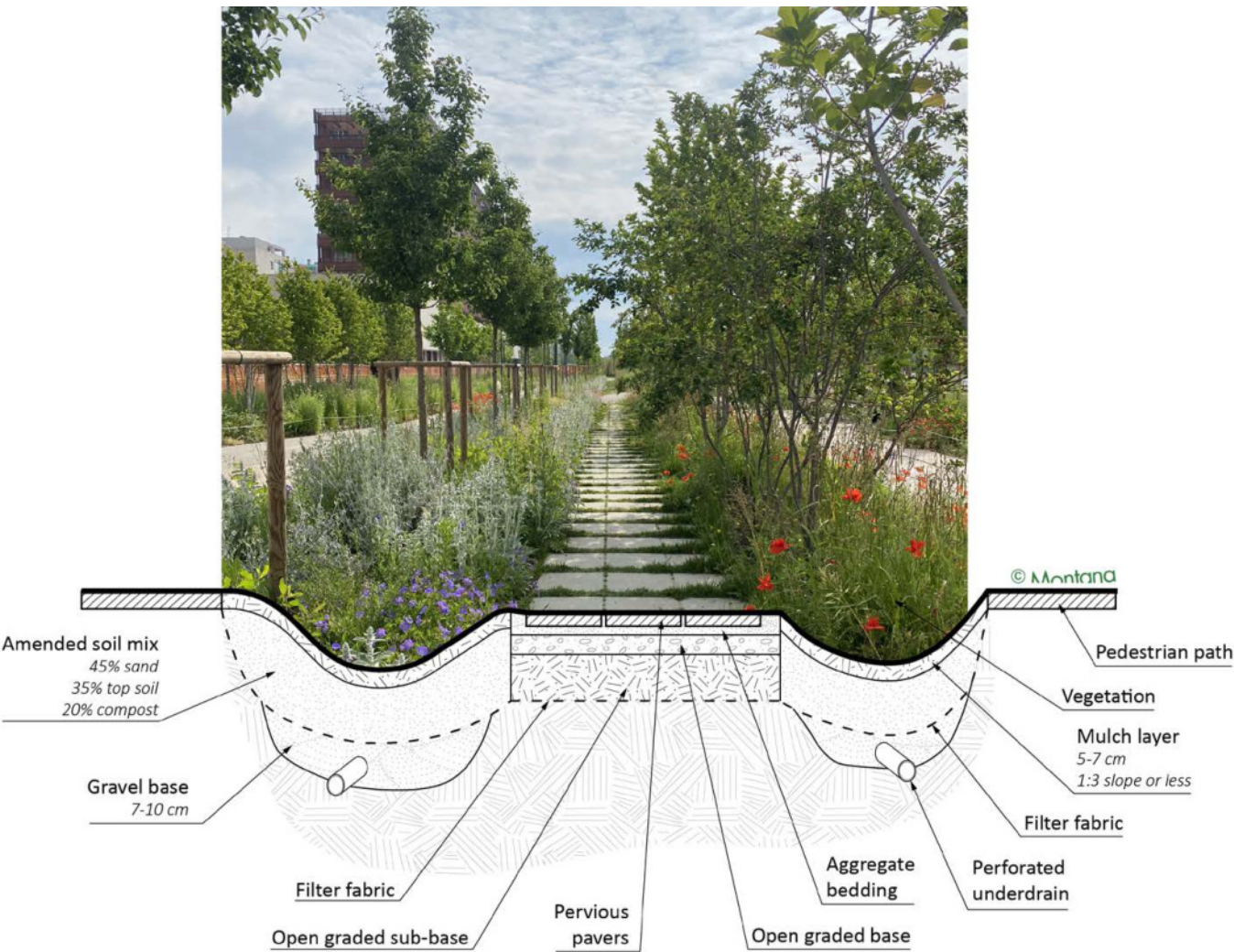
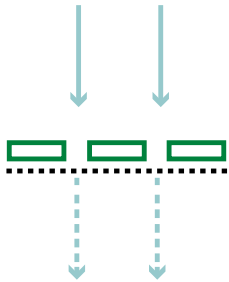
Public and urban scale interventions

Pervious paving

Pervious or permeable paving **allows water to vertically flow through hard surfaces**. As substitutes for impervious paving, they support both **pedestrian and vehicular traffic**.

A pervious paving system includes a subsurface base made of coarse aggregate for stormwater storage. In some designs, pervious pavement is supported by underground layers of soil, gravel and sand to increase storage and maximize infiltration rates. Pervious paving **removes sediment and other pollutants**.

It acts to reduce and distribute stormwater volume, encouraging groundwater infiltration. Multiple types of pervious paving, including precast pavers, in-place porous concrete and asphalt, porous asphalt, porous concrete, and gravel, offer varying levels of service. Reduction of the urban heat island effect is possible when using high-albedo, lightly coloured systems. Large scale vacuums must be used to clean out gravel, paver, and porous systems. Turf paver systems may need occasional mowing and irrigation.

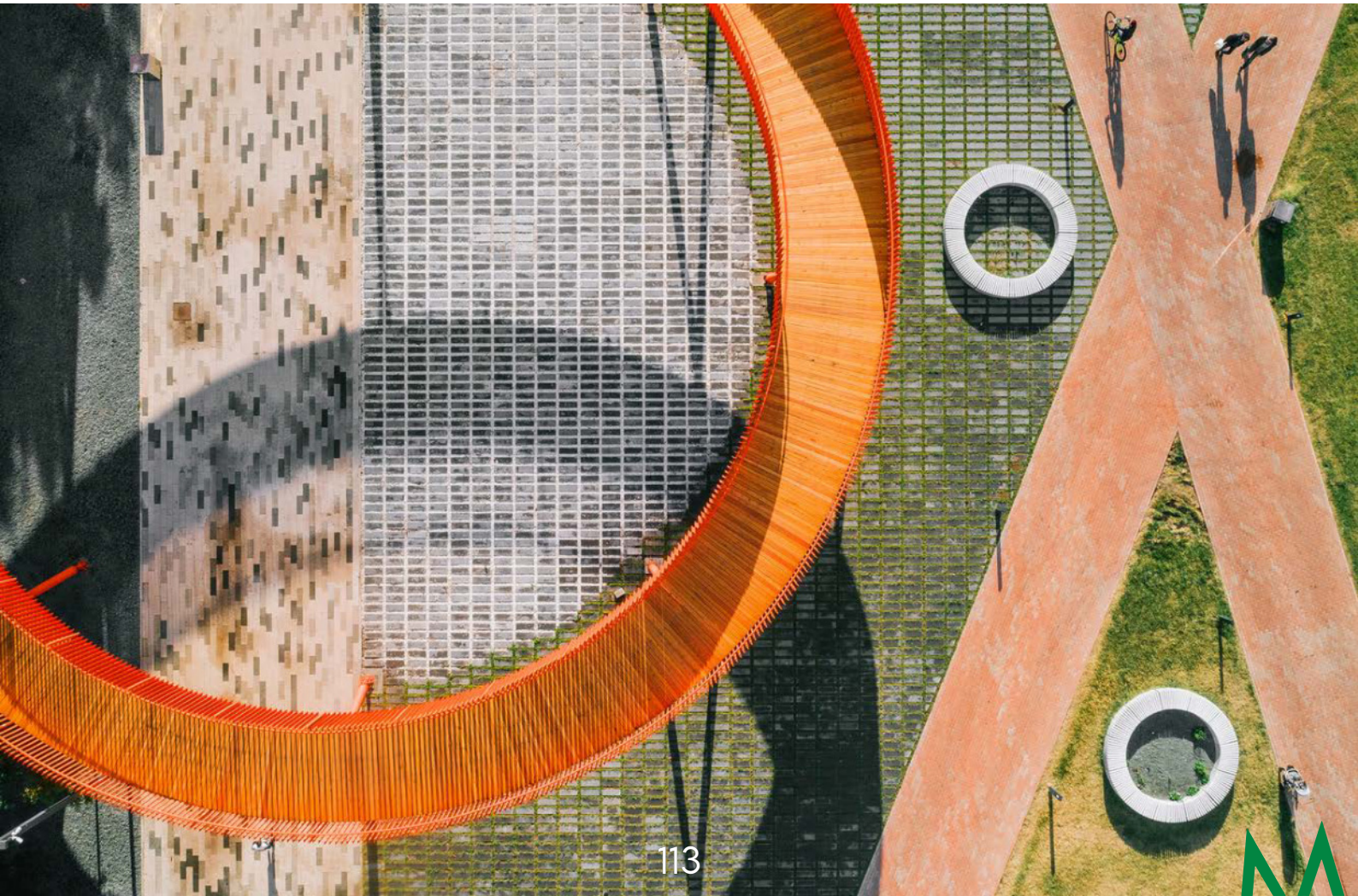


↗

Project: Parco 8 Marzo, Milano
by Montana S.p.A., Studio Laura Gatti, Studio Fabio Nonis.
Infographic: Montana S.p.A.
Pic source: Montana S.p.A.

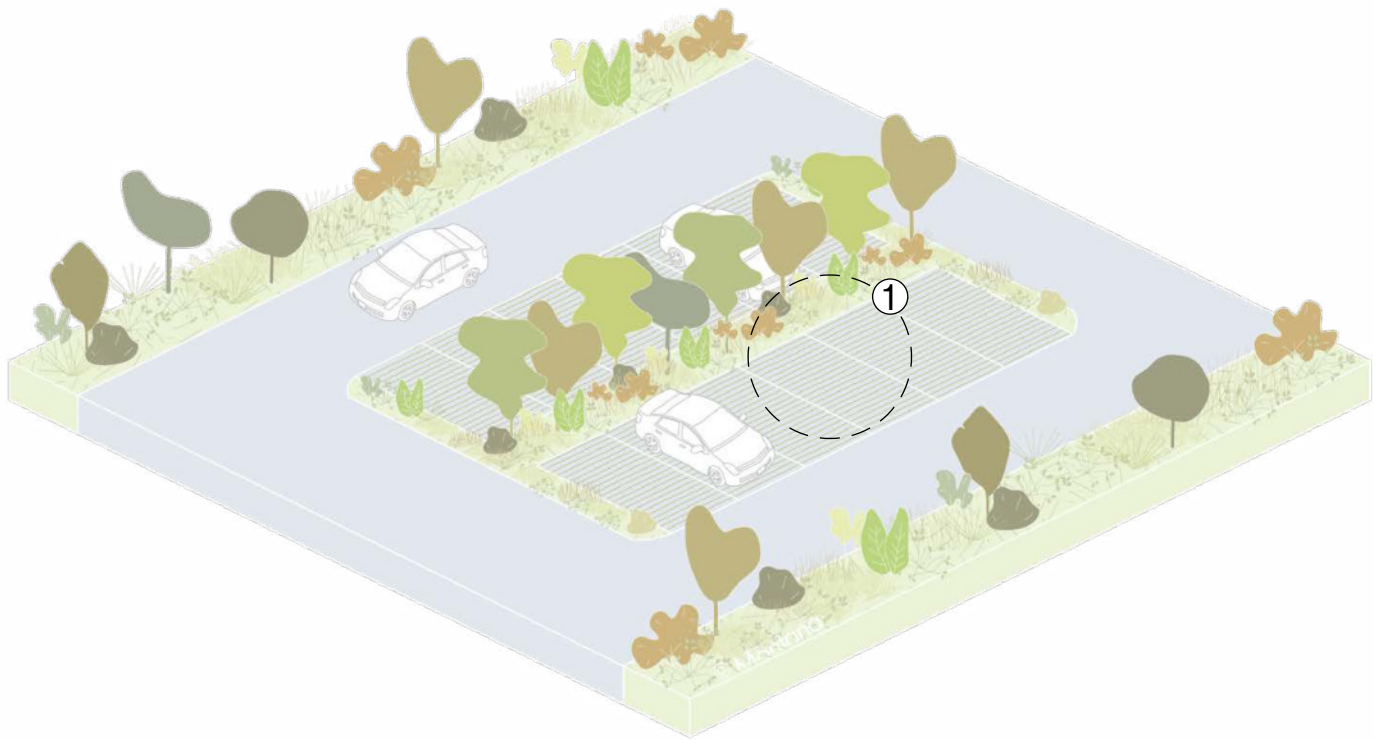
→

Azatlyk, Praça Central de Naberezhnye Chelny.
Pic source: Archdaily



Visualization

Visualization of pervious pavement in an urban context



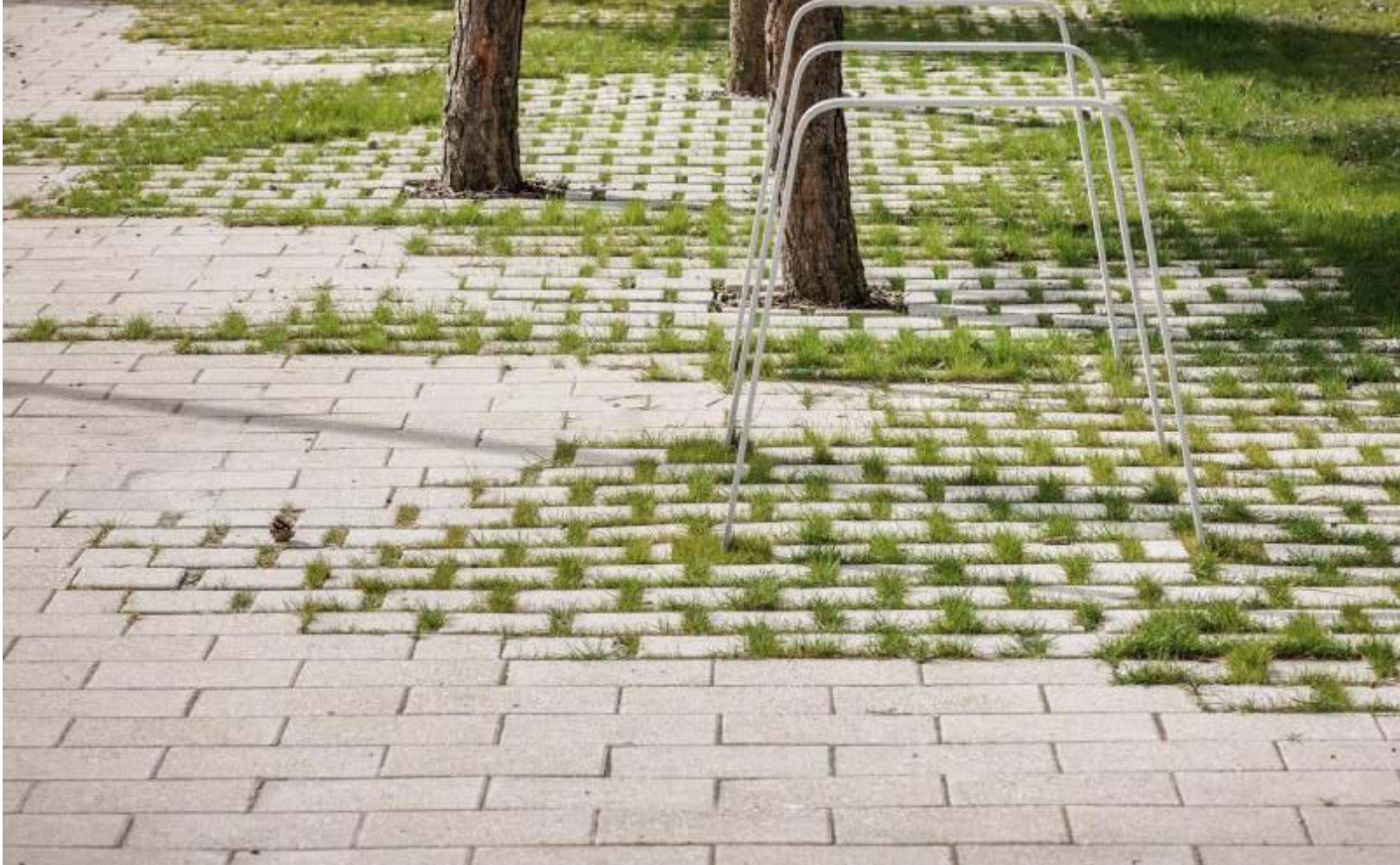
Details of increased benefits for the urban living environment



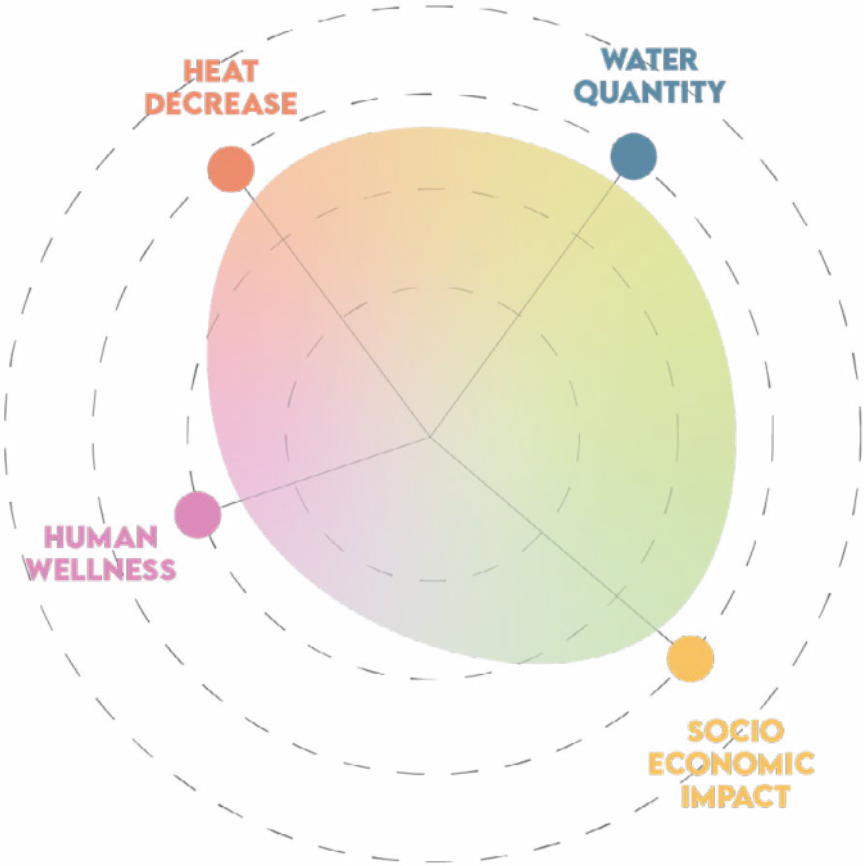
Pervious pavements allow water to **infiltrate through the surface**, reducing runoff and promoting **groundwater recharge**. This system **helps control flooding**, improves drainage, and **filters pollutants**, enhancing water quality while maintaining functional walkways or driveways.

↗
Training and accommodation center for apprentices, Bordeaux, France
Pic source: DIVISARE.

→
Pervious paving detail.
Pic source: Fondation Saint-Hubert



Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quantity and runoff control

Pervious paving allows rainfall to pass through the pavement surface and into the underlying aggregate layers, where stormwater can be temporarily stored, infiltrated into the soil, or gradually discharged through an underdrain. By reducing impervious surface runoff, it helps decrease runoff volumes, delay discharge, and attenuate peak flows, contributing to local flood mitigation and reduced pressure on drainage networks. Its performance depends on subsoil permeability, storage layer depth, pavement type, rainfall intensity, and regular maintenance to prevent clogging. (EPA, 2021; USGS, n.d.; FHWA, 2023).

Socio-economic impact

Although initial costs can be higher, pervious paving often lowers lifetime infrastructure costs. Greener, better-performing streetscapes can also raise property values, attract investment and support local jobs in sustainable construction and maintenance. (Antunes et al., 2018; Qamhia et al., 2024)

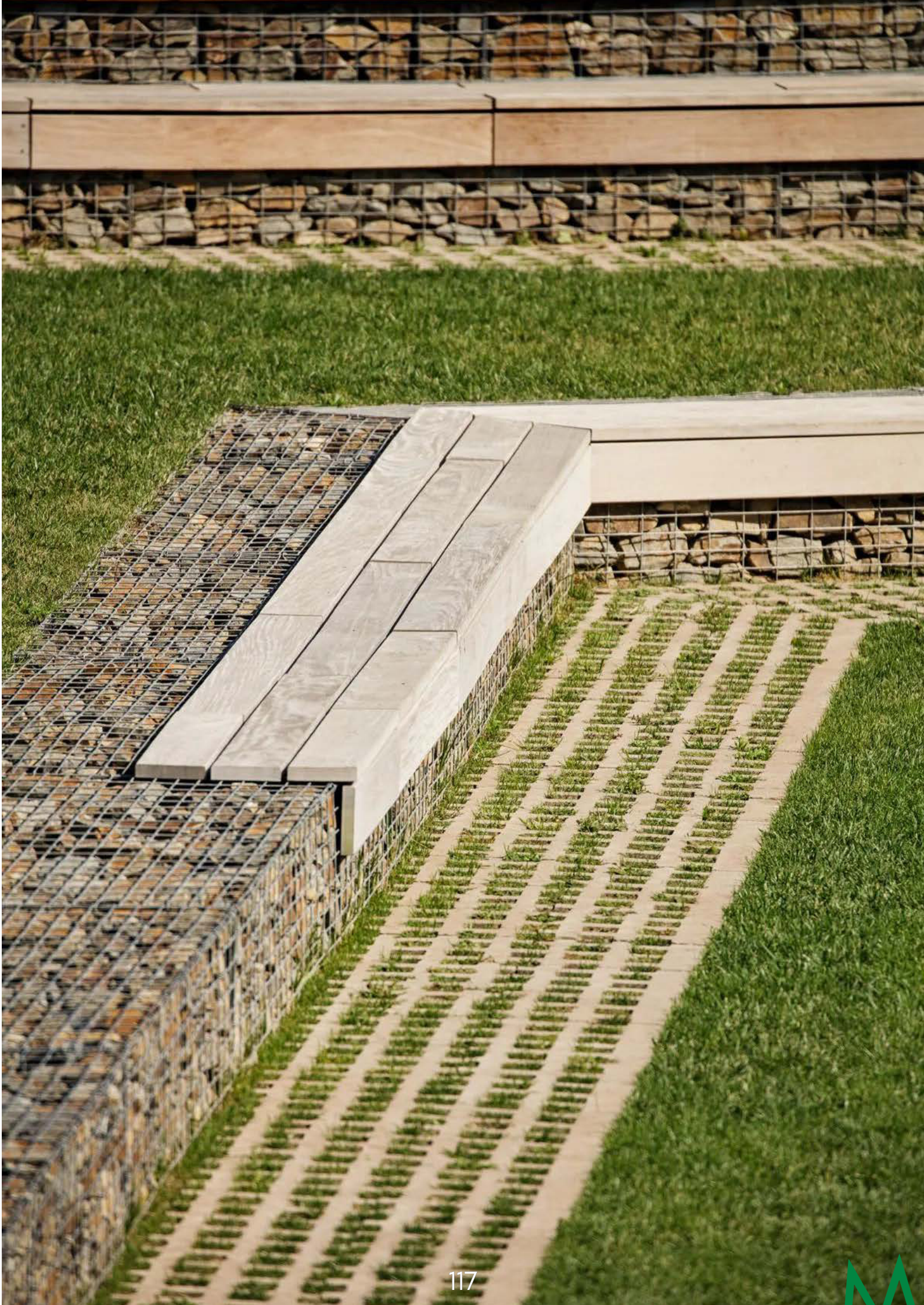
Human wellness

Pervious paving enhances pedestrian comfort and safety and encourages walking and cycling. It contributes to cleaner and more attractive streets that support mental and physical health and strengthen social interaction in public spaces. (Pinto et al., 2023; Wang et al., 2024)

Heat decrease

Pervious paving helps mitigate urban heat through evaporative cooling from moist pores and, in some designs, higher albedo compared with asphalt. It can remain noticeably cooler, especially after rain or sprinkling, improving outdoor thermal comfort and reducing cooling demand when paired with shade and vegetation. (Li et al., 2014; Amani et al., 2025)

→
Maquina de Batre Square Spain.
Pic source: Mooooo!



Modular permeable paving



The most common surface is concrete block permeable paving, but other modular surfacing materials can also be used (clay pavers, natural stone etc). Potential uses include pedestrian areas, private driveways, car parks, lightly trafficked roads.

Porous asphalt



Porous asphalt can be used as an independent surface or to provide a stronger base to concrete block permeable pavements where it is to be trafficked frequently by trucks. Porous asphalt surfacing reduces traffic noise. It can be used for car parks, private driveway, playgrounds and schools.

Grass reinforcement



Grass reinforcement uses plastic or concrete grids infilled with grass or gravel. This type of pavement is most suitable for lightly trafficked locations, especially where it only has seasonal use, so that the grass has time to recover. The uses for this kind of pavement are schools, private driveways, hotel and office car parks and leisure facilities.

Resin bound gravel



Resin bound gravel provides a wide range of finish colours, which makes it attractive for use in public, recreational spaces. This type of pavement is most suitable for lightly trafficked locations.

Porous concrete



Porous concrete can be used as a surfacing material or to provide improved structural stability to the base of concrete block permeable pavements where it is to be trafficked frequently by trucks. It's used mainly for car parks.

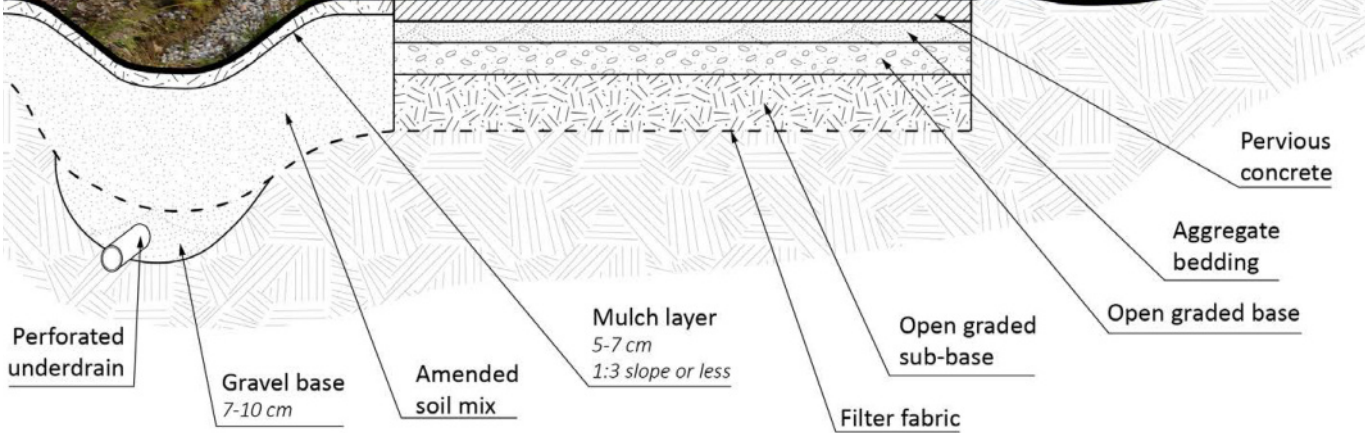
Macro pervious paving

Macro pervious systems are where normally impermeable surfaces are drained to channels or other collection systems designed to trap oil and silt. This approach allows water storage in the sub-base below impermeable surfaces in areas where there are high traffic loads and/or high shear forces from turning vehicles. This type of paving serve for all types of uses, as long as the site is not subject to very high silt loads and where regular maintenance can be assured.



↗
Example of a modular permeable pavement.
Pic source: Lurvey

→
Project: Parco 8 Marzo, Milano by Montana S.p.A.
Infographic: Montana S.p.A.
Pic source: Montana S.p.A.



Public and urban scale interventions

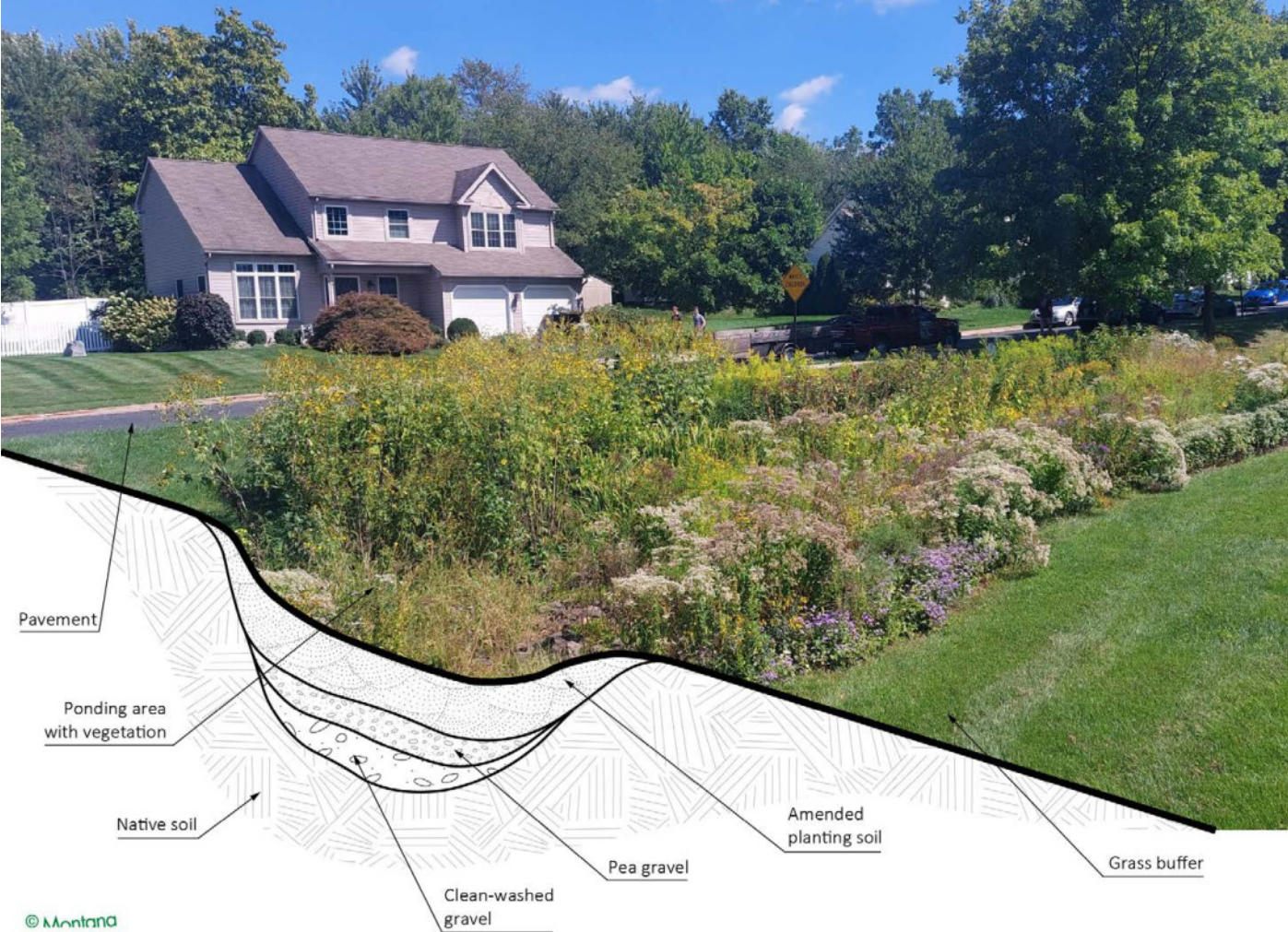
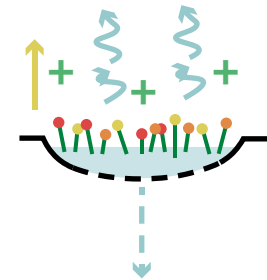
Rain garden

A rain garden is a **planted depression** designed to **infiltrate stormwater runoff**, but not hold it. A rain garden is commonly known as a **bioretention facility**.

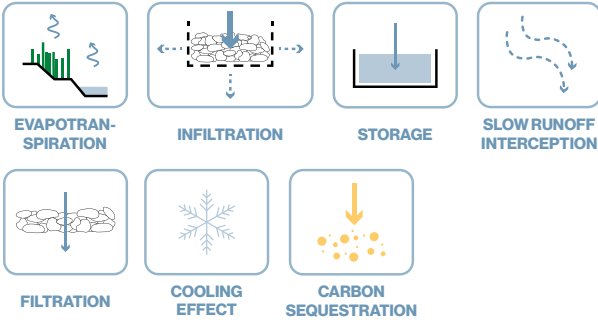
Stormwater pollutant mitigation is accomplished through **phytoremediation processes** as runoff passes through the plant and soil community. Rain gardens combine layers of organic sandy soil for infiltration, and mulch to promote microbial activity. Native plants are recommended based upon their intrinsic synergies with local climate, soil, and moisture conditions without the use of fertilizers and chemicals. Rain gardens are best applied on a relatively **small scale**. They work well along driveways and in low lying areas of a property.

The minimum distance between rain gardens and buildings should be assessed during the design phase, in accordance with applicable technical guidelines and site-specific conditions. Adequate separation from foundations is required to prevent water infiltration, structural damage, dampness, mould, or other moisture-related issues.

Also, location away from large trees allows exposure to sunlight so that rain gardens may dry out between storm events.



FUNCTIONS



SDGS GOALS



↗
 Infographic: Montana S.p.A.
 Pic source: Perkiomen Watershed Conservancy

→
 Woodland Rain Garden, Caddo Parish, Louisiana, USA.
 Pic source: Carbo



Visualization

Visualization of rain garden in an urban context



Details of increased benefits for the urban living environment



Rain gardens **capture runoff**, allowing it to **infiltrate the soil** while also **promoting evapotranspiration**. This process helps reduce surface runoff, prevent flooding, and **filter pollutants**, enhancing **groundwater recharge** and improving water quality in urban environments.



Rain gardens **provide habitats** for a **variety of plant species**, including native grasses, wildflowers, and shrubs. These plants **attract pollinators, birds, and beneficial insects**, supporting local ecosystems while also contributing to water management and ecological balance.



Rain gardens enhance the **accessibility of green spaces** by providing areas for passive recreation, such as walking or nature observation. These gardens offer aesthetic value and create **opportunities** for people to **connect with nature**, while contributing to environmental health.

Ballerup Boulevard, Denmark.
Pic source: Marianne Levinsen Landskab



Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Rain gardens capture runoff, hold it temporarily and promote infiltration instead of rapid discharge to sewers. Their engineered soil, mulch and plant-microbe communities act as bio-filters, reducing sediments, nutrients, metals and hydrocarbons while smoothing peak flows and supporting groundwater recharge. (Hunt et al., 2008; Karabay et al., 2024)

Water quantity and runoff control

Rain gardens temporarily collect and store runoff from impervious surfaces, allowing water to infiltrate through vegetation and soil media or be safely discharged through an overflow system. This reduces runoff volumes, delays discharge, and helps attenuate peak flows to the drainage network. (EPA, 2021; CIRIA, 2015; Susdrain, n.d.).

Biodiversity

Rain gardens create structurally diverse habitat within sealed urban areas. They provide nectar, seeds, cover and moist microhabitats for pollinators, birds, amphibians and soil biota, acting as small ecological stepping stones that

enhance connectivity. (Penn State Extension, 2023; Hanumesh et al., 2025)

Human wellness

Rain gardens provide everyday contact with nature that supports psychological restoration and outdoor activity. These spaces are linked with higher quality of life, stronger neighbourhood identity and more positive views of local institutions. (Song et al., 2020; Bessette, 2023)

Heat decrease

Shrubs and small trees shade adjacent hard surfaces, while evapotranspiration from plants and moist soils cools the surrounding air, lowering surface and near-surface air temperatures and contributing to mitigate urban heat islands. (Imran et al., 2019; Karabay et al., 2024)

Air quality

Rain gardens also support air-quality regulation: foliage traps particulate matter, and vegetation-soil systems absorb or transform some gaseous pollutants while sequestering carbon. They complement trees and parks in reducing local exposure to air pollution. (Pataki et al., 2011; Song et al., 2020)



Sønder vold Nature Park Denmark.
Pic source: SLA

Site selection

Rain gardens are applicable to most types of development, and can be used in both residential and non-residential areas to **mitigate polluted runoff from roads**.

They can be implemented in private curtilage for managing runoff from single properties, in small shared public areas, on car park islands, roundabouts, footpaths, traffic calming and pedestrian zones.

Dimension

The **width** of the system should be **greater than 0,60 m and less than 20 m**. If access is only available from one side, the maximum width should be 10 m.

The maximum length should be 40 m to avoid uneven distribution of water over the surface, and the total **filter area should not exceed 800 m²**.

Hydraulic design

Collected water is filtered through the strata of soil or engineering growing soil, called substrate. After the soil reaches its saturation limit, excess water pools on the surface of the soil and eventually infiltrates the natural soil below. The bioretention soil mixture should typically contain 60% sand, 20% compost, and 20% topsoil. Soils with higher concentrations of compost have shown improved effects on filtering groundwater and rainwater.

Non-permeable soil needs to be removed and replaced periodically to generate maximum performance and efficiency if used in the bioretention system. The sandy soil (bioretention mixture) cannot be combined with a surrounding soil that has a lower sand content because the clay particles will settle in between the sand particles and form a concrete-like substance that is not conducive to infiltration.

Infiltration system

Greater thicknesses of filter medium and a saturated drainage layer are **more appropriate where trees will be planted** in the system and also if the vegetation proposed is less tolerant of drought. The larger the surface area of the system the more valuable a permanent body of water is, because it allows water to be evenly distributed below the whole of the filter medium and provides better irrigation

for the plants that are remote from the inlet.

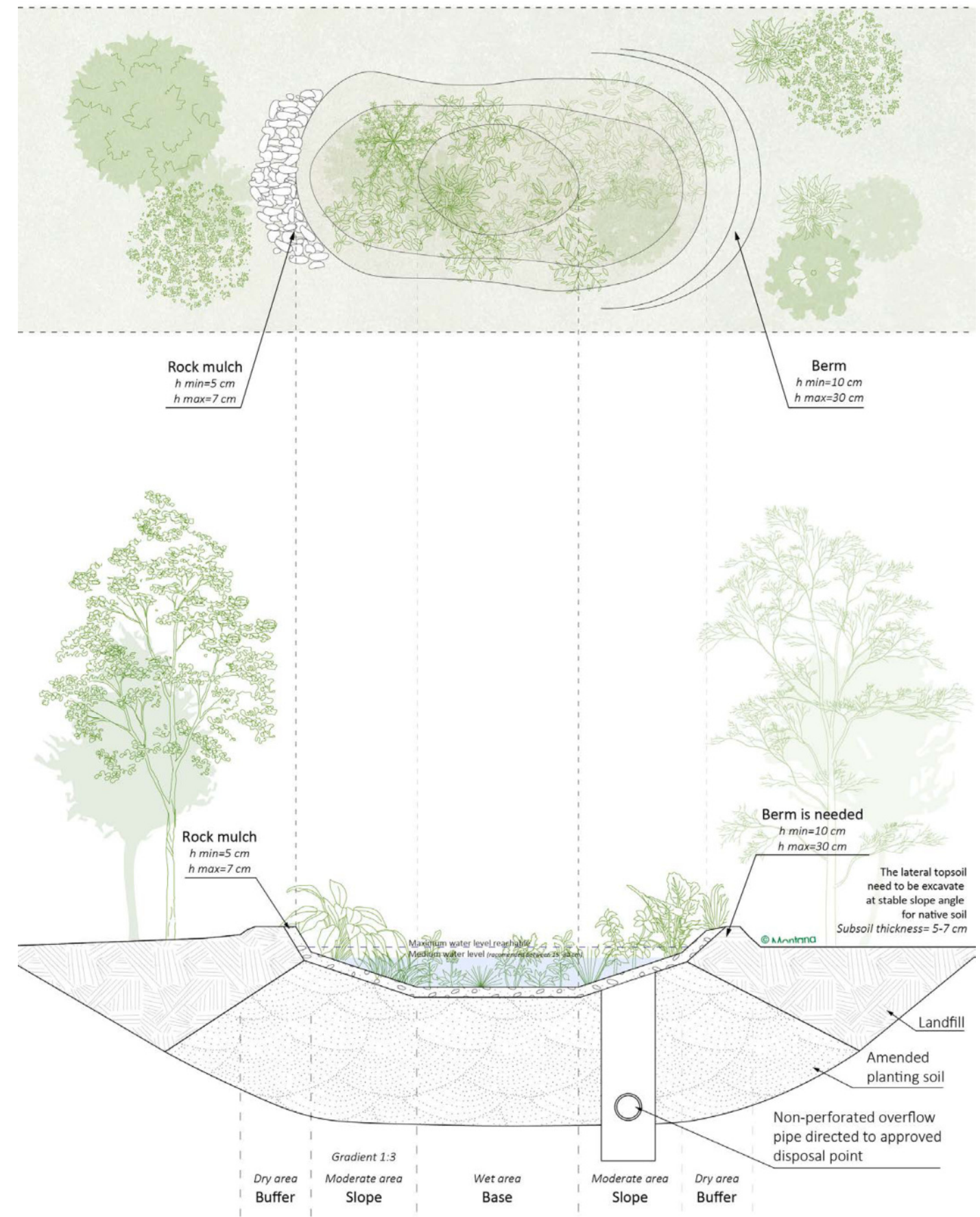
Interception design

Bioretention systems deliver interception because there is no runoff from them for the majority of small rainfall events. The water soaks into the filter medium and is removed by evapotranspiration and infiltration (where allowed). The extent of the volumetric reduction in runoff will depend on the infiltration rate of the surrounding soil, the catchment area, area and depth of the system, type of vegetation and the climate.

Maintenance

Also rain gardens need a regular maintenance. It's important to **water to promote plant growth** and survival, especially during the first two years and during dry spells; also inspect site following rainfall events and replace vegetation in any eroded areas and **remove trash and debris**.

Annually the rain garden need an inspection of the inflow area for sediment accumulation and the removal of any accumulated sediment or debris; the inspection site for erosion as well as sediment and mulch which have been moved around in the garden; and last, it's **important to test the planting bed for pH**. If the pH is below 5.2, limestone should be applied. If the pH is above 8.0, iron sulfate and sulfur should be applied.



↗
Plan and section of a rain garden.

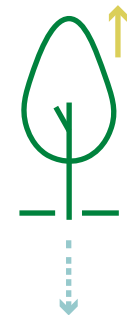
Drawing: Montana S.p.A.
Pic source: Montana S.p.A.

Public and urban scale interventions

Trees

Trees **can help protect and enhance the urban environment** in a number of important ways, for example:

- contributing to **surface water management**;
- valorizing the urban landscape;
- improving the health and well-being of local communities;
- **reducing annual building energy consumption** by moderating local climate;
- **filtering air pollutants**;
- reducing noises;
- enhancing wild life and creating an habitat for different species of animal;
- providing a source of food;
- **absorbing and storing CO2**.



FUNCTIONS

EVAPOTRANSPIRATION

SHADE

COOLING EFFECT

SLOW RUNOFF INTERCEPTION

AIR PURIFICATION

CARBON SEQUESTRATION

SDGS GOALS

3 GOOD HEALTH AND WELL-BEING

11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

↗
James Canning Gardens Toronto, Canada.

Pic source: Landezine

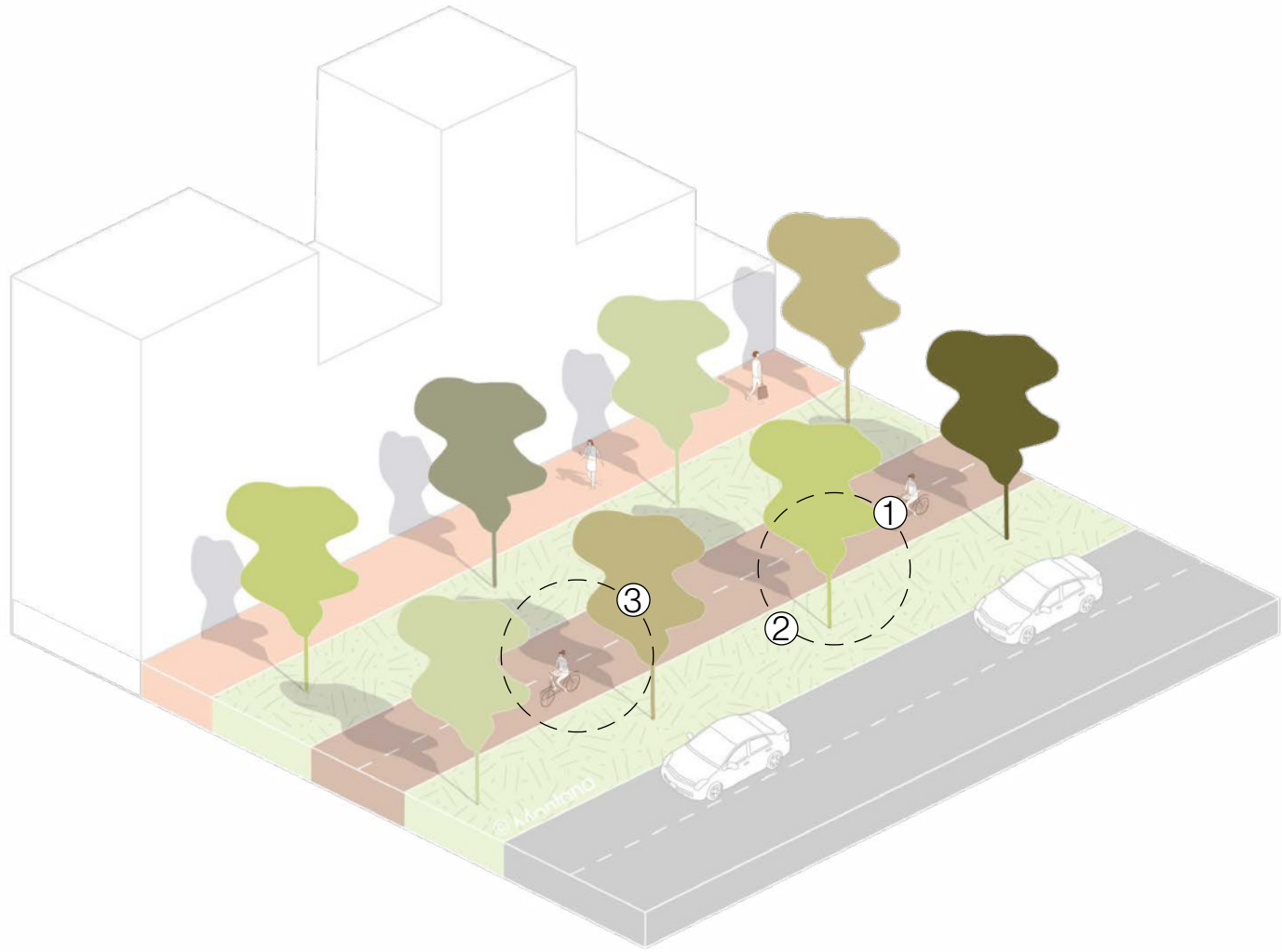
→
Passeig De St Joan Boulevard Barcelona, Spain.

Pic source: Landezine



Visualization

Visualization of trees in an urban context



Details of increased benefits for the urban living environment



Trees reduce runoff, improve infiltration, and **prevent erosion**, while filtering pollutants from stormwater. Trees also absorb carbon dioxide, release oxygen, and trap dust and particulate matter, **improving air quality** and helping mitigate the urban heat island effect.

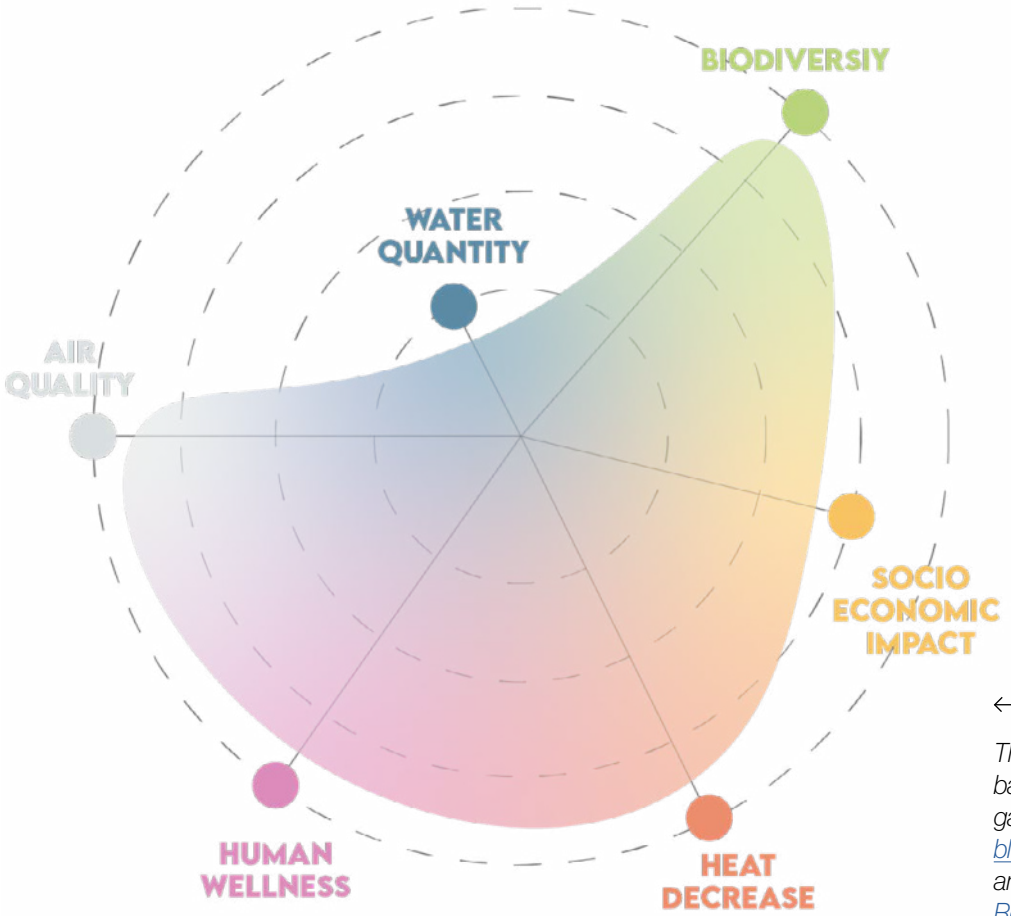


Trees support biodiversity by **providing habitats for a wide range of species**. Their leaves, flowers, and fruits offer food and shelter for birds, insects, and small mammals, while their **roots** stabilize the soil and **create microhabitats for underground organisms**, enriching local ecosystems.



Trees offer **green spaces** for relaxation and **recreation**, reducing stress, improving air quality, and providing opportunities for physical activity. Additionally, their **shade and cooling effects** help lower urban temperatures, creating **more comfortable outdoor environments**.

Benefits



This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quantity and runoff control

Trees reduce runoff by intercepting rainfall in their canopy, supporting evapotranspiration, and improving soil infiltration through their root systems. By lowering runoff volumes and delaying peak flows, they help reduce pressure on urban drainage networks. (EPA, 2016; EPA, 2026; Berland et al., 2017).

Biodiversity

Trees provide canopy, cavities, flowers and fruit that support birds, pollinators and other fauna even in dense city cores. (Canedoli et al., 2018; UNECE, 2022)

Socio-economic impact

Trees generate economic value through property value increase, avoided costs for stormwater management, energy use and public health. These benefits exceed planting and maintenance costs. (Nowak & Dwyer, 2007; Song et al., 2018)

Energy management

Strategically placed trees shade façades and roofs, lower ambient temperatures and reduce wind speeds, cutting cooling—and in some

climates heating—demand. (McPherson & Simpson, 2003; Nowak et al., 2017)

Heat decrease

Through shading and evapotranspiration, tree canopies cool local microclimates. Well-watered urban trees can significantly reduce near-surface air temperatures even during extreme heat events. (Winbourne et al., 2020; Li et al., 2023)

Human wellness

Tree-rich greenspace is associated with lower mortality, reduced cardiovascular risk and better mental health, more physical activity and stronger social ties. (Twohig-Bennett & Jones, 2018; Kondo et al., 2021)

Air quality

Trees capture particulate matter and absorb gaseous pollutants like ozone and NO₂, with large pollution removal and health benefits—provided canopies are planned to support, pollutant dispersion. (Nowak et al., 2006; Forest Research, 2023)

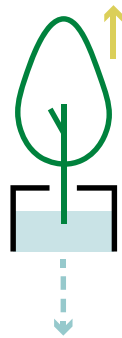
Public and urban scale interventions

Trees filter box

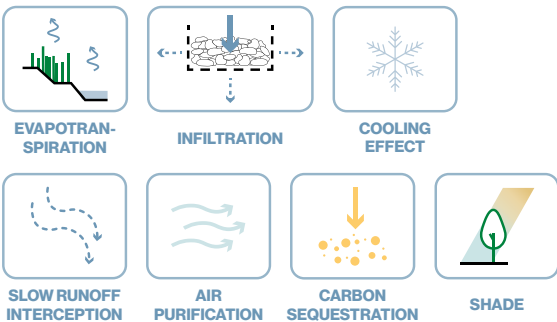
A tree box filter or in ground well consists of a **container filled with amended soil and planted with a tree**, underlain by crushed gravel media.

Tree root systems treat and uptake stormwater runoff captured from the street into the box filter. An underdrain carries treated runoff to either a surface discharge location or a larger retention system for secondary treatment. The life of the tree is short, so trees need replacement every five to ten years. Tree box filters can also be planted with hardy shrubs and herbaceous plants tolerant of inundations.

Tree box filters and wells can be incorporated into urban retrofits with the added benefits of water quality improvement and reduction of the urban heat island effect. As with other filtration devices, tree box filters require occasional inspection to remove large debris and/or trash.



FUNCTIONS

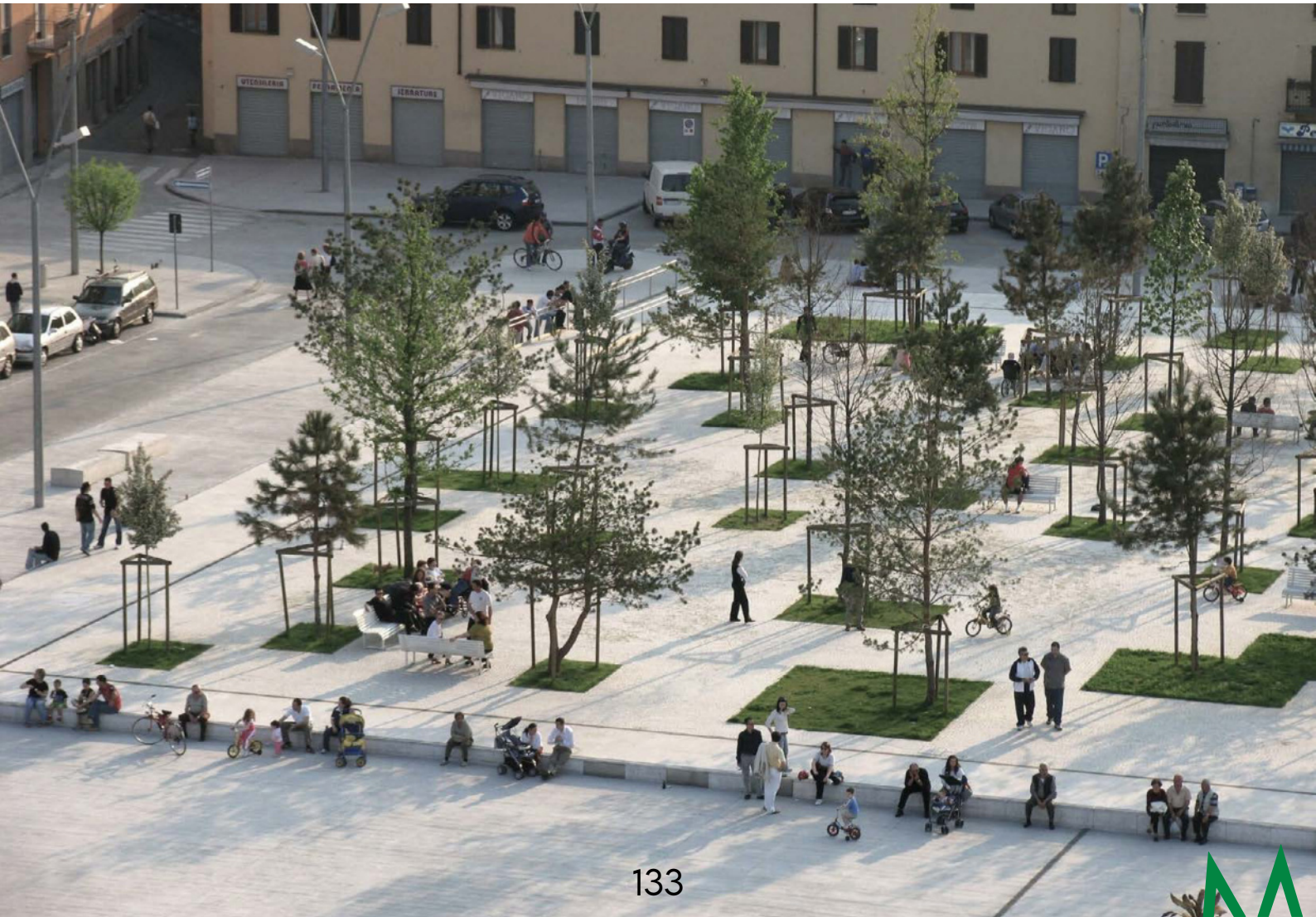


SDGS GOALS



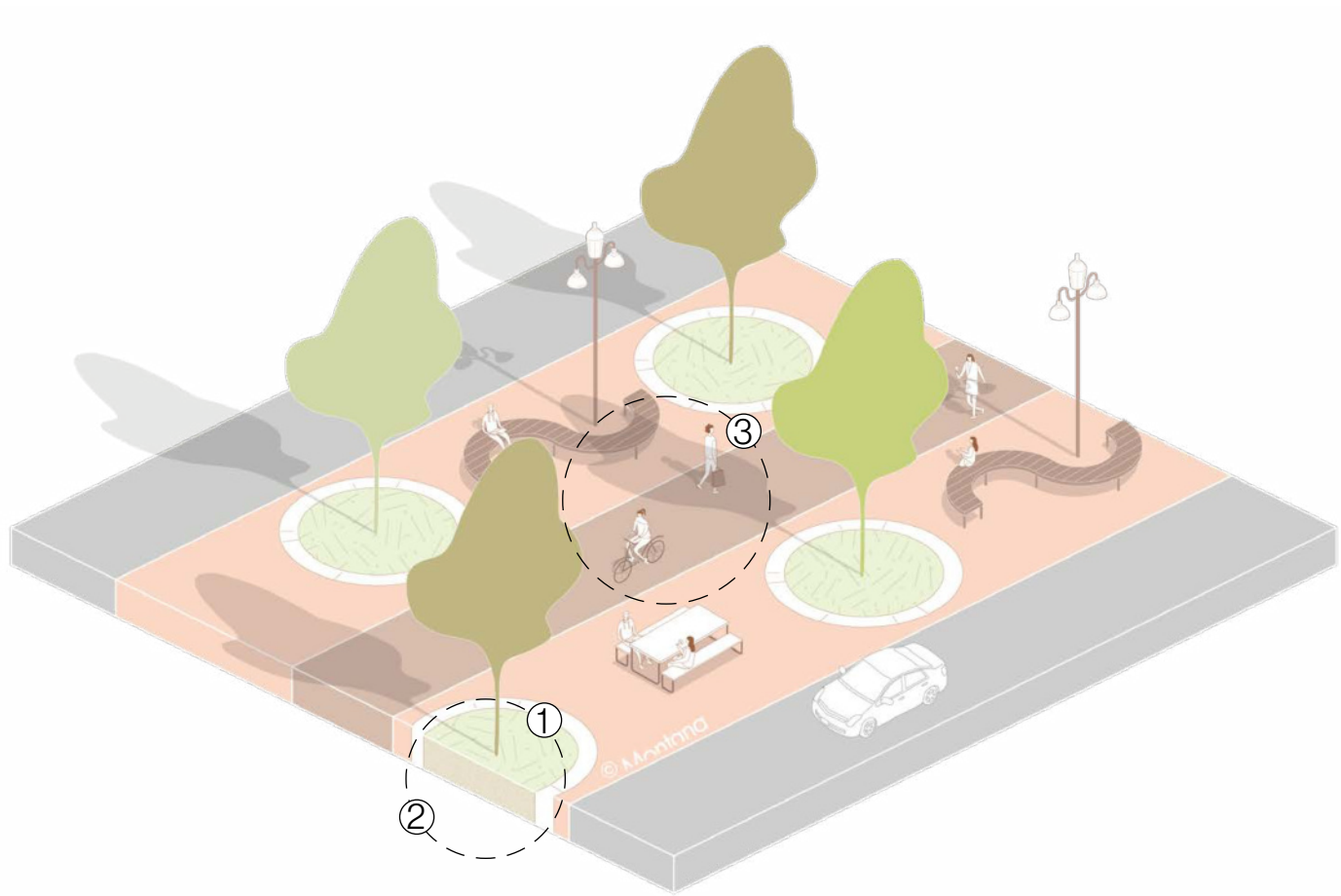
↗
Use of tree filter box in a private square of Zurich, Switzerland.
Pic source: Loeliger Strub

→
Urban and landscape development of Square Gramsci, Milan, Italy.
Pic source: Perrault Architecture

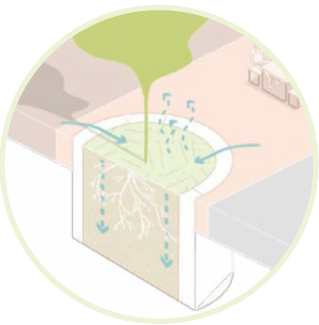


Visualization

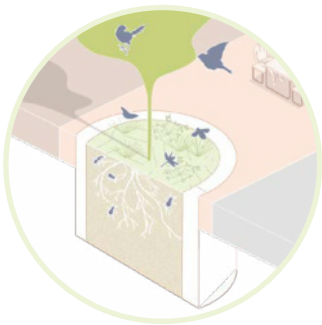
Visualization of tree filter boxes in an urban context



Details of increased benefits for the urban living environment



Tree filter boxes **capture runoff** and allow it to **infiltrate** through the soil. The plants in the box help **filter pollutants**, reduce surface runoff, and improve water quality by **absorbing nutrients** and **contaminants** before they reach larger water systems.

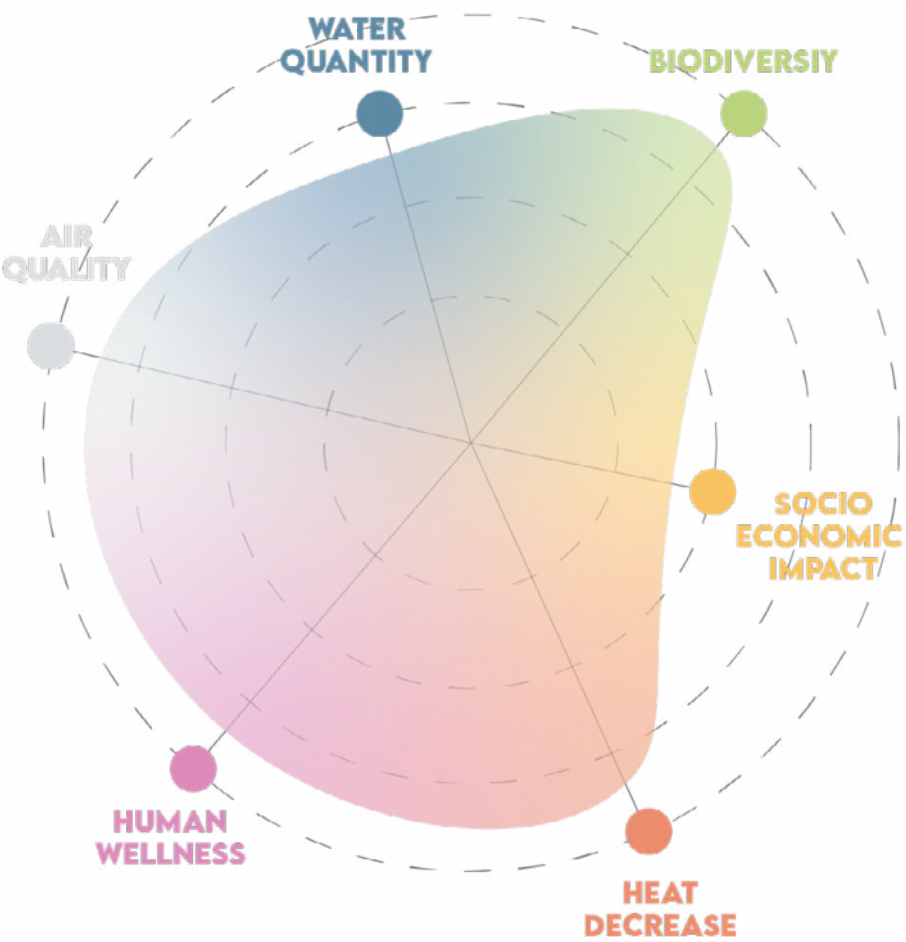


Tree filter boxes support biodiversity by **providing habitats** for a variety of **plant species** and **beneficial insects**. The plants in the boxes offer food and shelter, **attracting pollinators** and **small wildlife**, while helping to maintain local **ecological balance** and promote urban biodiversity.



Tree filter boxes improve air quality, reduce urban heat, and providing green spaces in cities. They offer aesthetic value, help reduce stress, and promote mental well-being, while also **cooling the surrounding environment** and improving the overall **quality of urban life**.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Tree filter boxes capture the first flush of runoff, filtering it through soil and roots, achieving high removal of suspended solids and notable reductions in nutrients, metals and hydrocarbons. (Rector et al., 2013; Minnesota Pollution Control Agency, 2022)

Water quantity and runoff control

Tree filter boxes capture runoff from nearby paved surfaces and temporarily store it within a compact bioretention cell. By promoting filtration, infiltration, and controlled discharge, they help reduce runoff volumes, delay peak flows, and relieve pressure on urban drainage networks. (EPA, 2021; Rutgers University, 2019; Ahmed & Borst, 2019).

Biodiversity

Tree filter boxes insert living vegetation into sealed streetscapes, creating micro-habitats and nectar/seed sources that act as stepping stones for birds, insects and other urban wildlife. (Minnesota Pollution Control Agency, 2022; Gallardo-López et al., 2024)

Energy management

Integrating shade-providing trees into street corridors lowers solar heat on pavements and façades and boosts evapotranspirative cooling, thereby reducing building cooling demand. (Minnesota Pollution Control Agency, 2022; McPherson & Simpson, 2003)

Heat decrease

Networks of tree filter boxes lead to measurable reductions in surface and near-surface air temperatures and helping to mitigate urban heat-island effects at street scale. (Minnesota Pollution Control Agency, 2022; Alonzo et al., 2024)

Human wellness

By greening they contribute to reduced stress, improve mental health and more walking and social interaction. (Twohig-Bennett & Jones, 2018; Minnesota Pollution Control Agency, 2022)

Air quality

Tree canopies intercept particulate matter and stomatal uptake of gases such as NO₂ and O₃, while helping to limit ozone formation. (Nowak et al., 2006; Minnesota Pollution Control Agency, 2022)

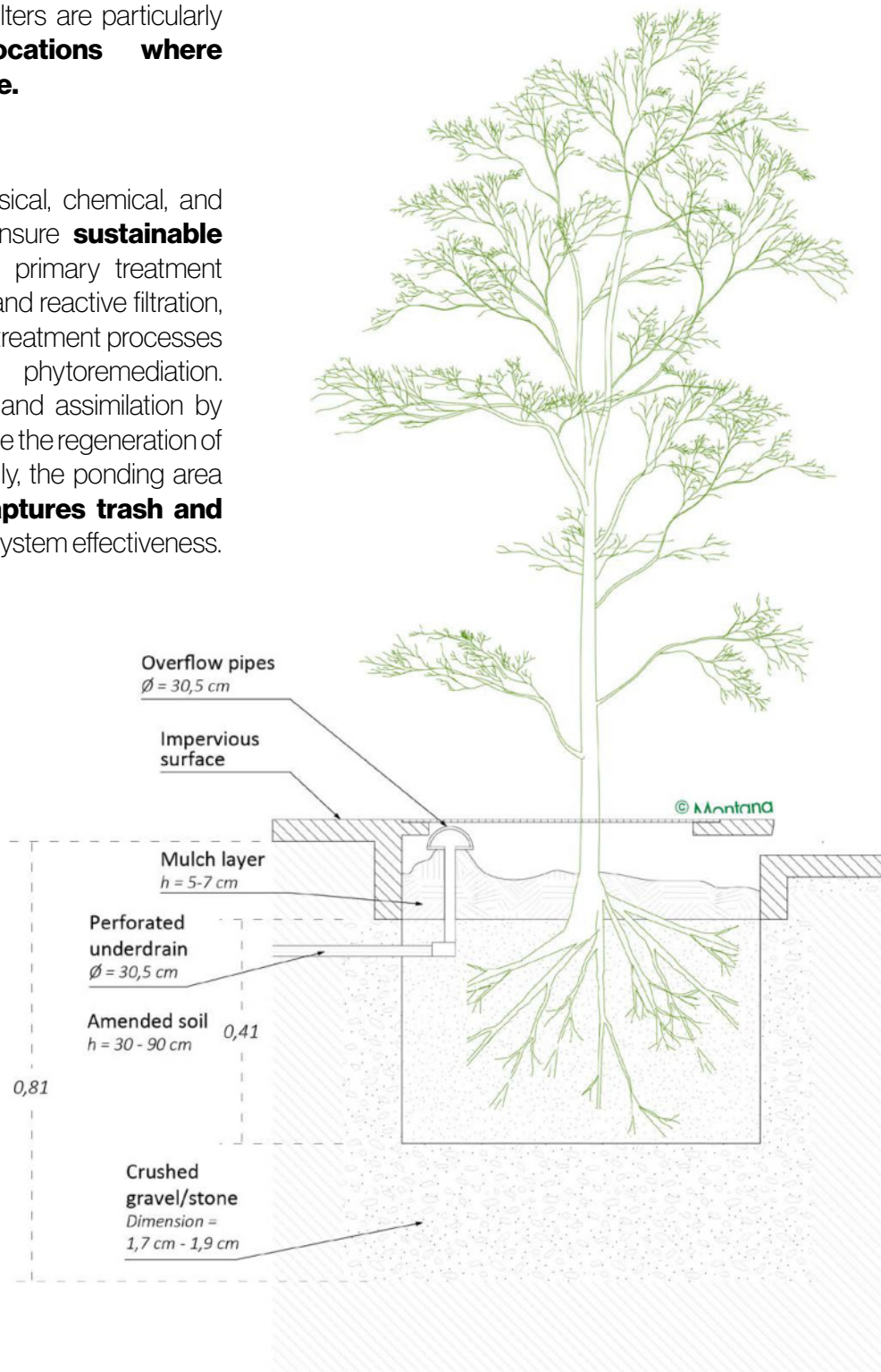
Site selection

Tree box filters are frequently implemented in **densely urbanized environments**, including along roads, sidewalks, and parking lots. The primary benefits of tree box filters include their **standardized designs**, ease of construction, and cost-effective maintenance. These filters are highly adaptable to various developments due to their compact footprint, shallow elevation, and absence of driving head requirements. Additionally, multiple configuration options provide flexibility in meeting diverse site-specific needs. Tree box filters are particularly **advantageous in locations where infiltration is not feasible**.

Treatment design

Tree box filters utilize physical, chemical, and biological processes to ensure **sustainable pollutant removal**. The primary treatment mechanisms include inert and reactive filtration, augmented by inter-storm treatment processes such as microbial and phytoremediation. Contaminant degradation and assimilation by microbes and plants facilitate the regeneration of adsorption sites. Additionally, the ponding area above the mulch layer **captures trash and debris**, enhancing overall system effectiveness.

→
Section of a tree box filter.
Section: Montana S.p.A.
Pic source: Montana S.p.A.

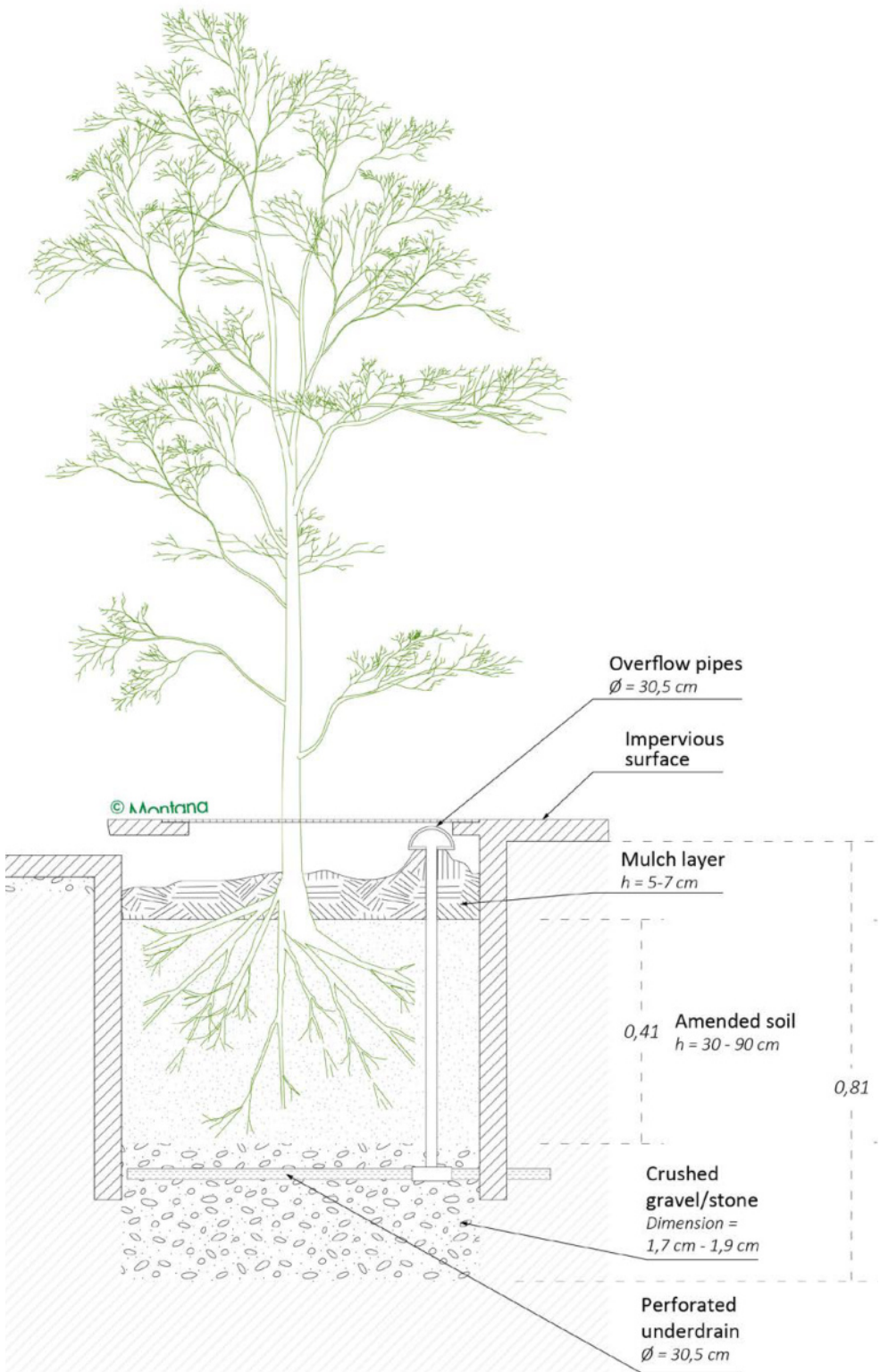


Maintenance

Tree box filters have certain limitations. As natural systems, they require **adequate irrigation** to ensure the survival of the plant and microbial community during drought conditions. They should not be activated until the site is fully stabilized to prevent media contamination from construction runoff. Maintenance of tree box filters is generally straightforward, involving the use of a rake and

shovel to **remove spent mulch**, sediment, trash, and debris from the system. The media surface is then replenished with new mulch, and the plant is pruned or replaced as necessary. This maintenance is conducted from the surface, eliminating the need for confined space entry or specialized tools. Depending on site load and climate conditions, maintenance is typically required **once or twice per year**.

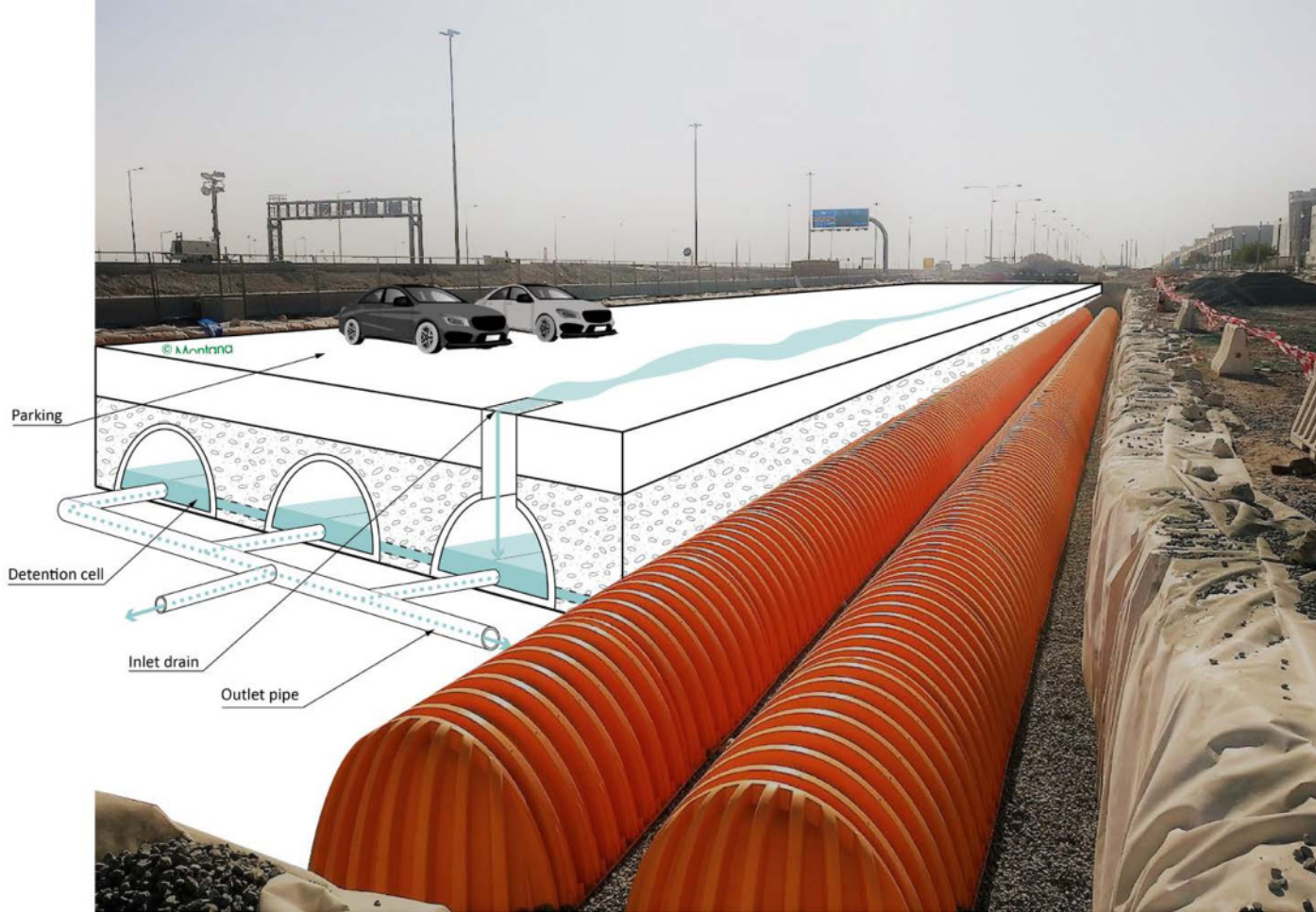
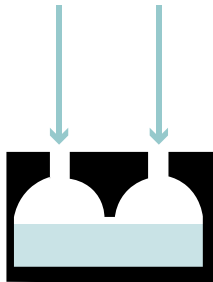
←
Section of a tree box filter with a perforated underdrain and an overflow pipe.
Section: Montana S.p.A.
Pic source: Montana S.p.A.



Public and urban scale interventions

Underground detention

Underground detention (or linear detention) systems **detain stormwater runoff prior to its entrance into a conveyance system.** Underground storage systems store and slowly release runoff into the LID network. Some systems can infiltrate stormwater if the soil beneath is permeable. Underground storage is employed in places where available surface area for ongrade storage is limited. Underground storage **reduces peak flow rate** through metered discharge and has potential for infiltration. Improved water quality is achieved by sedimentation, or the settling of suspended solids. Though at first costly, underground detention systems are easy to access and maintain.



FUNCTIONS



SDGS GOALS



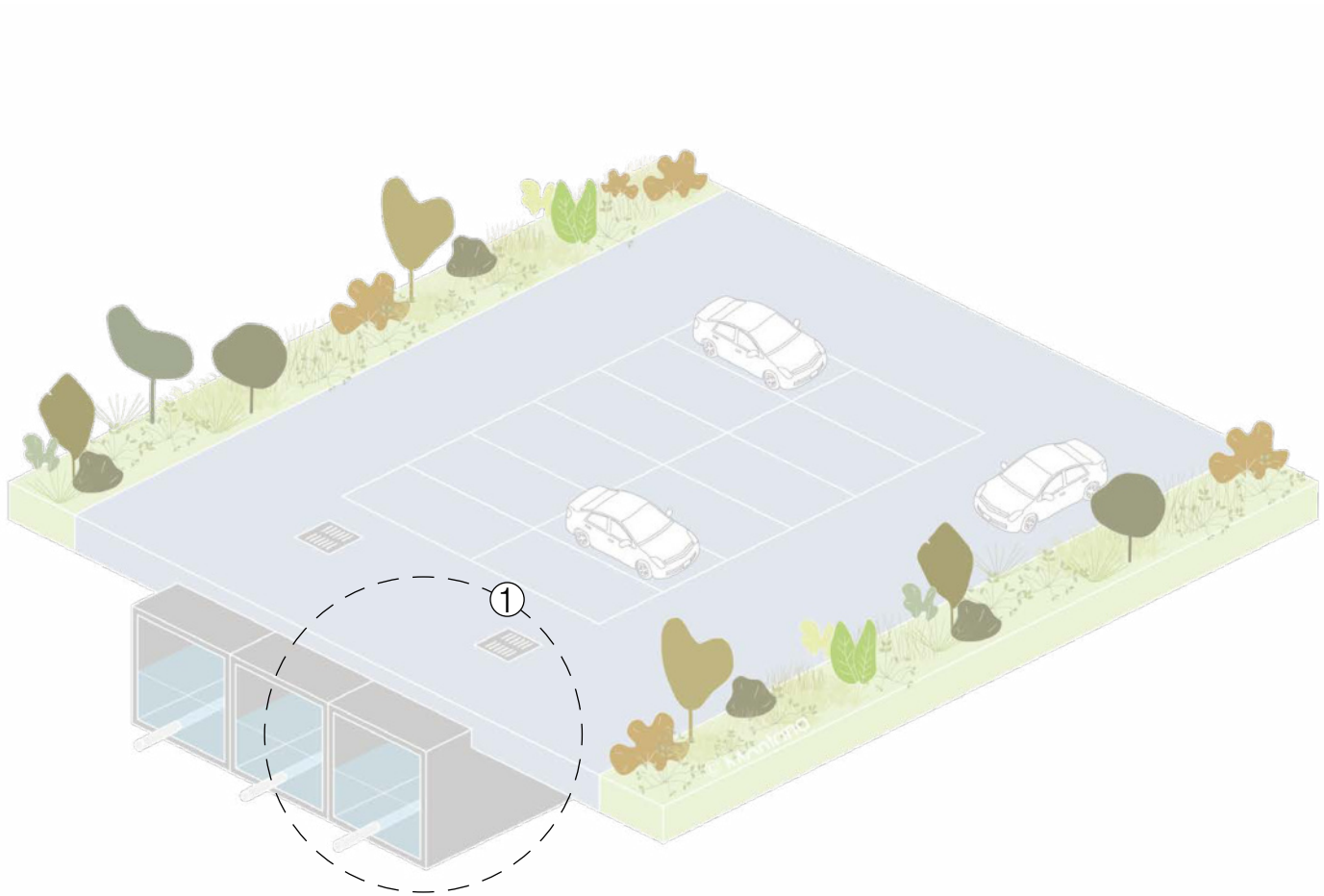
↗
Infographic: Montana S.p.A.
Pic source: SWC Canada Inc.

→
Example of an underground detention system.
Pic source: SWC Canada

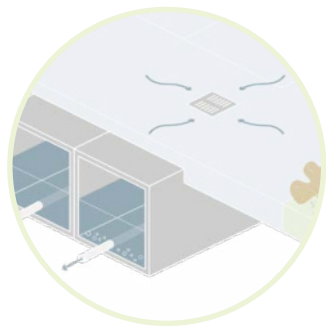


Visualization

Visualization of underground detention systems in an urban context

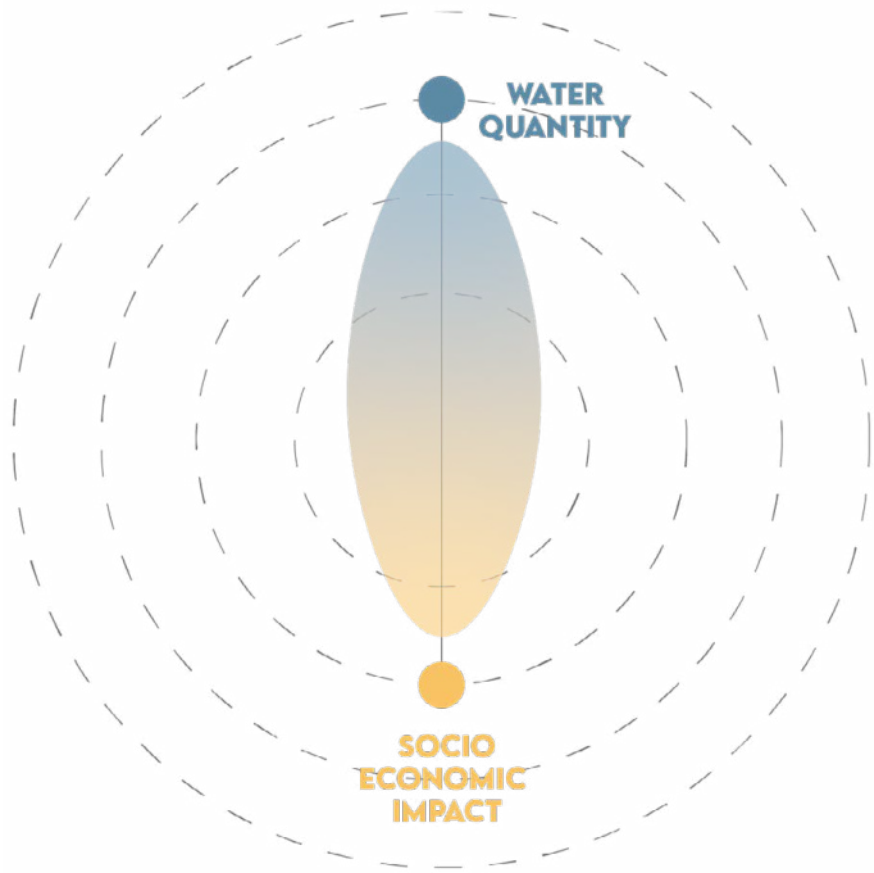


Details of increased benefits for the urban living environment



Underground detention systems manage stormwater by capturing runoff and storing it below ground. These systems **control the flow of water**, reduce surface runoff, and **prevent flooding** by slowly releasing stored water over time, while also improving drainage and reducing the risk of erosion.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Underground detention systems store stormwater in subsurface vaults, shaving peak flows and lowering downstream flood risk. When combined with pre-treatment and, where possible, controlled infiltration, they can remove a significant share of suspended solids and associated pollutants while limiting thermal impacts on receiving waters compared with exposed basins. (Dotson, 2008; Todeschini & Papiri, 2012)

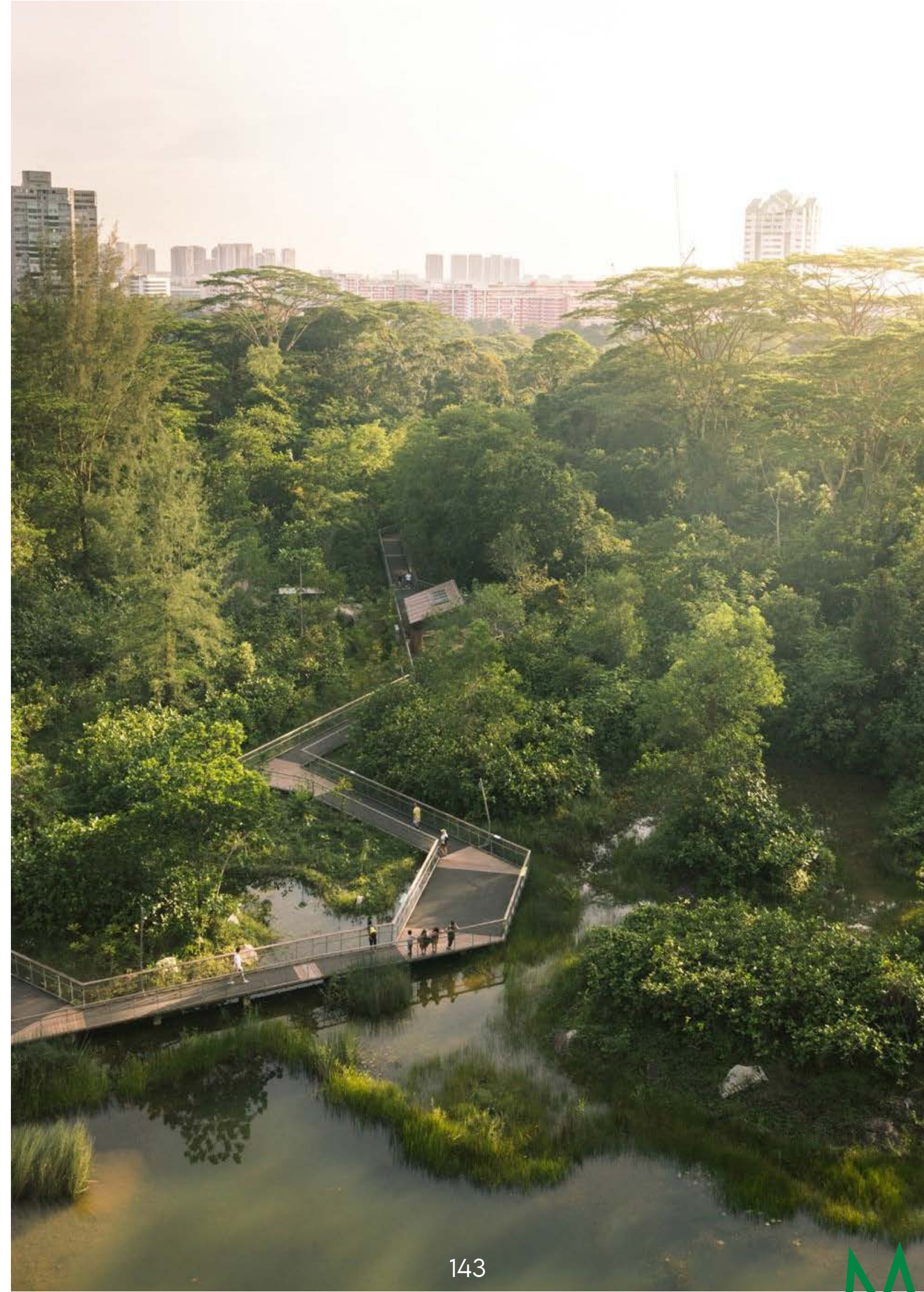
Socio-economic impact

By placing storage underground, surface land can be used for buildings, parks or sports facilities—an important advantage where land values are high. Case studies, such as multifunctional parks built over large tanks, illustrate how underground detention can simultaneously reduce flood risk, meet regulatory requirements and deliver new public amenities that strengthen neighbourhood resilience. (Dalvit, 2024; St Martin, 2025)

03. Interventions for natural areas and rural lands

- 144 Phytodepuration
- 150 Phytoremediation
- 156 Pocket forest
- 160 Riparian buffer
- 164 Sand filter
- 170 Wet pond
- 176 Wetland

→
Rifle Range Nature Park
Singapore.
Pic source: Landezine

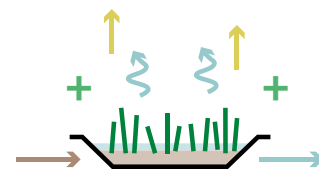


Phytodepuration

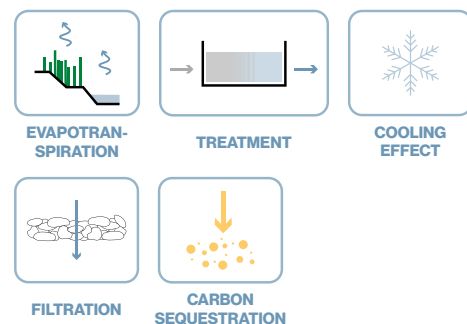
Phytodepuration is a **natural treatment technique that reproduces natural purification processes in a controlled environment.**

Phytodepuration is a system that uses shrubs, plants and flowers instead of traditional purifying systems.

The effectiveness and functioning of the purification system essentially depends on the behaviour of the plants used. Plants have an elevated capacity to absorb and use certain elements, thus preventing the contamination of surface or subterranean water bodies; they also promote microorganisms in the soil that attack and destroy a good portion of organic pollutants. Furthermore, treatment efficiency depends on used techniques. There are different techniques: **horizontal flow treatment; vertical flow treatment and free water surface.**



FUNCTIONS



SDGS GOALS



↗
Phytodepuration system for sewer overflow, Gorla Maggiore (VA), Italy.

Pic source: Ecpmuseo della Valle Olona

→
Hortes de baix thermal gardens, Spain.

Pic source: EUMies Award



Horizontal flow

In these systems **wastewater is uniformly distributed on the whole length of the basin** through a **pipe disposed on the ground** at the entrance of the basin. Wastewater is fed into the system in a continuous flow and it flows through the basin and exits at its end. The filter medium is made of inert material of constant size. Filtration and biological degradation processes, carried out both by anaerobic and aerobic microorganisms, remove organic matter. Nitrogen is removed by nitrification, denitrification, ammonia volatilization and root adsorption. Metals and phosphorus are adsorbed on the inert material surface.

Vertical flow

This technique is similar to the Horizontal flow one, but the **wastewater is fed from the top** through a web of pipes, which distributes it on the whole basin surface. **Wastewater goes down the basin in a horizontal flow** and is collected at its bottom. Basin filling is not continuous. Filling-emptying phases of the basin **allow a higher oxygen concentration** than in the Horizontal flow system, increasing the efficiency of nitrification and organic material degradation. To have a continuous purification process a second filter bed is needed or a collecting and regulating pool can be introduced.

Free water surface

The free water surface treatment are **basins with an elongated shape** having **variable depth** depending on the macrophytes used and on the level of treatment realized. **Wastewater is pre-treated** by grid filtration and primary sedimentation to remove the largest particles and reduce the concentration of suspended solid particles. The **FWS** systems are fed continuously and the wastewater entering the basin is in direct contact with the atmosphere. The upper layer of the stream is in an aerobic condition, while the deeper layers are in anaerobic conditions. Aerobic and anaerobic microorganisms destroy organic material, suspended in the stream or settled on its bottom. Chemical-physical and biological processes remove metals from the water.

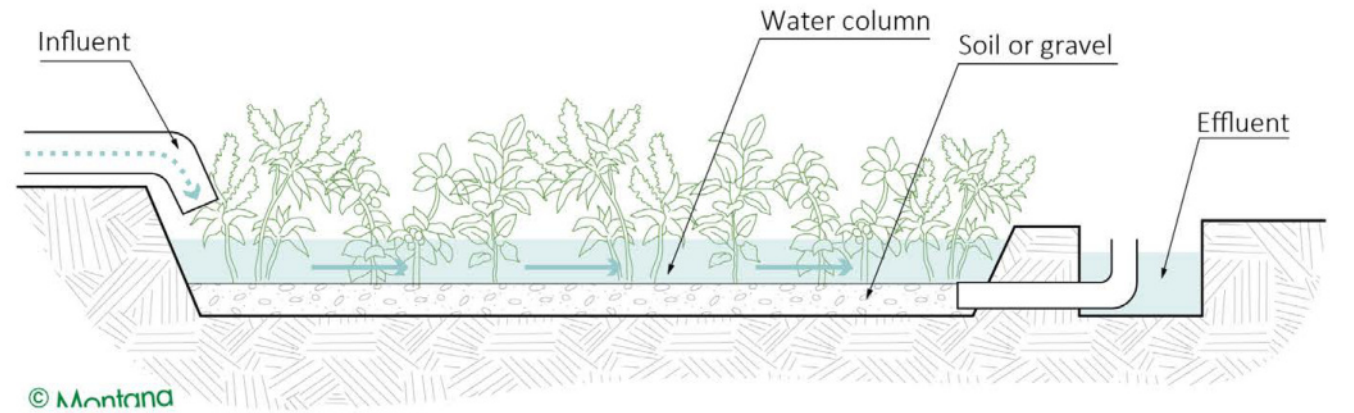
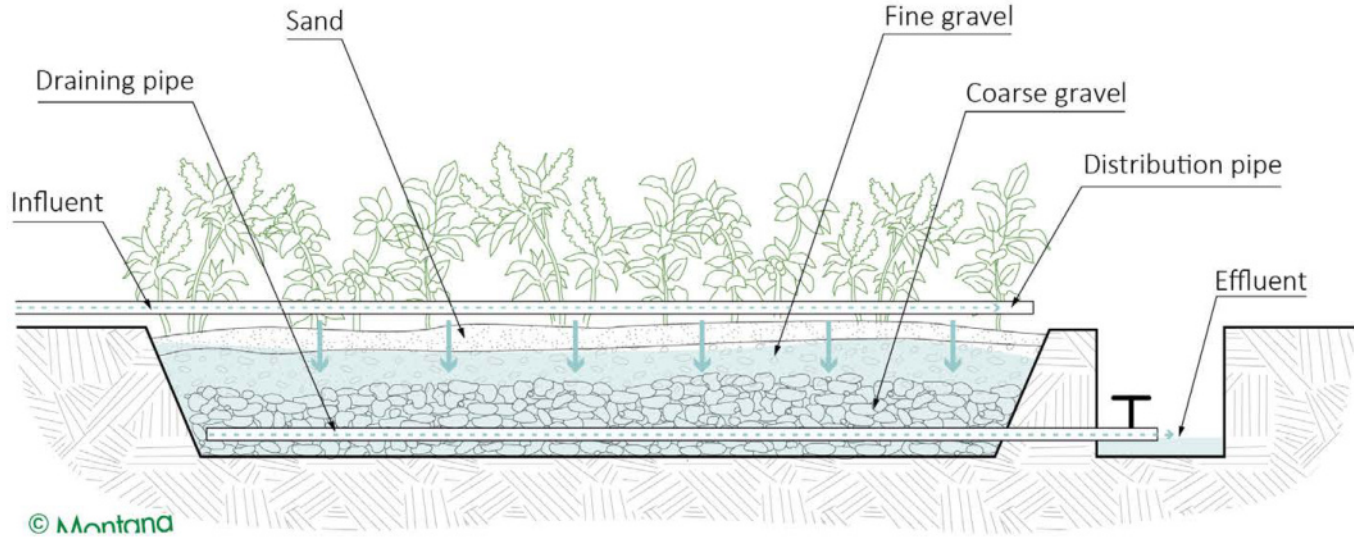
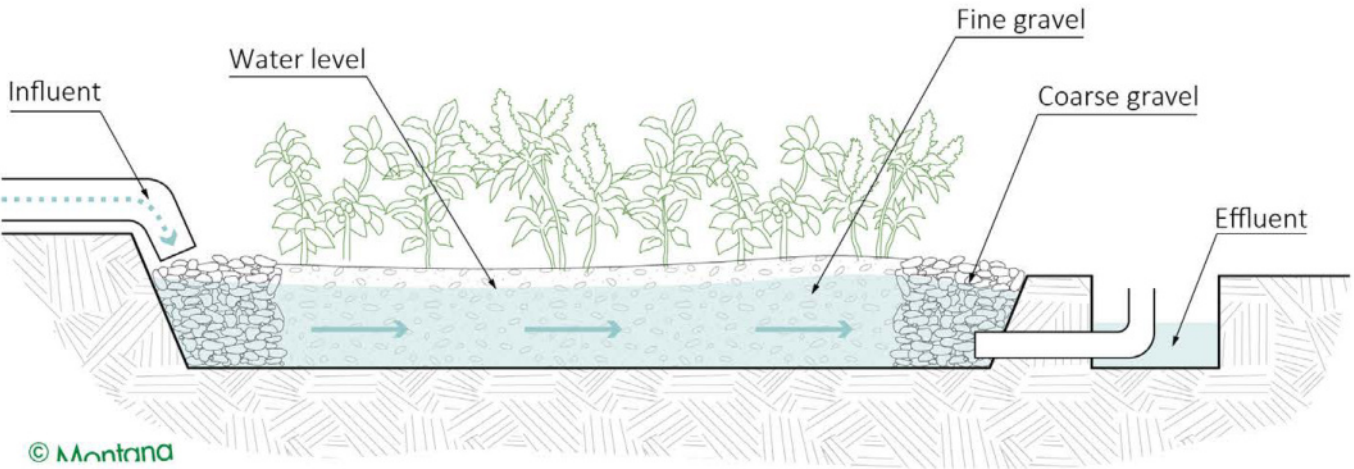


↑
Saint Queen Park of the Docks,
Paris, France.

Pic source: Landezine Internation
Landscape Award

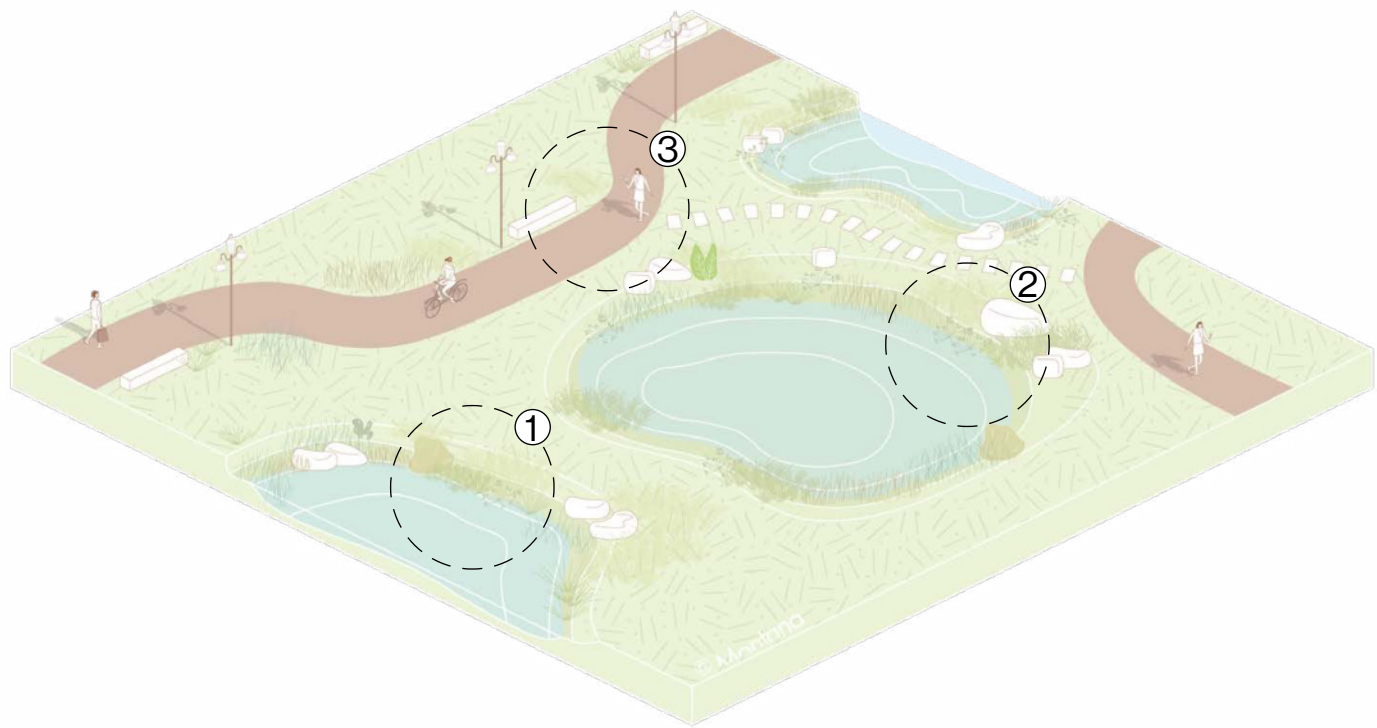
↗
Sections of a horizontal flow
system, a vertical flow system
and at the bottom a free water flow
system.

Sections: Montana S.p.A.
Pic source: Montana S.p.A.

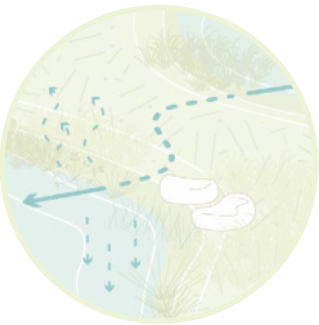


Visualization

Visualization of phytodepuration areas in an urban context



Details of increased benefits for the urban living environment



Phytodepuration manages a **natural treatment process** that **enhances water clarity**, reduces contaminants, and promotes ecosystem health. The system also **promotes infiltration**, and **evapotranspiration**, enhancing both water purification and environmental sustainability.

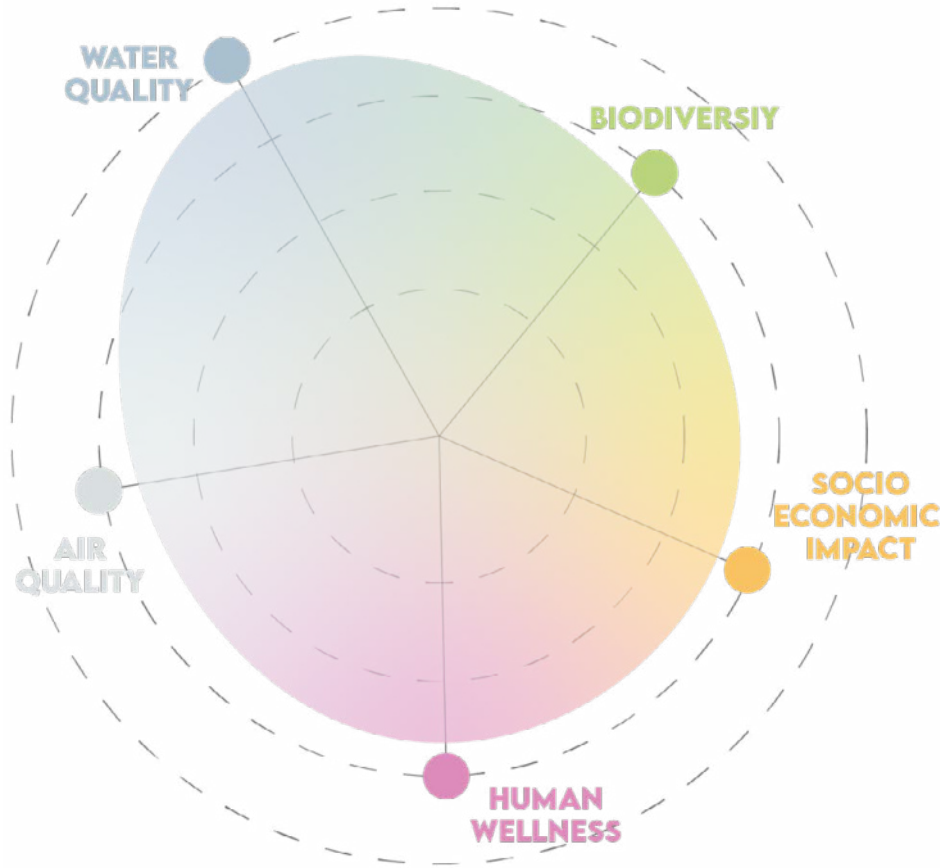


Phytodepuration systems creates diverse plant habitats that support various species, including **aquatic plants, insects, and birds**. The system fosters a **thriving ecosystem**, with plants that attract **pollinators** and provide shelter, contributing to local biodiversity.



This solution can be designed to offer **recreational value** by incorporating green spaces for passive activities such as **walking or birdwatching**. These areas can be **enjoyable for visitors** while supporting environmental sustainability.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Phytodepuration systems remove many micropollutants from wastewater and runoff, producing safe discharge. Their storage and long retention times also dampen peak flows, support flood attenuation and groundwater recharge. (Vymazal, 2011; Ferreira et al., 2023)

Biodiversity

The open water mosaic, emergent vegetation and dry margins provide habitat for invertebrates, amphibians, birds and small mammals, turning engineered basins into biodiversity hotspots. (Barman et al., 2024; Agaton & Guila, 2023)

Socio-economic impact

Phytodepuration often shows lower capital and operating costs than conventional mechanical plants, particularly for small and medium communities. (Ghermandi, 2005; Shah et al., 2023)

Heat decrease

Phytodepuration wetlands act as local cooling islands, often several degrees cooler than built-up areas. (Sun et al., 2012; Wetlands International, 2020)

Human wellness

Phytodepuration facilities become attractive blue-green public spaces that support mental restoration, physical activity and social interaction. (Gascon et al., 2015; WHO Regional Office for Europe, 2023)

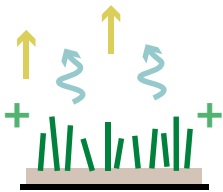
Air quality

Vegetation intercepts particulate matter and gaseous pollutants on leaf surfaces, while cooling and higher humidity can help limit ground-level ozone formation and dust resuspension. (Ferreira et al., 2023; Nieuwenhuijsen, 2021)

Interventions for natral areas and rural lands

Phytoremediation

Phytoremediation is the **use of plants to remediate or clean up environmental pollutants.** Phytoremediation projects commonly **involve growing plants in areas with polluted soil to absorb or break down the pollutants.**



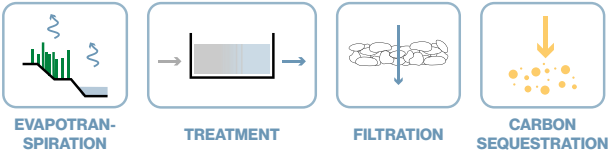
Phytoremediation is widely accepted as a cost-effective environmental restoration technology, is an alternative to engineering procedures that are usually more destructive to the soil.

Phytoremediation of contaminated sites should ideally not exceed one decade to reach acceptable levels of contaminants in the environment.

There are different techniques: **phytostabilization, phytodegradation, phytovolatilization, evapotranspiration, rhizodegradation** and **phytoextraction.**



FUNCTIONS



SDGS GOALS



↗
Phytoremediation to rehabilitate former industrial sites, Montréal, Canada.

Pic source: WWF

→
Phytoremediation with sorghum growing, Trecate, Italy.

Pic source: Research Gate



Phytostabilization

Phytostabilization aims to **retain contaminants in the soil** and prevent further dispersal. Contaminants can be stabilized in the roots or within the rhizosphere.

Phytodegradation

Phytodegradation involves the **degradation of organic contaminants** directly, **through the release of enzymes from roots**, or through metabolic activities within plant tissues.

In phytodegradation organic contaminants are taken up by roots and metabolized in plant tissues to less toxic substances. Phytodegradation of hydrophobic organic contaminants have been particularly successful.

Phytovolatilization

Phytovolatilization involves the **uptake of contaminants by plant roots and its conversion to a gaseous state**, and release into the atmosphere. This process is driven by the evapotranspiration of plant.

Plants that have high evapotranspiration rate are sought after in phytovolatilization.

Evapotranspiration

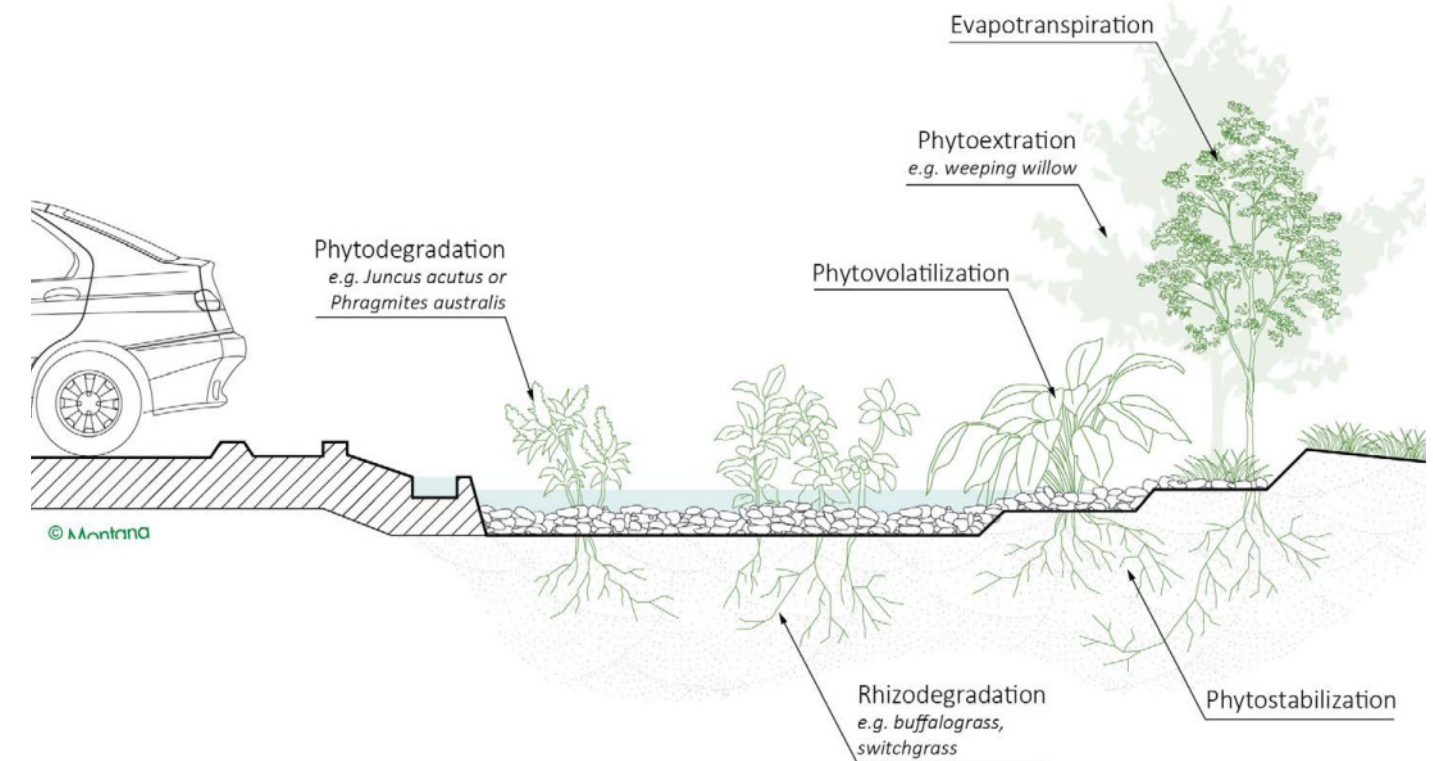
Evapotranspiration is the process in which the rain interception by the leaves, the water uptake and the water transpiration by the plant provide hydraulic control on the contaminated area.

Phytoextraction

Phytoextraction uses the **ability of plants to accumulate contaminants in the aboveground**, harvestable biomass. This process involves repeated harvesting of the biomass in order to lower the concentration of contaminants in the soil. Phytoextraction is either a continuous process (using metal hyperaccumulating plants, or fast growing plants), or an induced process (using chemicals to increase the bioavailability of metals in the soil).

Rhizodegradation

Rhizodegradation is the **breakdown of contaminants in the soil** through the bioactivity of rhizosphere organisms (bacteria, yeast and fungi). Microbial communities are enhanced by roots activity.



Section of a phytoremediation area next to a parking lot.

Drawing: Montana S.p.A.
Pic source: Montana S.p.A.



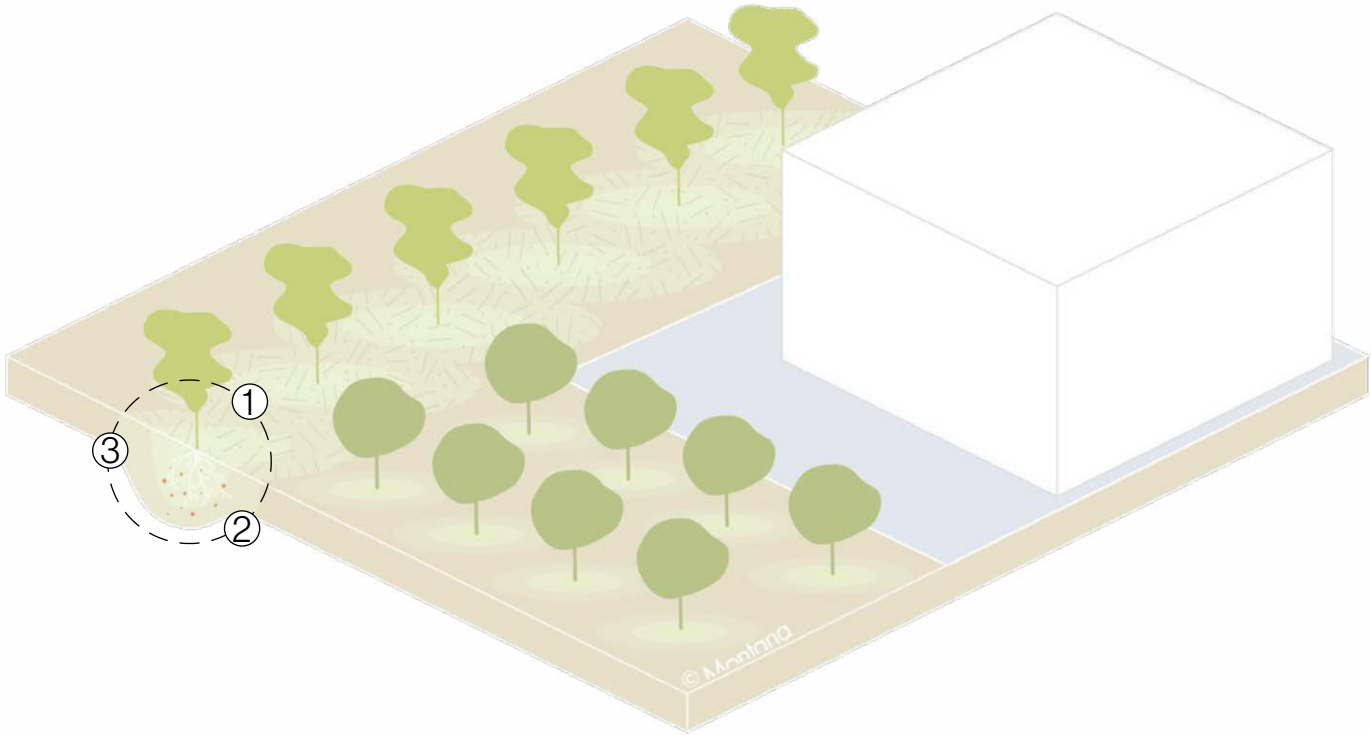
Life ECOREMED project,
Marcianise, Caserta, Italy.

Pic source: Osservatorio Socialis

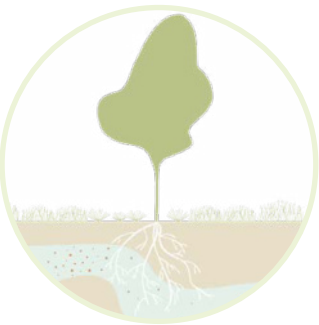


Visualization

Visualization of phytoremediation areas in an industrial context



Details of increased benefits for the urban living environment



Phytoremediation utilizes plant roots to **absorb and filter contaminants from water**. The roots trap heavy metals and excess nutrients, improving water quality and reducing the risk of pollution in natural water resources.

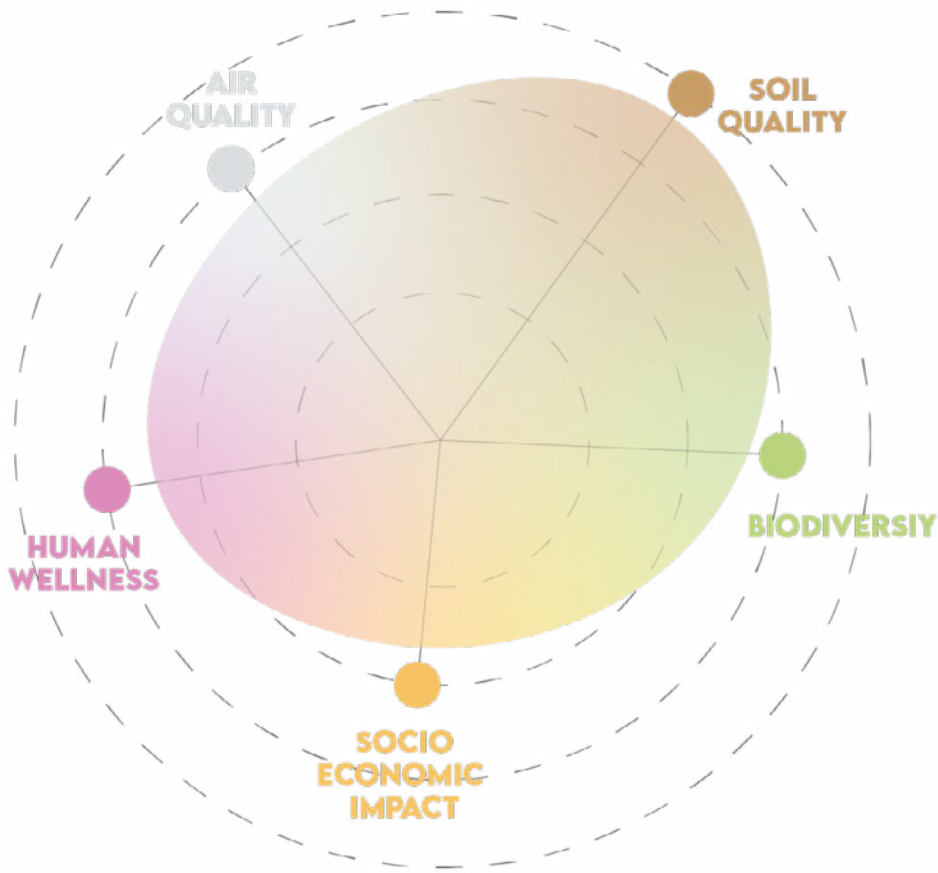


Plants **absorb contaminants** from the soil through their roots and transfer them to the plant tissues. Once metabolized, these contaminants are **converted into non-toxic compounds**, which are then **released** as gaseous substances into the atmosphere, contributing to environmental purification.



Plants **store** absorbed **contaminants** in their tissues, reducing the concentration of harmful substances in the soil. **Through the harvesting** process, plants are collected and safely disposed of, effectively **removing contaminants** from the system and restoring soil health.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Phytoremediation improves water quality by capturing, transforming or immobilising dissolved contaminants before they spread through the hydrological system. In saturated root zones, it reduces loads of metals, nutrients, pesticides and micropollutants and acts as a low-maintenance polishing step alongside conventional treatment. (Sharma, 2021; Wei et al., 2020)

Biodiversity

Phytoremediation restores structured plant communities that provide habitat for soil organisms, invertebrates, birds and pollinators, turning brownfields into ecological stepping stones. (Guidi Nissim et al., 2023; Di Stasio et al., 2025)

Soil quality

Phytoremediation can improve soil quality by using plants to extract, stabilise, degrade, or transform contaminants in polluted soils. Vegetation and root activity can also support microbial processes, soil structure, and erosion control, contributing to the gradual recovery of degraded sites.

(EPA, 2015; Kafle et al., 2022; Sustainability, 2023).

Socio-economic impact

It often has lower capital and operating costs, and can preserve or enhance land value on large or moderately contaminated sites, positioning it as both an environmental and socioeconomic strategy. (Lee et al., 2023; Phang et al., 2024)

Human wellness

Phytoremediation reduces chronic exposure pathways linked to respiratory, cardiovascular and other health burdens. Accessible green spaces also provides restorative views, recreational opportunities and a better neighbourhood image. (Guidi Nissim et al., 2023; Urban Innovative Actions, n.d.)

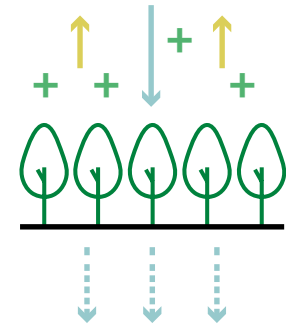
Air quality

Vegetated surfaces intercept particulate matter and foster capture or degradation of gaseous pollutants. Species with rough or waxy leaves efficiently trap fine particles, while plant-microbe systems can degrade certain volatile organic compounds and immobilise deposited metals. (Wei et al., 2020; Duan et al., 2024)

Interventions for natral areas and rural lands

Pocket forest

Thepocketforestisthe**ecosystemcontaining all of the trees, plants and associated animals in the urban environment.** Pocketforestplaysanimportantroleinaddressing environmental engineering problems, including those related to **erosion control, noise** and **air pollution abatement, wastewater management, watershed protection,** and glare, reflection, and traffic control. Urban trees can affect stream flows as well, by their ability to **intercept rainfall** and **affect soil infiltration rates of water.** These acts **can reduce surface water runoff,** which can indirectly affect water quality by reducing the amount of sediment and urban pollutants entering a stream system.



FUNCTIONS

EVAPOTRAN-
SPIRATION

SHADE

COOLING
EFFECT

SLOW RUNOFF
INTERCEPTION

AIR
PURIFICATION

CARBON
SEQUESTRATION

SDGS GOALS

3 GOOD HEALTH
AND WELL-BEING

6 CLEAN WATER
AND SANITATION

11 SUSTAINABLE CITIES
AND COMMUNITIES

13 CLIMATE
ACTION

15 LIFE
ON LAND

↗
A pocket forest in Zaandam, The Netherlands.

Pic source: National Geographic

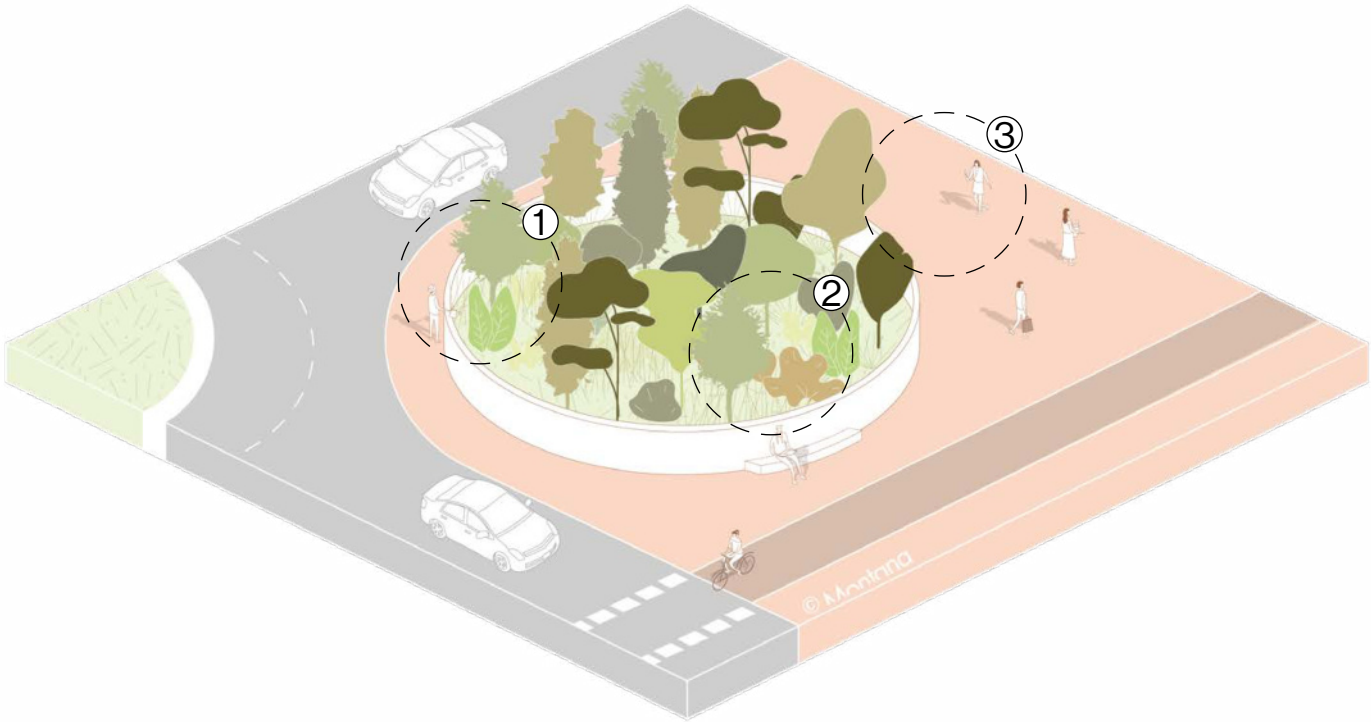
→
Holland Park Villas by Gillespies

Pic source: Landezine



Visualization

Visualization of pocket forests in an urban context



Details of increased benefits for the urban living environment



The dense vegetation of pocket forests increases soil infiltration and reduce surface runoff by helping **absorb rainwater**, promoting **groundwater recharge** while also **mitigating flooding and erosion**. This solution also filters pollutants and improves overall drainage.

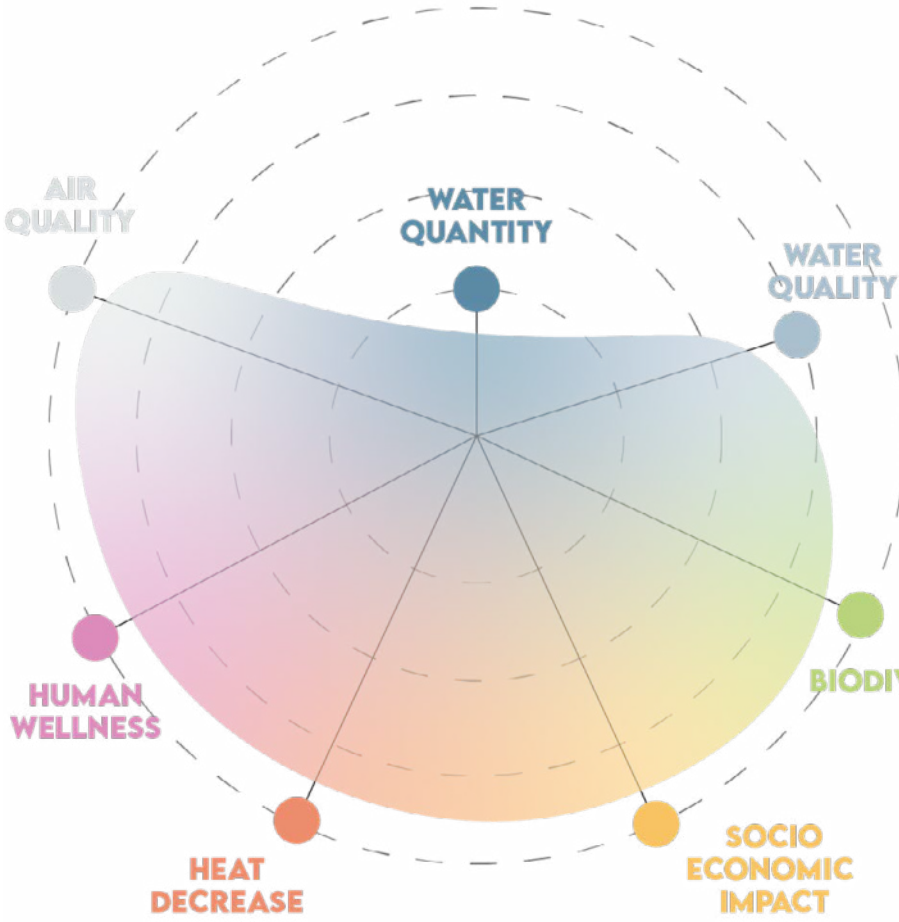


Pocket forests boost biodiversity by **providing habitats** for a wide range of plant and animal species. The **diverse vegetation**, including native trees, shrubs, and groundcovers, **supports pollinators**, birds, insects, and small mammals, **enriching urban ecosystems**



Pocket forests offer **peaceful green spaces** for relaxation, recreation, and connection with nature. Their vegetation **improves air quality** and helps **lower the perceived temperature**, creating a more comfortable environment in urban areas

Benefits



Water quality and sediment management

Pocket forests act as tiny vegetated sponges in sealed districts. This reduces runoff volumes and peaks, eases pressure on drainage systems and filters sediments and pollutants before water reaches streams or groundwater. (U.S. EPA, n.d.; USGS, 2022)

Heat decrease

Dense, multi-layered canopies provide shade and strong evapotranspiration, allowing pocket forests to cool their surroundings by several degrees and soften local urban heat islands, especially around built up areas. (Euronews Green, 2025; Srinivasan, 2025)

Biodiversity

By mimicking the layered structure of natural woodland with a rich mix of native species, pocket forests provide nectar, cover and nesting sites for insects, birds and small mammals. Even on very small plots, they can rapidly become biodiversity hotspots and stepping stones within wider urban green networks. (Torkington, 2023; UNature Team, n.d.)

Human wellness

Pocket forests help reduce stress and psychological distress while supporting everyday physical activity and social interaction. When communities are involved in planting and care, these micro-forests also function as outdoor classrooms and safe spaces for children and other vulnerable groups. (UNature Team, n.d.; Plan T, 2024)

Socio-economic impact

Pocket forests help regenerate neglected land, build social capital and raise environmental awareness. They can enhance an area's attractiveness for investment while creating opportunities for green jobs, volunteering and outdoor education. (Lobo, 2025; Vaidya, 2025)

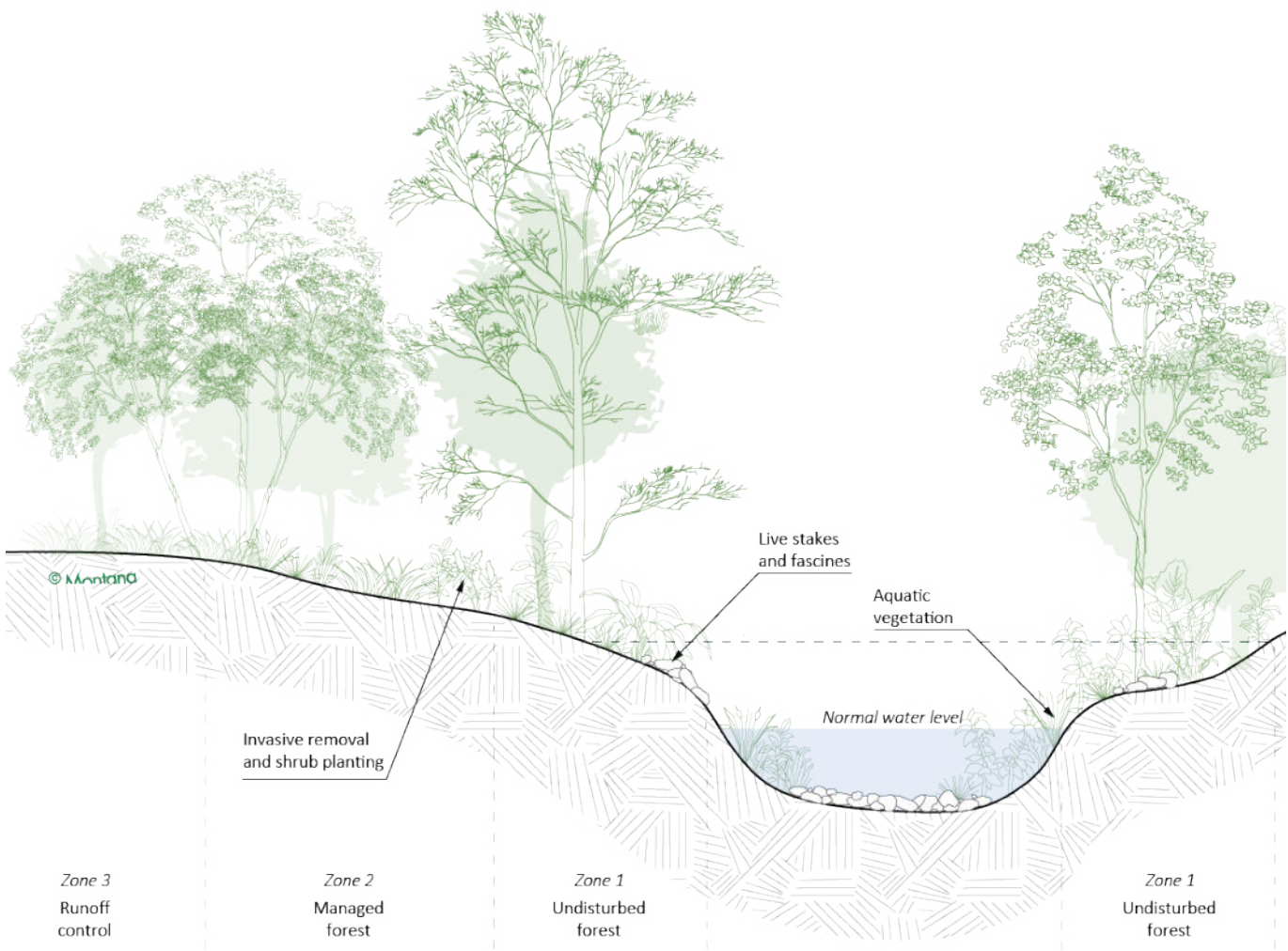
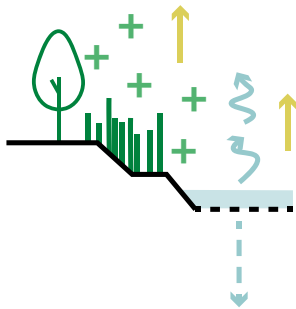
Air quality

The dense foliage traps particulate matter and dust on leaves and bark, while stomata absorb gaseous pollutants and the stand sequesters CO₂. They can reduce local pollution peaks, especially when used as buffers along roads or around schools. (Srinivasan, 2025; SUGi, 2023)

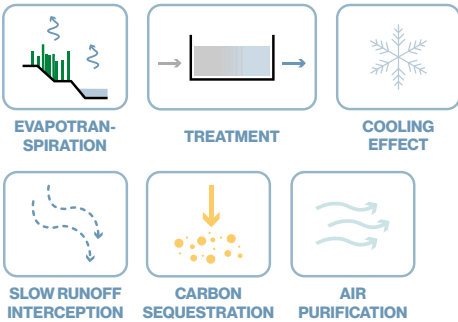
Interventions for natral areas and rural lands

Riparian buffer

A riparian buffer is a **strip of hydric soil** with facultative vegetation **along the banks of a river** or stream offering niche ecotone services. Riparian buffers are a simple, inexpensive way to **protect and improve water quality through local plant communities**. Between 50% and 85% of stormwater pollutant loads can be filtered within 30 to 90m vegetated buffers. Buffer strips structurally stabilize banks and shorelines to prevent erosion and slumping. Trees and shrubs provide shade to maintain consistent water temperature necessary for nutrient exchange and the survival of some aquatic life. Buffer width is based on surrounding context, soil type, size and slope of catchment area, and vegetative cover. Riparian buffers are most effective when combined with flow attenuation devices to avoid scouring from high velocity flows throughout a stream channel. Some management is required when riparian buffers are near urban development.



FUNCTIONS



SDGS GOALS



↗
Section of a riparian buffer.

Section: Montana Sp.A.
Pic source: Montana Sp.A.

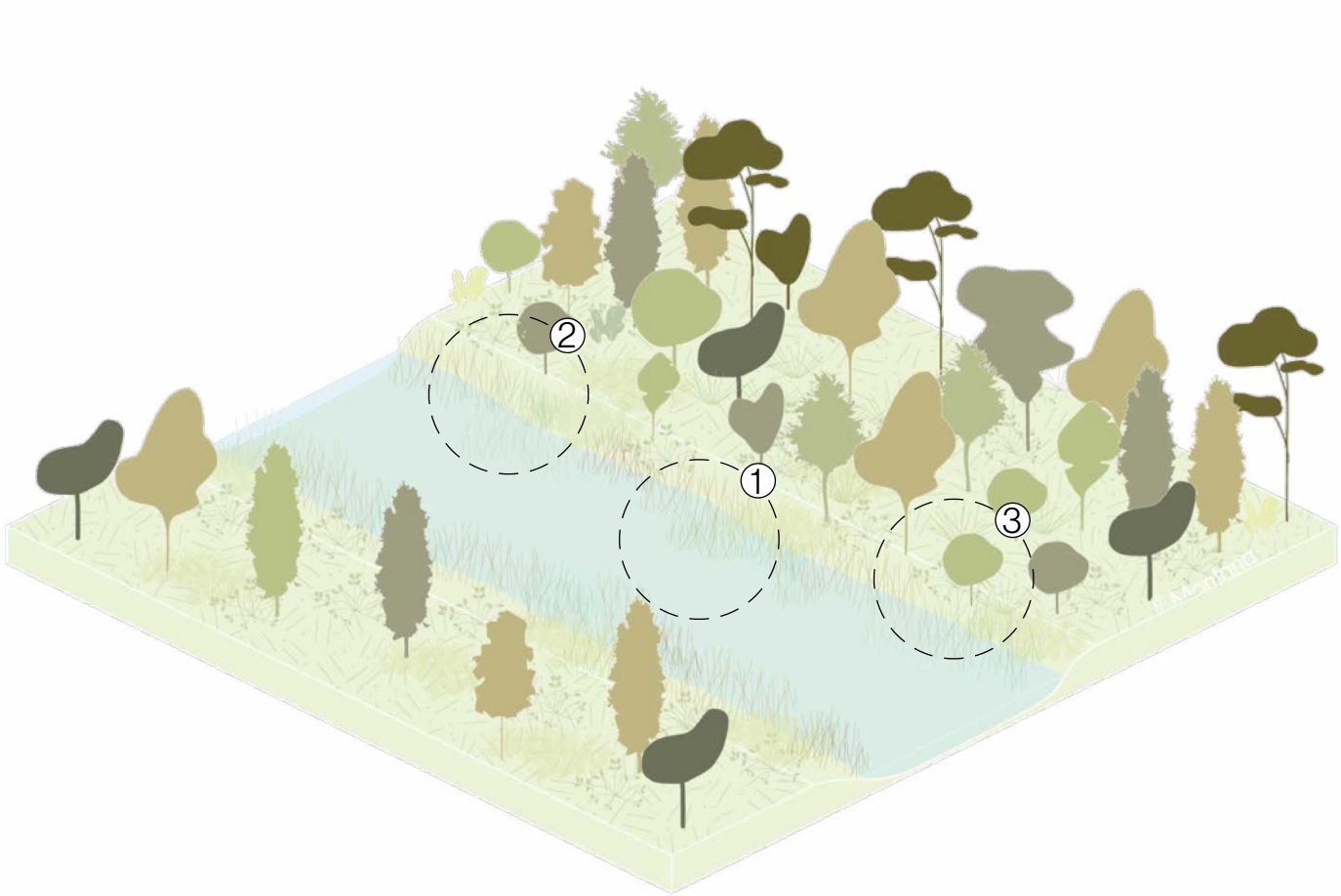
→
Example of a Riparian Buffer around a river in New Zealand.

Pic source: NIWA



Visualization

Visualization of riparian buffers in an urban context



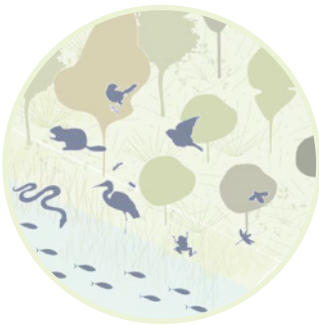
Details of increased benefits for the urban living environment



These vegetated zones help stabilize the soil along waterways, **reducing erosion**, and filtering pollutants from slowed runoff. They enhance water quality by allowing water to **infiltrate**, and **preventing sediment and nutrients from reaching water bodies**, ultimately improving ecosystem health.

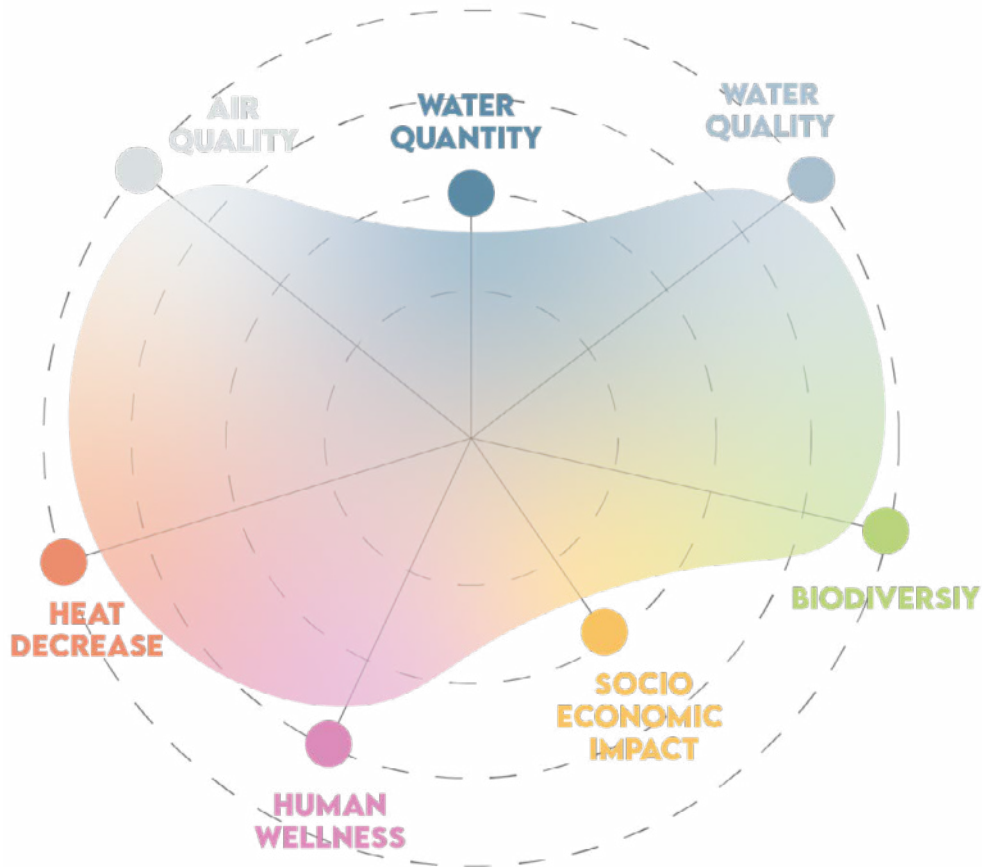


Riparian buffers **support diverse vegetation**, including native trees, shrubs, grasses, and aquatic plants. These create a **healthy environment for surrounding ecosystems**. They also contribute to maintaining water quality and enhancing the overall habitat.



Riparian buffers provide **essential habitats for a wide range of wildlife**, including birds, amphibians, and insects. The area offers food, shelter, and breeding sites, while the proximity to water provides crucial resources for animals. This diversity of fauna contributes to ecological balance.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Riparian buffers improve water quality by filtering sediments, nutrients, pesticides, and pathogens before they reach streams, reducing non-point source pollution and eutrophication risk. They can also help moderate flood peaks and support catchment-scale water resilience. (Wu et al., 2023; Majumdar & Avishek, 2025)

Human wellness

Riparian buffers safeguard drinking-water quality, reduce exposure to flood and erosion hazards and support more stable river-based livelihoods. They provide accessible places for recreation, nature contact and stress relief. (Davis et al., 2025; European Environment Agency, 2020)

Water quantity for runoff control

Riparian buffers slow runoff before it reaches rivers and streams, promoting infiltration and helping reduce peak flows. By supporting natural floodplain functions, they contribute to flood attenuation and more resilient water management. (EPA, 2021; USDA NRCS, n.d.; Palinkas et al., 2023).

Heat decrease

Tree-lined riparian buffers reduce solar radiation reaching streams and can lower average summer water temperatures by about 0.6–1.0 °C, easing thermal stress on cold-water species. Riparian vegetation cools adjacent microclimates through shading and evapotranspiration, helping mitigate urban heat islands. (Fuller et al., 2022; European Environment Agency, 2024)

Biodiversity

They connect terrestrial and aquatic habitats and support high species richness and functional diversity. Their complex vegetation offers habitat and movement corridors and restoration of degraded strips is linked to recovery of services such as pollination and natural pest control. (Davis et al., 2025; Majumdar & Avishek, 2025)

Air quality

This solution improves air quality by capturing airborne particulates and gaseous pollutants on tree canopies and understory vegetation, similar to other forested systems. By stabilising soils they also limit resuspension of dust and agrichemicals. (Fares et al., 2019; U.S. EPA, 2012)

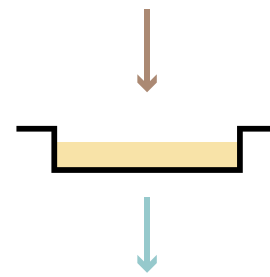
Sand filter

Sand filters are **single** or **multi-chambered structures** designed to treat surface water runoff through **filtration** using a **sand bed** as the primary filter medium.

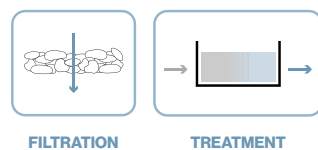
The filters can be designed with an impervious lining, or to allow infiltration, depending on the soil type. Temporary storage of runoff is achieved through ponding above the filter layer. They are used where particularly **high pollutant removal** is required. There are some design criteria to follow in order to create a proper sand filter:

- filter area to spread design water quality treatment volume to maximum depth of 150 mm;
- filter depths of 0.45 – 0.6 m;
- sand sizes of 0.5 – 1.0 mm
- combined volume of sedimentation and filter chamber should provide >75% of treatment;
- min sedimentation chamber length:width ratio 2:1.

There are three types of sand filter: **surface**, **perimeter** and **underground**.



FUNCTIONS



SDGS GOALS

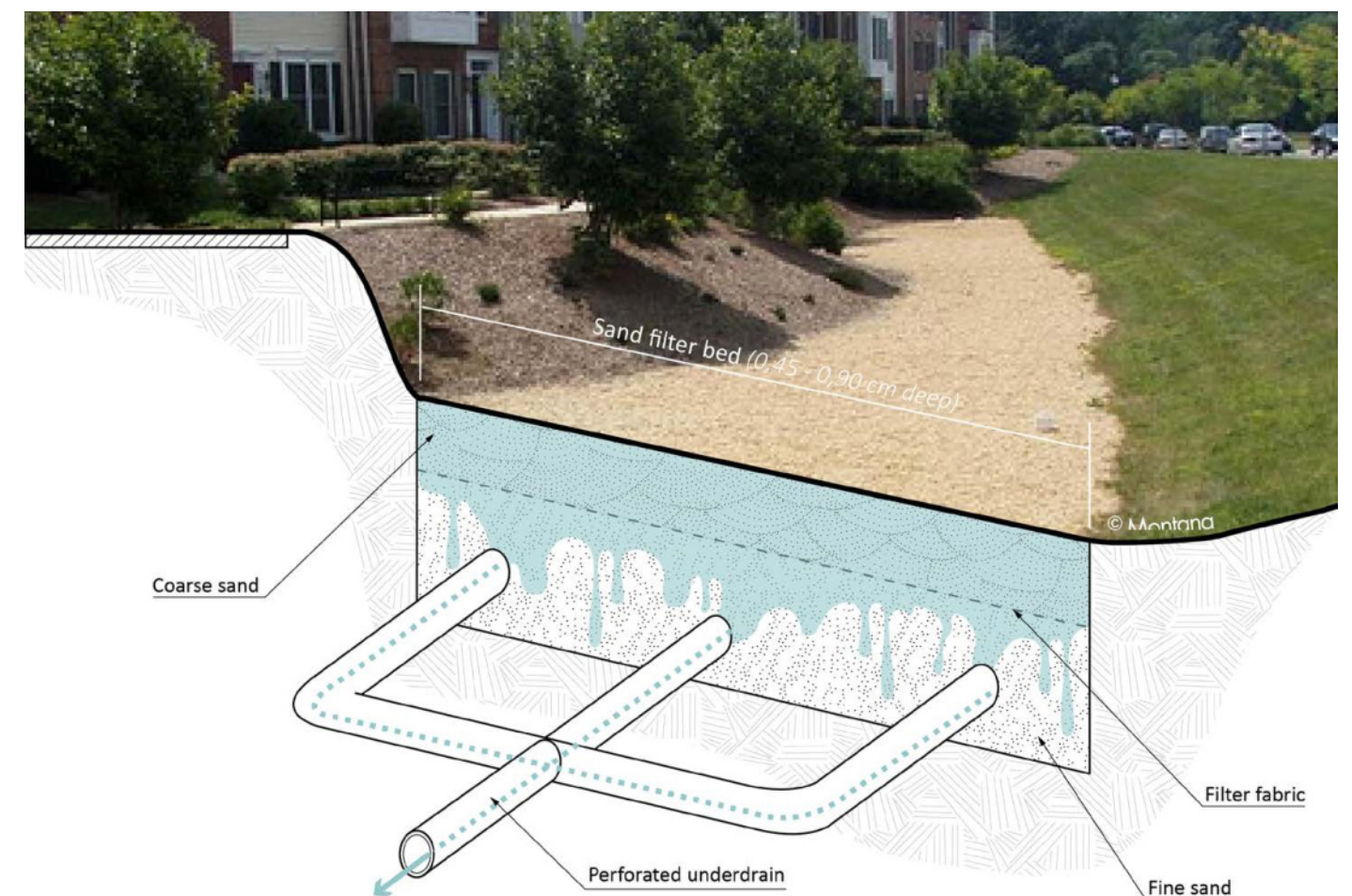


↗
Example of a sand filter.

Pic source: Aqualis

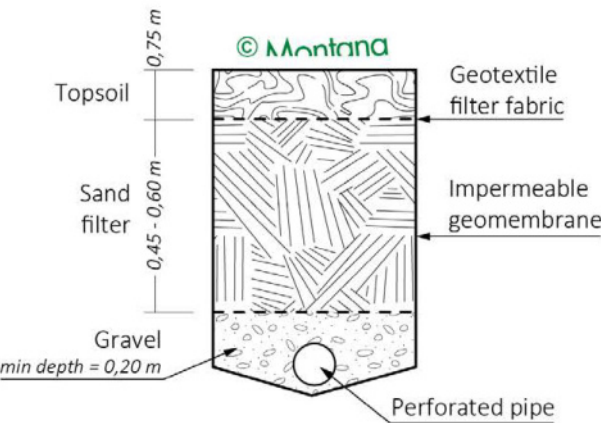
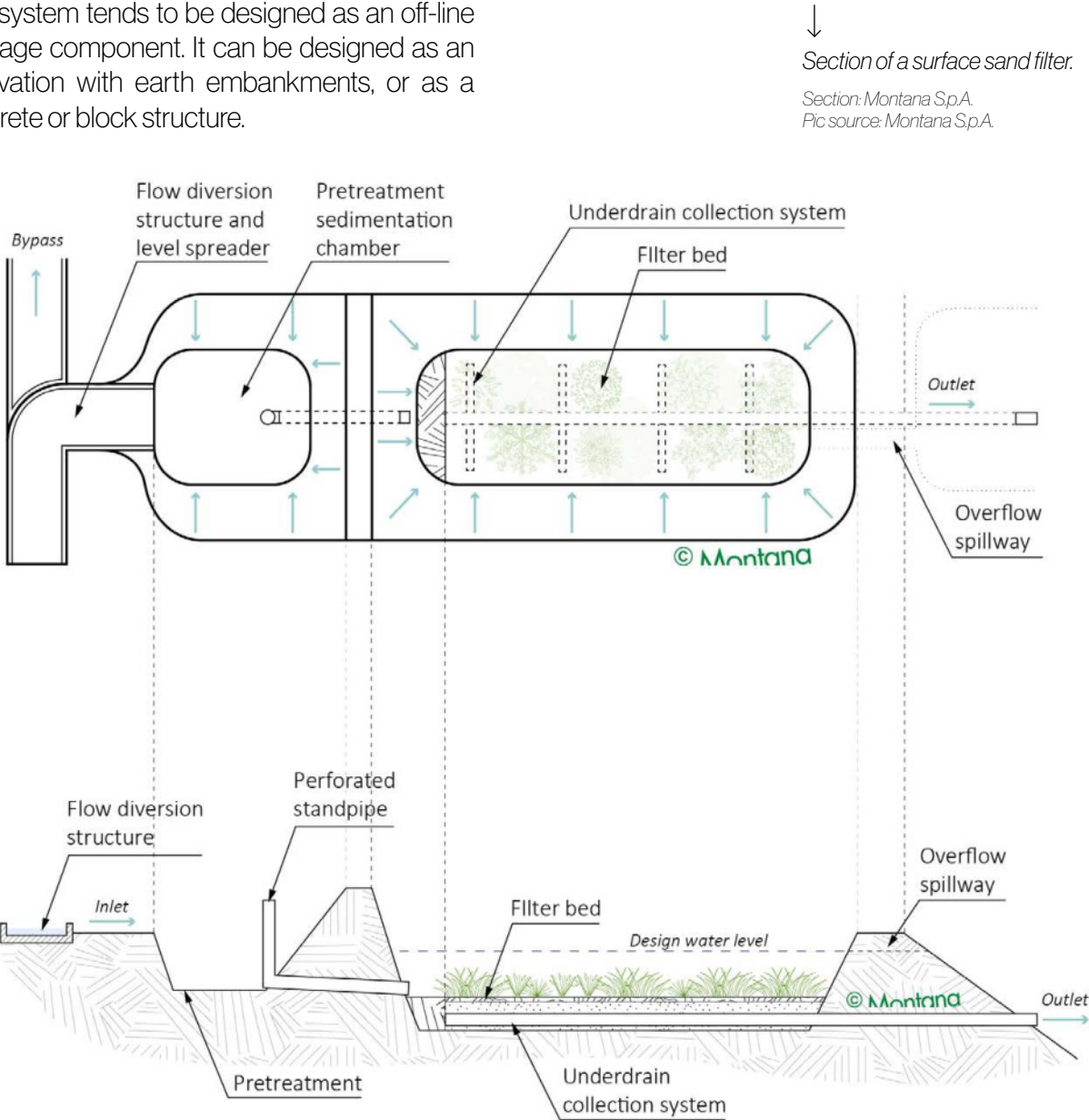
→
Infographic: Montana S.p.A.

Pic source: NJ Future



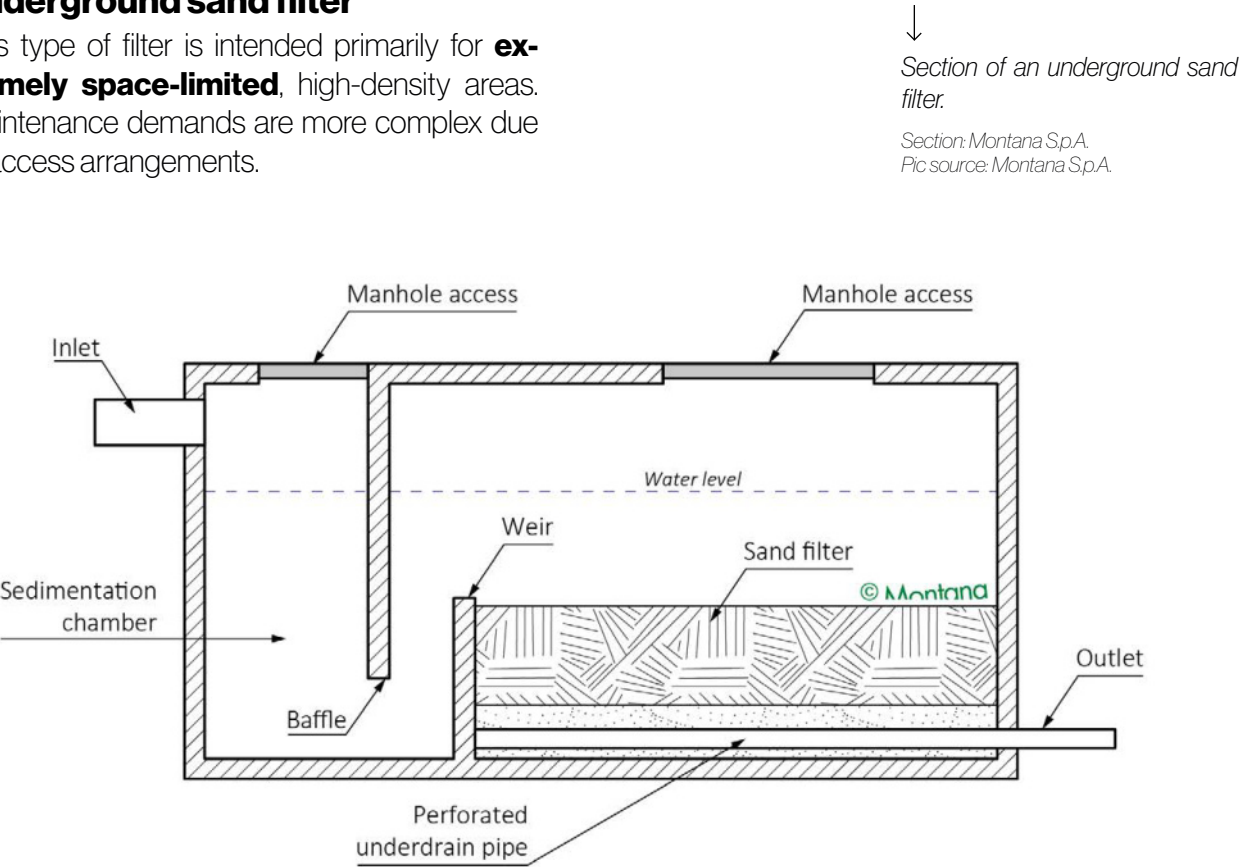
Surface sand filter

The surface sand filter is a **ground level, open structure** consisting of a pre-treatment sedimentation forebay and a filter bed chamber. This system tends to be designed as an off-line drainage component. It can be designed as an excavation with earth embankments, or as a concrete or block structure.



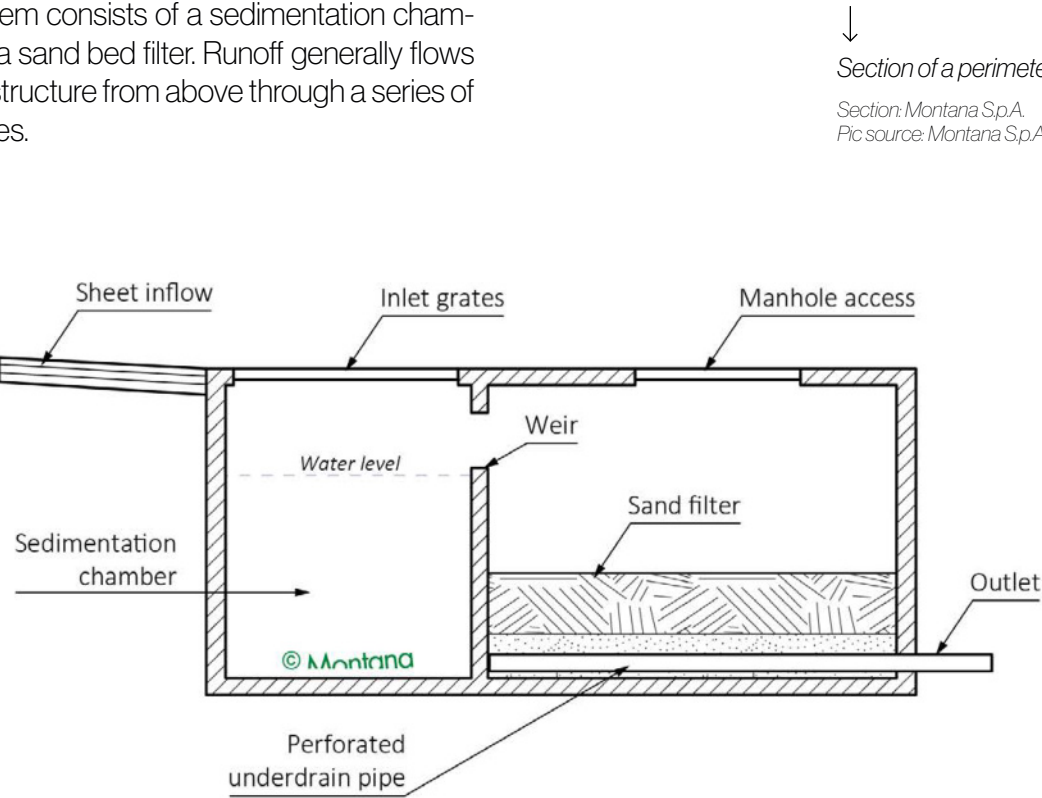
Underground sand filter

This type of filter is intended primarily for **extremely space-limited**, high-density areas. Maintenance demands are more complex due to access arrangements.



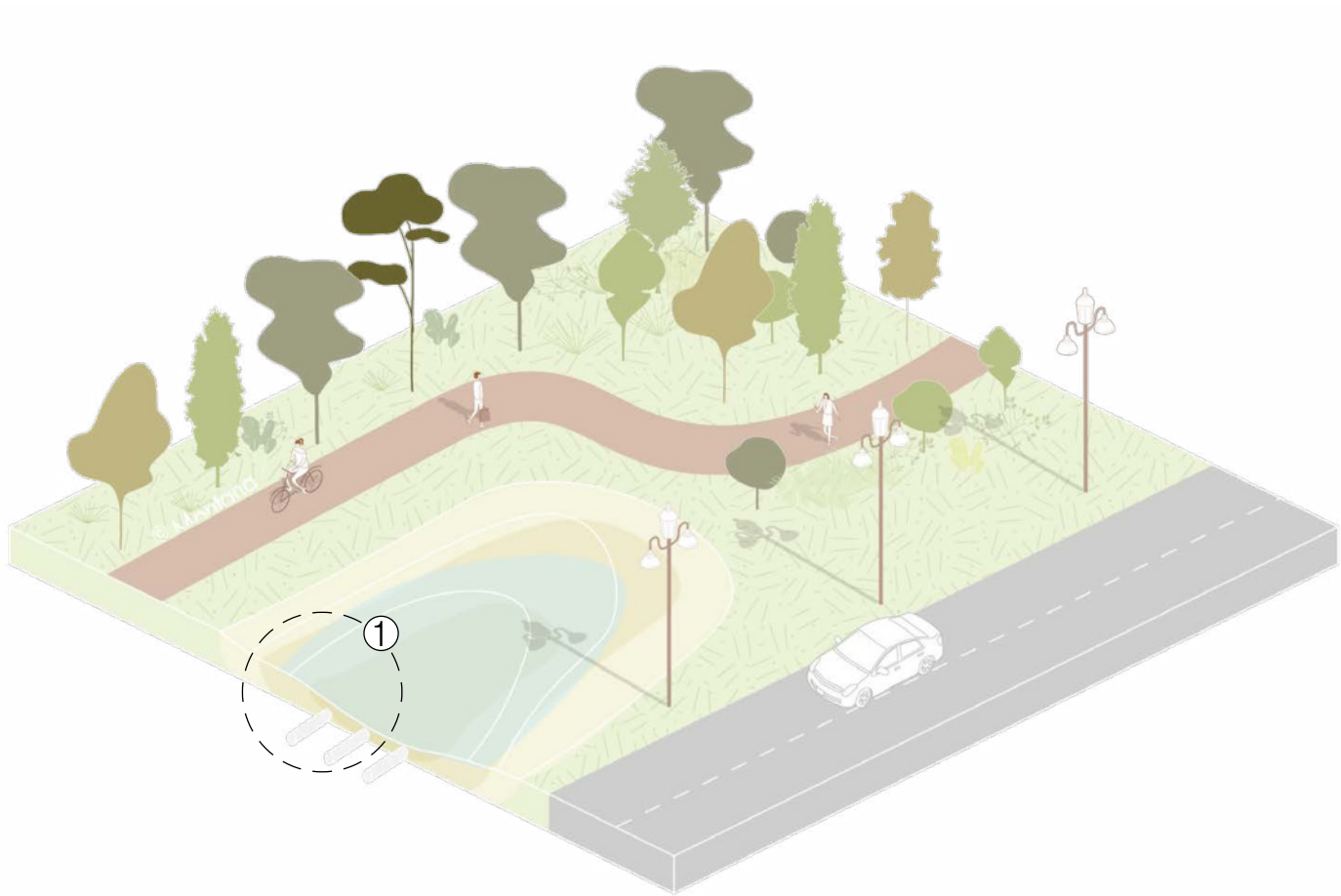
Perimeter sand filter

A perimeter sand filter is an **enclosed filter system** typically constructed just **below ground level** along the edge of an impervious area such as a car park. The system consists of a sedimentation chamber and a sand bed filter. Runoff generally flows into the structure from above through a series of inlet grates.

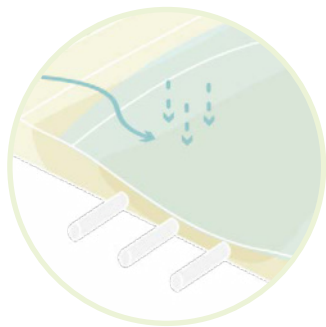


Visualization

Visualization of sand filter areas in an urban context

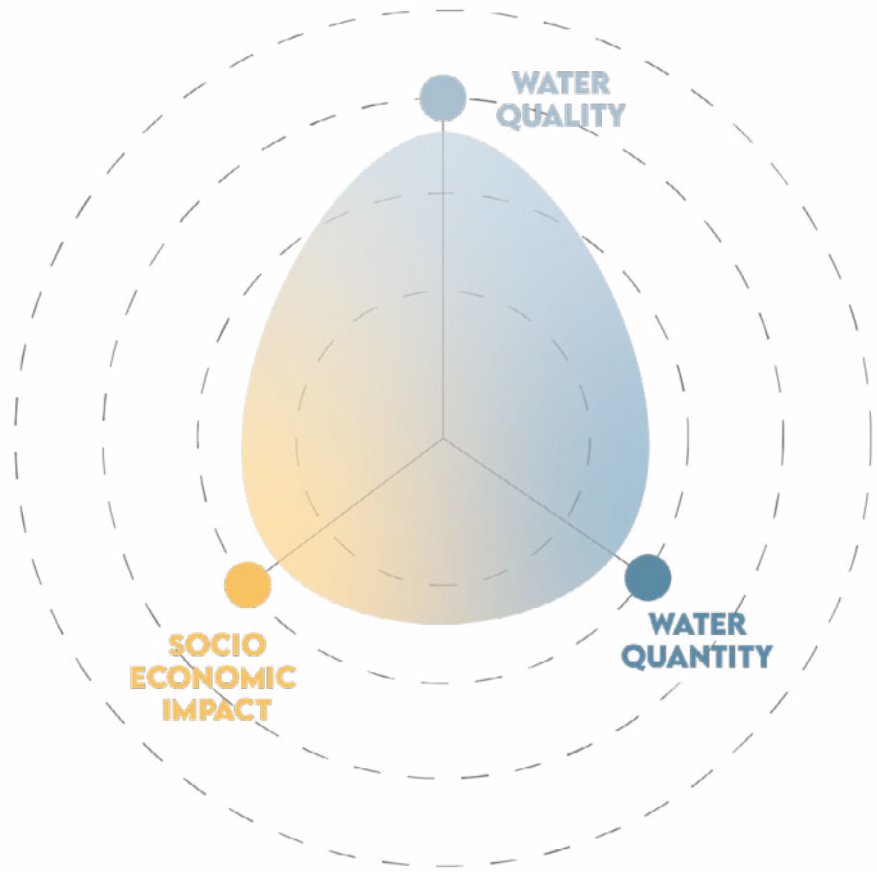


Details of increased benefits for the urban living environment



A sand filter solutions improve water quality by **trapping** and removing **particles, sediments, and contaminants** from runoff or wastewater.

Benefits



←
This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Sand filters, including biosand filters, improve water quality by sedimentation, physical straining, and biodegradation. Stormwater filters reduce suspended solids, bacteria, metals, and phosphorus, while supporting groundwater recharge in suitable soils (U.S. EPA, 2021; Reddy et al., 2020). Biosand filters remove over 90% of coliforms and nearly all metals, with modifications like iron oxide or biochar enhancing removal of heavy metals and bacteria (Sepe et al., 2011; Eniola & Sizerici, 2024).

Water quantity and runoff control

Sand filters temporarily collect stormwater runoff in a sedimentation or storage chamber before passing it through a sand filtration layer and discharging it through an underdrain or outlet. Their main function is water quality treatment, but they can also contribute to runoff control by slowing discharge, managing the design flow rate, and providing limited temporary storage. Their hydrological performance depends on available storage volume, filter media permeability, outlet design,

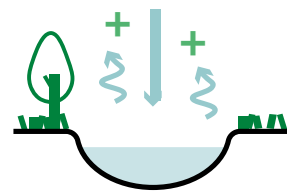
drainage configuration, contributing catchment area, and maintenance to prevent clogging. (EPA, 2021; CIRIA, 2015; Urban Drainage and Flood Control District, 1997).

Socio-economic impact

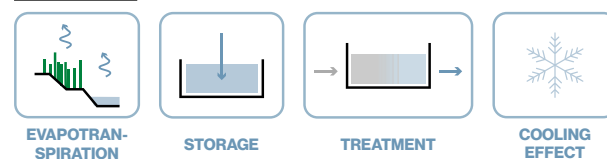
Sand filters offer significant socioeconomic benefits at both urban and household levels. For urban stormwater, they are cost-effective, with moderate capital costs and low maintenance (U.S. EPA, 2021). At the household level, biosand filters in rural communities provide high benefit-cost ratios, reducing medical expenses, fuel costs, and time lost due to illness, while improving productivity and school attendance (Sepe et al., 2011). Additionally, they are among the most cost-effective point-of-use solutions and support local green businesses, retaining economic value within the community (Hogarh et al., 2015; Eniola & Sizerici, 2024).

Wet pond

A wet pond, also known as a wet pool, is a **constructed stormwater pond** that retains a **permanent pool of water**, with minor biological treatment. Wet ponds **remove pollutants** through biological uptake processes and sedimentation. The amount of pollutants that are removed from stormwater runoff is proportionate to the length of time runoff remains in the pond, as well as the relation of runoff to retention pond volume. Since retention ponds must maintain a permanent pool, they cannot be constructed in areas with insufficient precipitation or highly permeable soils, unless the soil is compacted or overlain with clay. Generally, continual drainage inputs are required to maintain permanent pool levels. One advantage of a retention pond is the presence of **aquatic habitat** when properly planted and maintained. The use of a pond aerator is necessary to prevent stagnation and algae growth that can lead to eutrophication, or an anaerobic environment. Regular maintenance inspections are needed to ensure proper drainage, aerobic functioning and aeration, and vegetative health. Trash, debris, and sediment will need to be removed periodically.



FUNCTIONS



SDGS GOALS



*The Oxford Retention Basin,
Marina del Rey, Los Angeles
County, California.*

*Pic source: Institute for Sustainable
Infrastructure*



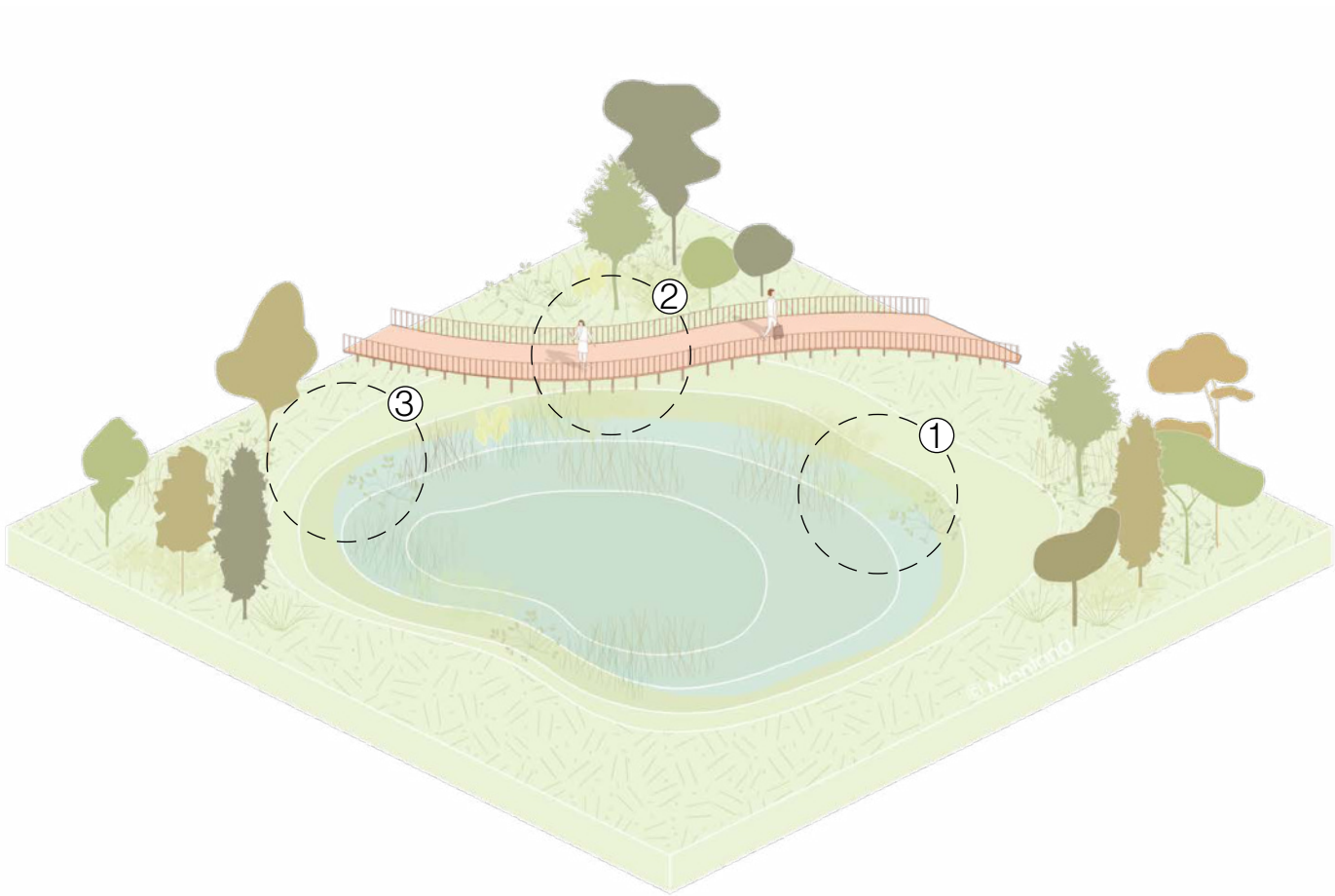
*Duke Water Reclamation Pond,
Durham, North Carolina.*

Pic source: World Landscape Architect



Visualization

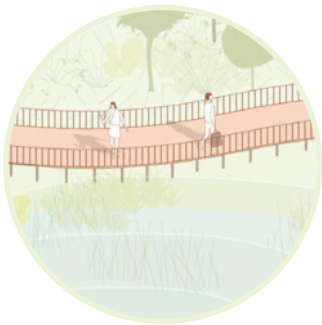
Visualization of wet ponds in an urban context



Details of increased benefits for the urban living environment



Wet ponds collect runoff allowing it to settle, **improving water quality**. The pond's vegetation helps **filter pollutants**, while the **water slowly infiltrates** or is released, reducing flooding and preventing erosion.

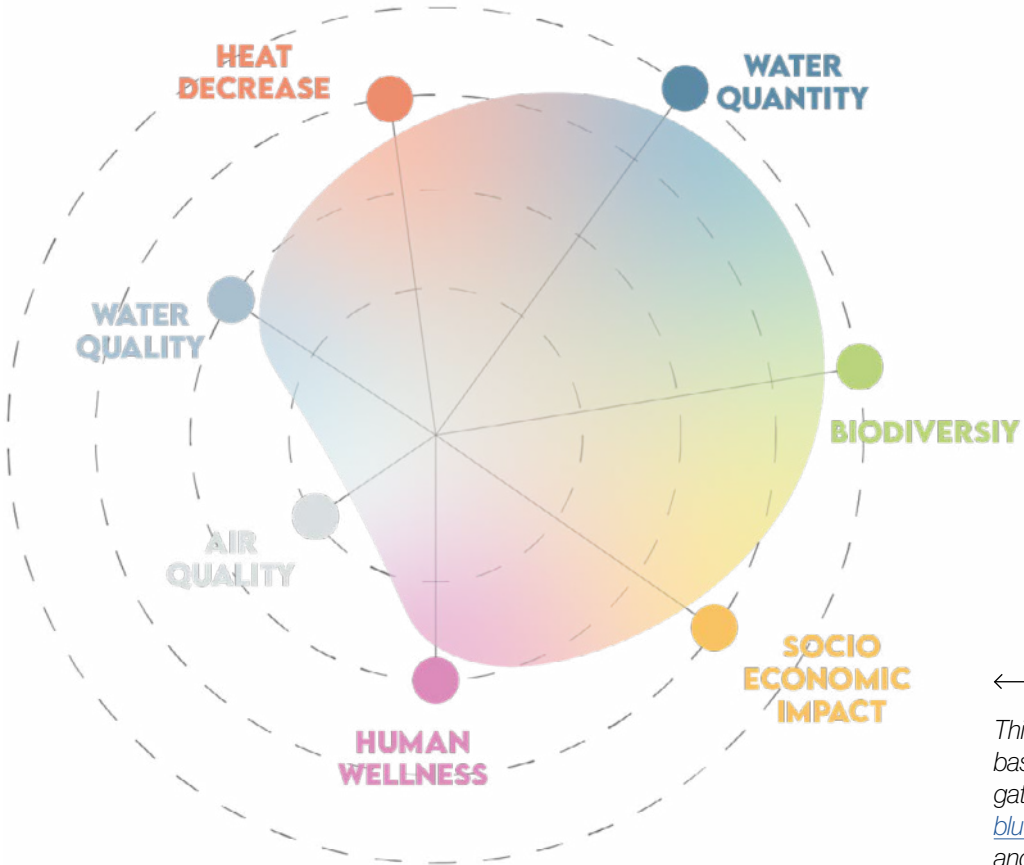


Wet ponds support biodiversity by providing **habitats for aquatic plants, insects, birds, and amphibians**. The diverse vegetation and water environment create a **thriving ecosystem** that supports a variety of species, contributing to local biodiversity and ecological health.



Wet ponds offer **recreational opportunities**, such as walking, birdwatching, and nature observation, enhancing human wellness. These green spaces provide **peaceful environments** that reduce stress, improve mental health, and offer scenic areas for relaxation while contributing to **urban sustainability**.

Benefits



This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).

Water quality and sediment management

Stormwater is slowed in a permanent basin, lowering peak flows and downstream flood risk, allowing sediments and particle-bound nutrients to settle, reducing suspended solids and nutrient loads before discharge. (LSRCA, 2020; Krivtsov et al., 2022)

Water quantity and runoff control

Wet ponds temporarily store stormwater above a permanent water pool and release it gradually through controlled outlets. This helps reduce peak flows, manage runoff rates, and mitigate downstream flood risk. (EPA, 2021; CIRIA, 2015; Susdrain, n.d.).

Biodiversity

This element provides habitat for invertebrates, amphibians, fish and birds, often approaching the richness of natural urban wetlands. Larger, structurally complex ponds can act as refuges and key nodes in urban pondscapes that sustain ecological connectivity. (Hassall & Anderson, 2015; Biggs et al., 2024)

Socio-economic impact

Wet ponds combine utility with amenity, recreation and educational value. These services translate into avoided damage costs and increased site value, and pond networks are recognised as cost-effective NbS for climate adaptation. (Krivtsov et al., 2022; Biggs et al., 2024)

Human wellness

Research links views of water, wildlife watching and quiet routes for walking or jogging, with better self-reported well-being, more physical activity and, reduced psychological distress. (Gascon et al., 2017; WHO Regional Office for Europe, 2023)

Heat decrease

Open water and moist vegetated edges promote evaporative cooling and higher humidity, moderating local air temperatures and contributing to urban heat-island mitigation. (Krivtsov et al., 2022; Biggs et al., 2024)

Site selection

Existing site conditions should be considered in the design and location of a retention basin. Features such as topography, wetlands, structures, utilities, property lines, easements, etc., may impose constraints on the location or construction of the basin.

Dimension

The **size** of the permanent pool will be **based on the desired pollutant removal efficiency**. The “dry” storage volume above the permanent pool will be sized for downstream channel erosion and/or flood control. The size of these two components together will determine the size of the basin.

All retention basins should be a **minimum of 6 m from any structure** or property line, and 30 m from any septic tank/drainfield. Retention basins should be a **minimum of 15 m from any steep slope** (greater than 15%). Alternatively, a geotechnical report must address the potential impact of any retention basin that is to be constructed on or near such a slope.

Depth

The depth of the permanent pool will affect several features of a retention basin:

- aquatic plant selection;
- fish and wildlife habitat selection;
- the rate at which nutrients are cycled.

Retention basins and artificial marshes built too shallow will **not support fish populations year round**. Basins built too deep may stratify, creating anaerobic conditions that may result in the resolubilizing of pollutants that are normally bound in the sediment.

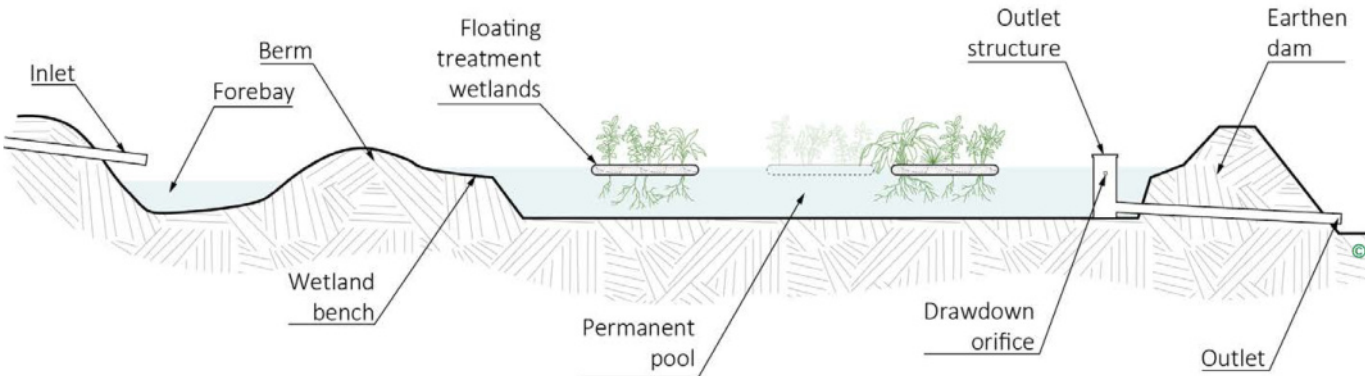
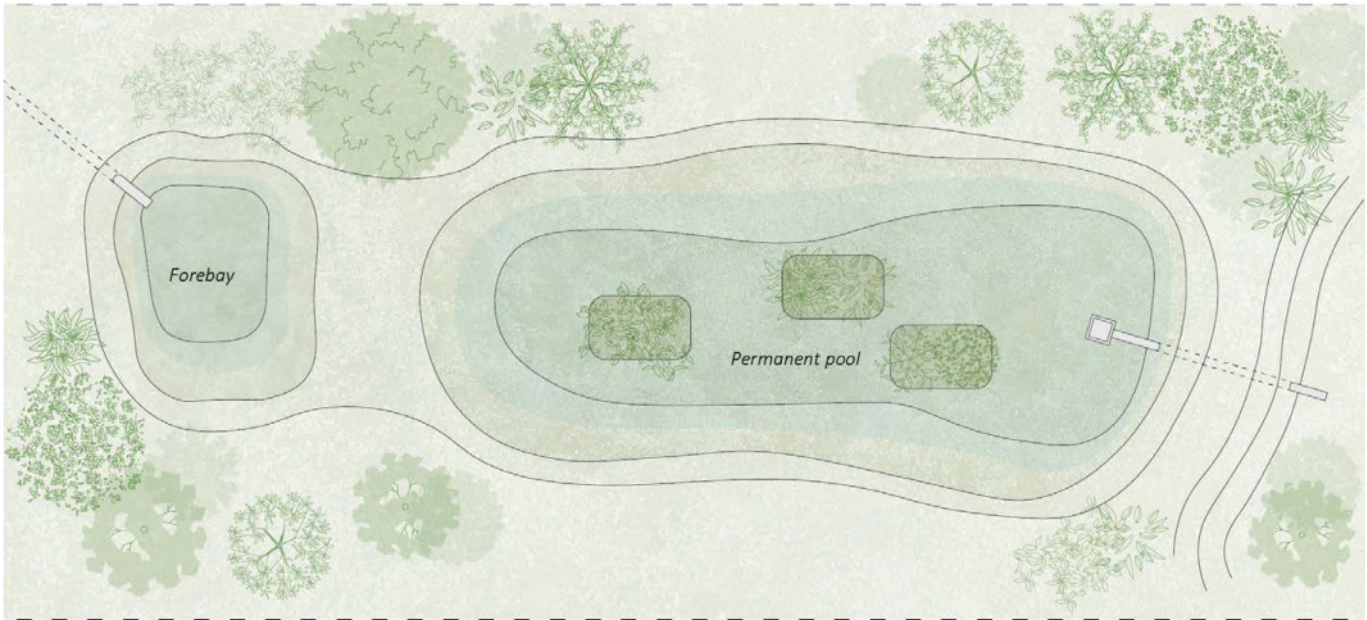
The depth of a stormwater management basin should vary to include as much diversity as possible, with an average depth of 0,90 to 1,80 m. Approximately 15% of the basin area should be less than 0,45 m deep. This can be accomplished by using an aquatic bench along the perimeter of the permanent pool.

Water quality enhancement

A retention basin is typically selected for its **water quality enhancement abilities** and/or aesthetic value. The flexibility of providing for additional control components (channel erosion control, flood control, habitat, etc.) increases their value. The permanent pool of a retention basin serves to enhance the quality of the stormwater within it.

Soil

The final design and acceptance should be based on an actual subsurface analysis and a permeability test, accompanied by appropriate engineering recommendations. The goal of a subsurface analysis is to determine if the soils are suitable for a retention basin. The textural character of the soil horizons and/or strata units within the subsoil profile should be identified to at least 90 cm below the facility bottom. Permeable soils are not suited for retention basins. The depth of the permanent pool can influence the rate at which water will infiltrate through the existing soil. The soil permeability may be such that the basin can support a shallow marsh or constructed wetland. However, as the depth of the permanent pool increases, the increased head or pressure on the soil may increase the infiltration rate.



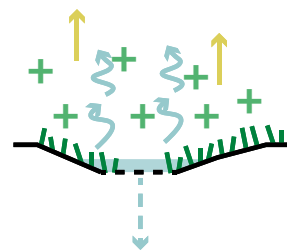
↗
Section of a wet pond.
Section: Montana S.p.A.
Pic source: Montana S.p.A.

Interventions for natral areas and rural lands

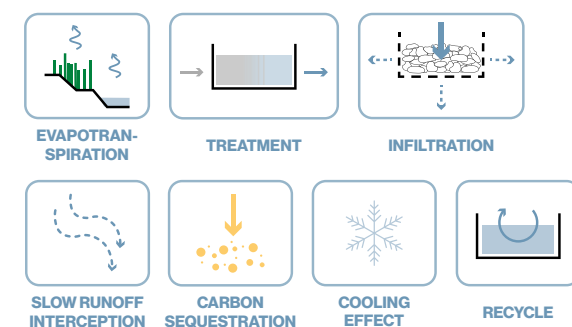
Wetland

Wetlands are **areas of land that remain wet for part or all of the year** due to their landscape position. Historically, they were referred to as swamps, marshes, bogs, fens, or sloughs, depending on their characteristics.

Wetlands have **higher biological activity than most ecosystems**, allowing them to transform common pollutants in conventional wastewater into harmless byproducts or essential nutrients that support further biological productivity. These transformations occur through natural processes powered by sunlight, wind, soil, plants, and animals.



FUNCTIONS



SDGS GOALS

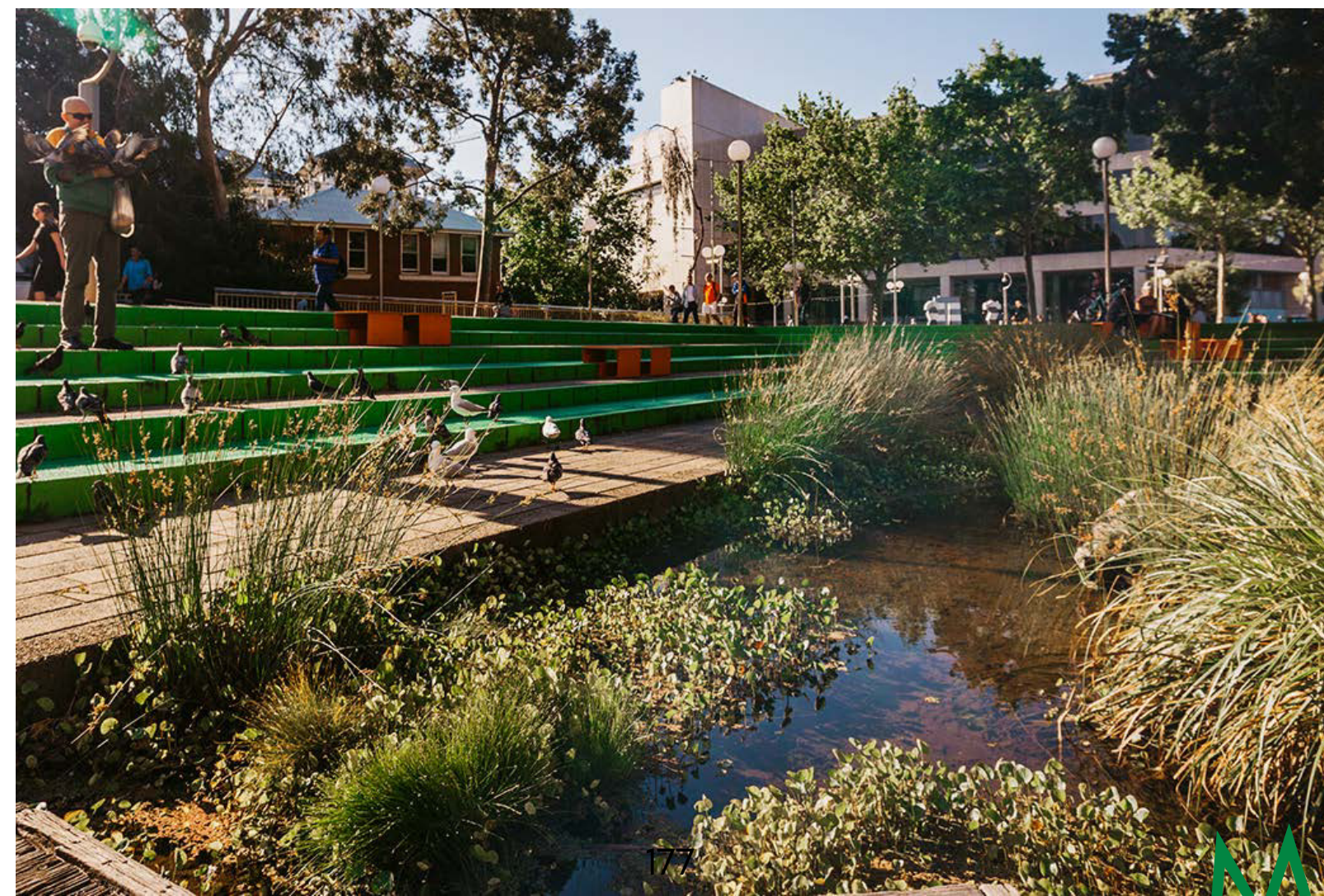


↗
North Cave Wetlands Nature Reserve

Pic source: Yorkshire Wildlife Trust

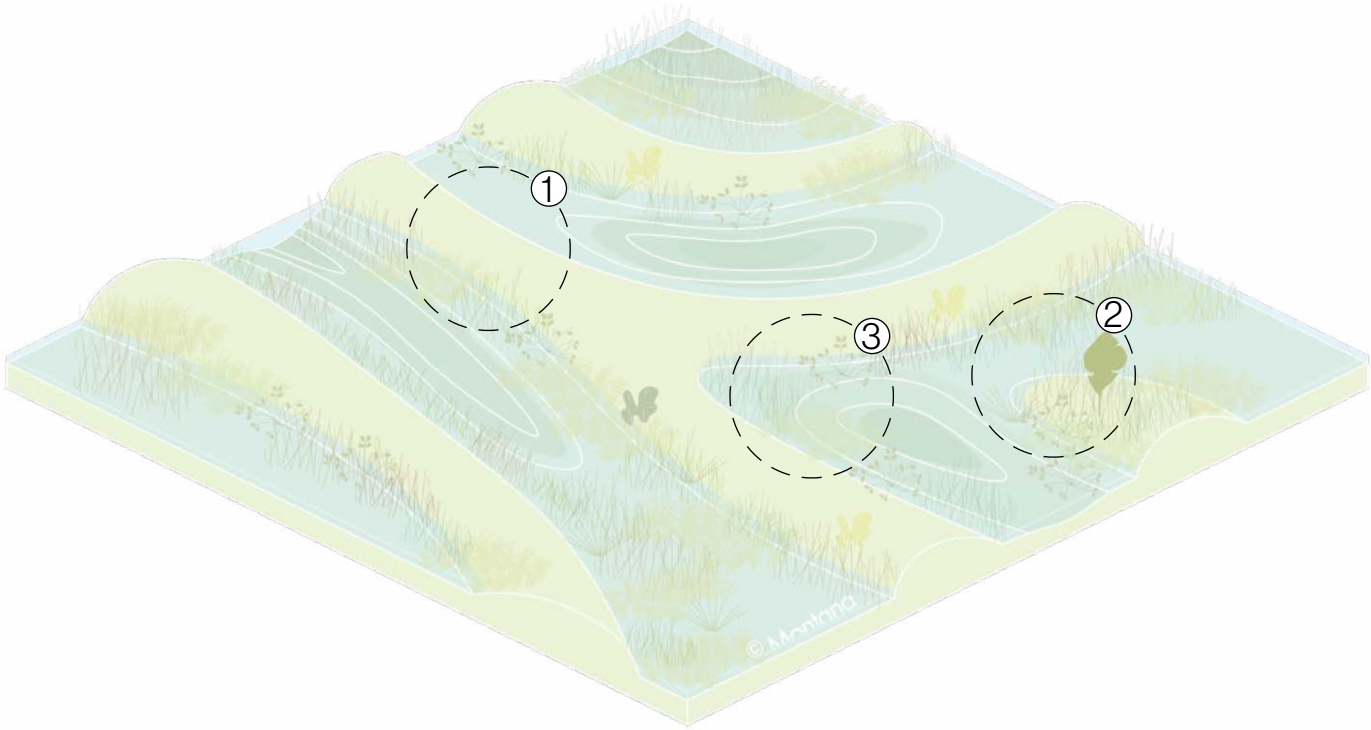
→
Urban wetland area in Perth, Australia.

Pic source: Perth Cultural Centre

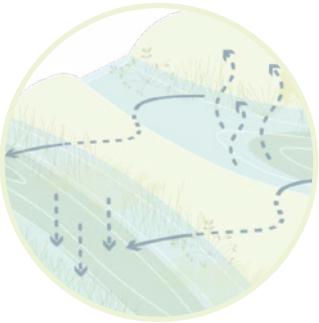


Visualization

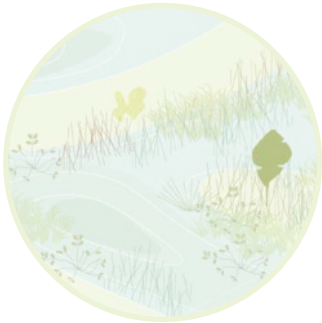
Visualization of wetlands



Details of increased benefits for the urban living environment



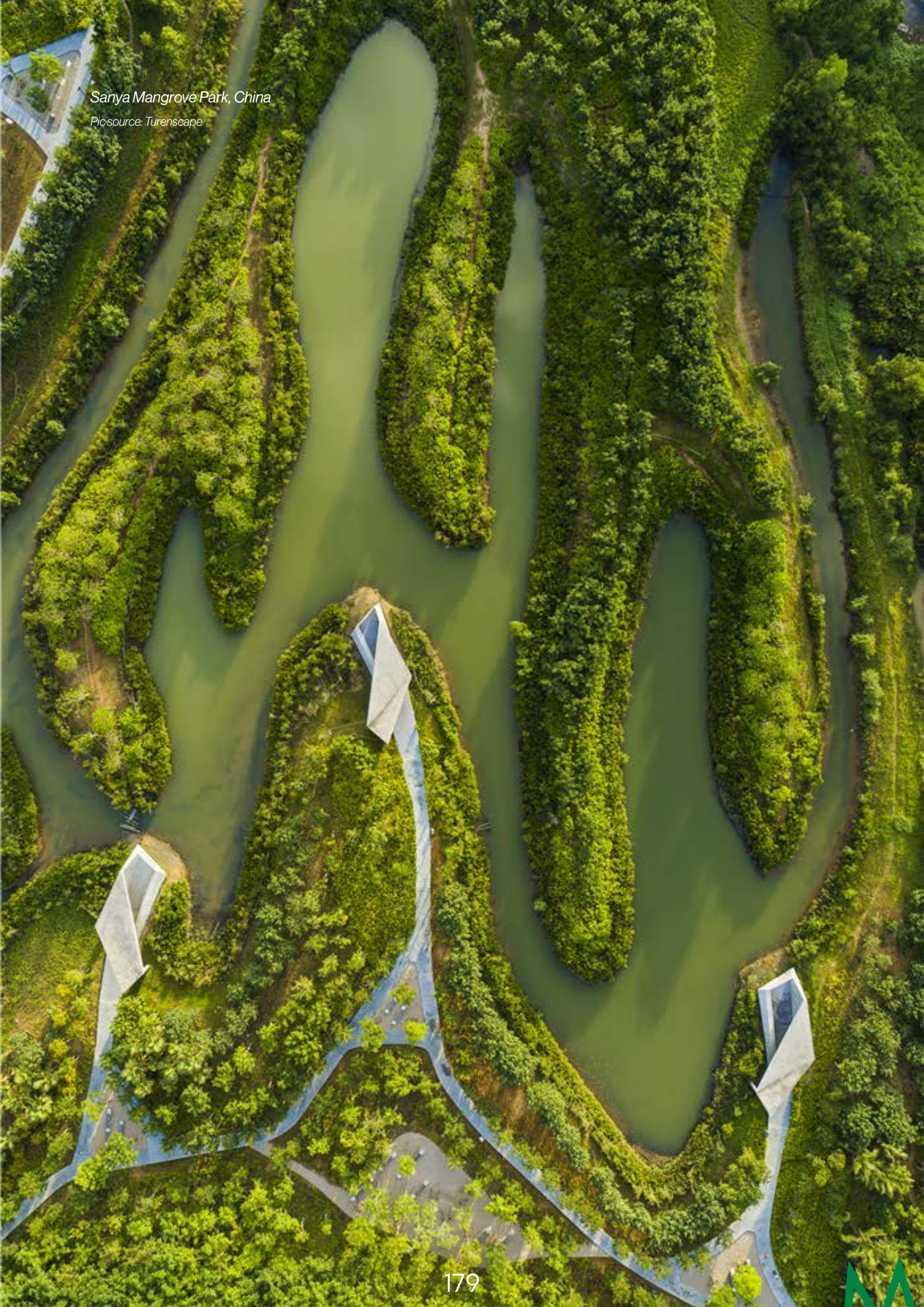
Wetlands help treat and manage water by **filtering pollutants, trapping sediments, and absorbing excess nutrients** from runoff. Their ability to store and slowly release water reduces flooding, improves water quality, and enhances groundwater recharge.



Wetlands **support** a variety of vegetation types, including **emergent plants** like cattails and bulrushes, **submerged plants**, and **aquatic grasses**. This diverse plant community plays a vital role in **stabilizing soil**, enhancing **nutrient cycling**, and providing **food and shelter for wildlife**.

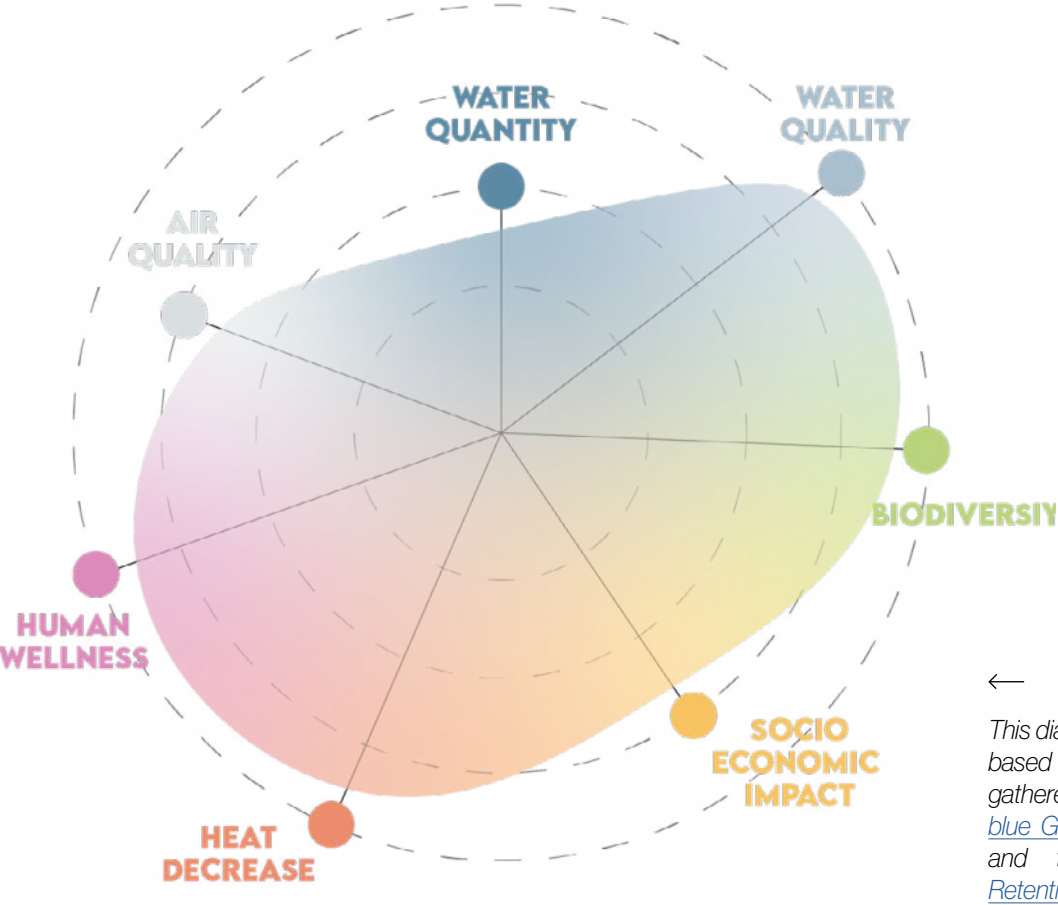


Wetlands are **rich in biodiversity**, providing habitats for numerous species of birds, amphibians, insects, and small mammals. These ecosystems **support critical life stages**, such as breeding and feeding, for many species, making wetlands essential for local and **migratory wildlife** populations.



Sanya Mangrove Park, China
Pic source: Turenscap

Benefits



← This diagram was developed based on information gathered from [Urban Green-blue Grids for resilient cities](#) and the [Natural Water Retention Measures project](#).



↑ Aquaculture in China
Pic source: Globally Important Agriculture Systems

↓ Laguna de Tuctubamb, Peru.
Pic source: Pinterest

Water quality and sediment management

Wetlands act as the “kidneys of the landscape”, trapping sediments and transforming nutrients and pollutants so that cleaner water is released downstream. Their storage capacity and slow drainage regulate floods and help maintain baseflows. (Delle Grazie & Gill, 2022; Rogerson, 2019)

Biodiversity

Wetlands are global biodiversity hotspots: around 40% of known plant and animal species depend on them, including many threatened fish, amphibians and waterbirds. Even small urban and peri-urban wetlands provide critical habitat and stopover sites when properly managed. (Wetlands International, n.d.; Ramsar Convention, 2021)

Socio-economic impact

By purifying water, buffering floods and supporting fisheries, rice systems and tourism, wetlands sustain livelihoods and generate large value of ecosystem services. (Ramsar Convention, n.d.; UNDP, 2024)

Heat decrease

Open water, saturated soils and dense vegetation allow wetlands to create local “cool islands” that moderate extreme air temperatures. Wetland complexes can lower daytime temperatures and counter urban heat-island effects when conserved as connected networks across a city. (Gungor et al., 2018; Gong et al., 2020)

Human wellness

Wetlands offer places for recreation and nature connection. Regular exposure to such environments is linked with lower psychological distress, better mood, higher physical activity and stronger social cohesion. (Gascon et al., 2017; WHO Regional Office for Europe, 2019)

Air quality

Wetland vegetation and surrounding green buffers intercept airborne particulates and influence regional nitrogen, sulphur and carbon cycles, while wetland cooling can indirectly limit ozone formation and heat-related pollution peaks. (Delle Grazie & Gill, 2022; WHO/UN-Water, 2025)



Site selection

Ponds and wetlands can be **created by using an existing natural depression**, by **excavating a new depression**, or by **constructing embankments**. Existing natural water bodies should not be used as a means by which to dispose of surface water runoff where this would create a risk that pollution events. Locating ponds and wetlands close to existing ones can also benefit biodiversity.

How natural wetlands work

Natural wetlands serve numerous functions that are beneficial to both humans and wildlife, with **water filtration** being one of the most crucial. As water flows through a wetland, its flow rate decreases, allowing **suspended solids to be trapped by vegetation** and settle out. Other **pollutants are converted into less soluble forms**, assimilated by plants, or rendered inactive. Wetland vegetation also creates optimal conditions for microorganisms, which play a pivotal role in the transformation and removal of pollutants through a series of complex

processes. Nutrients such as nitrogen and phosphorus are introduced into wetlands via stormwater runoff, agricultural areas where fertilizers or manure are applied, and leaking septic systems. These excess nutrients are often absorbed by wetland soils and taken up by plants and microorganisms. This natural filtration process effectively reduces nutrient loads and enhances water quality, underscoring the vital ecological services provided by wetlands.

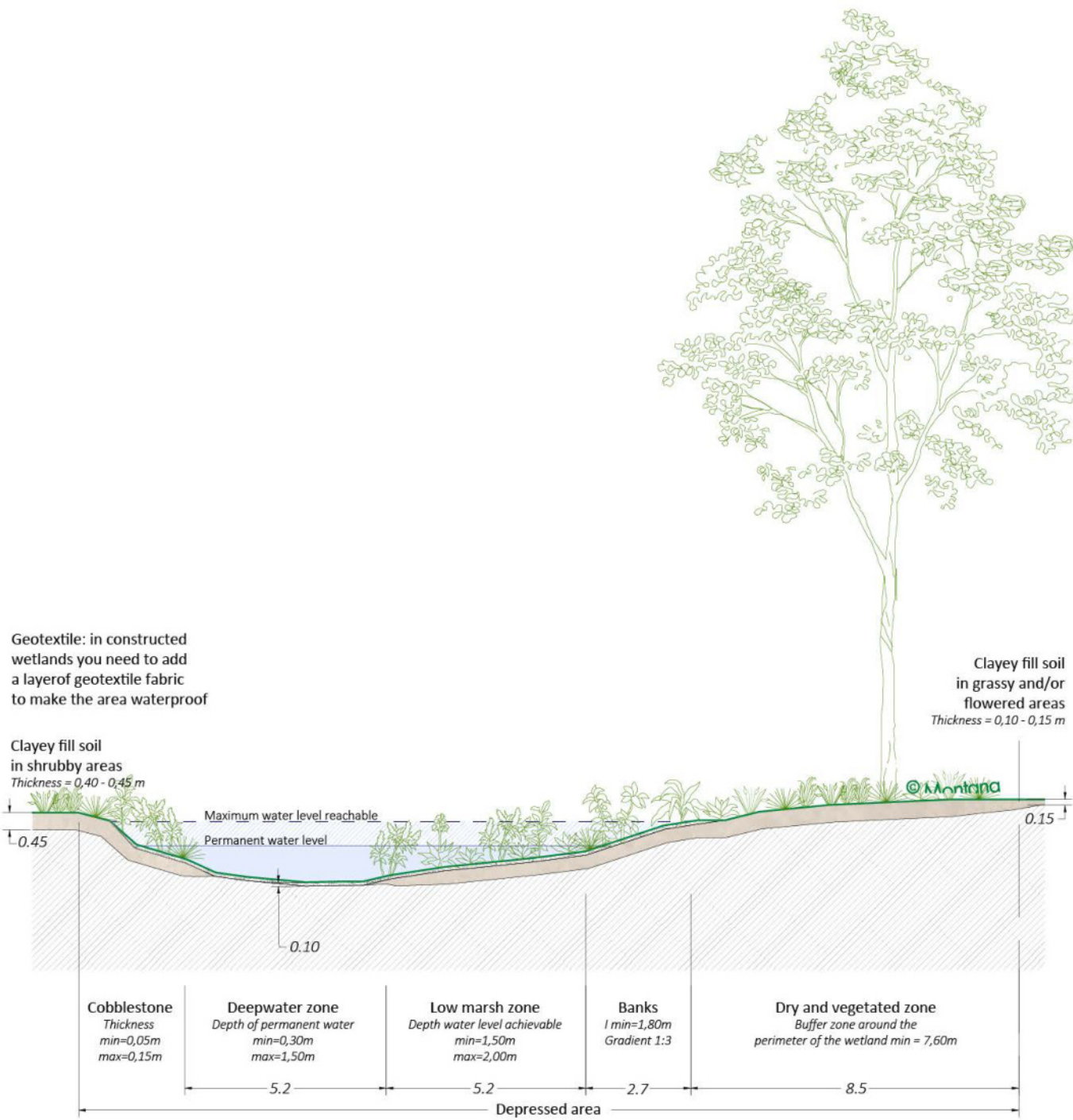
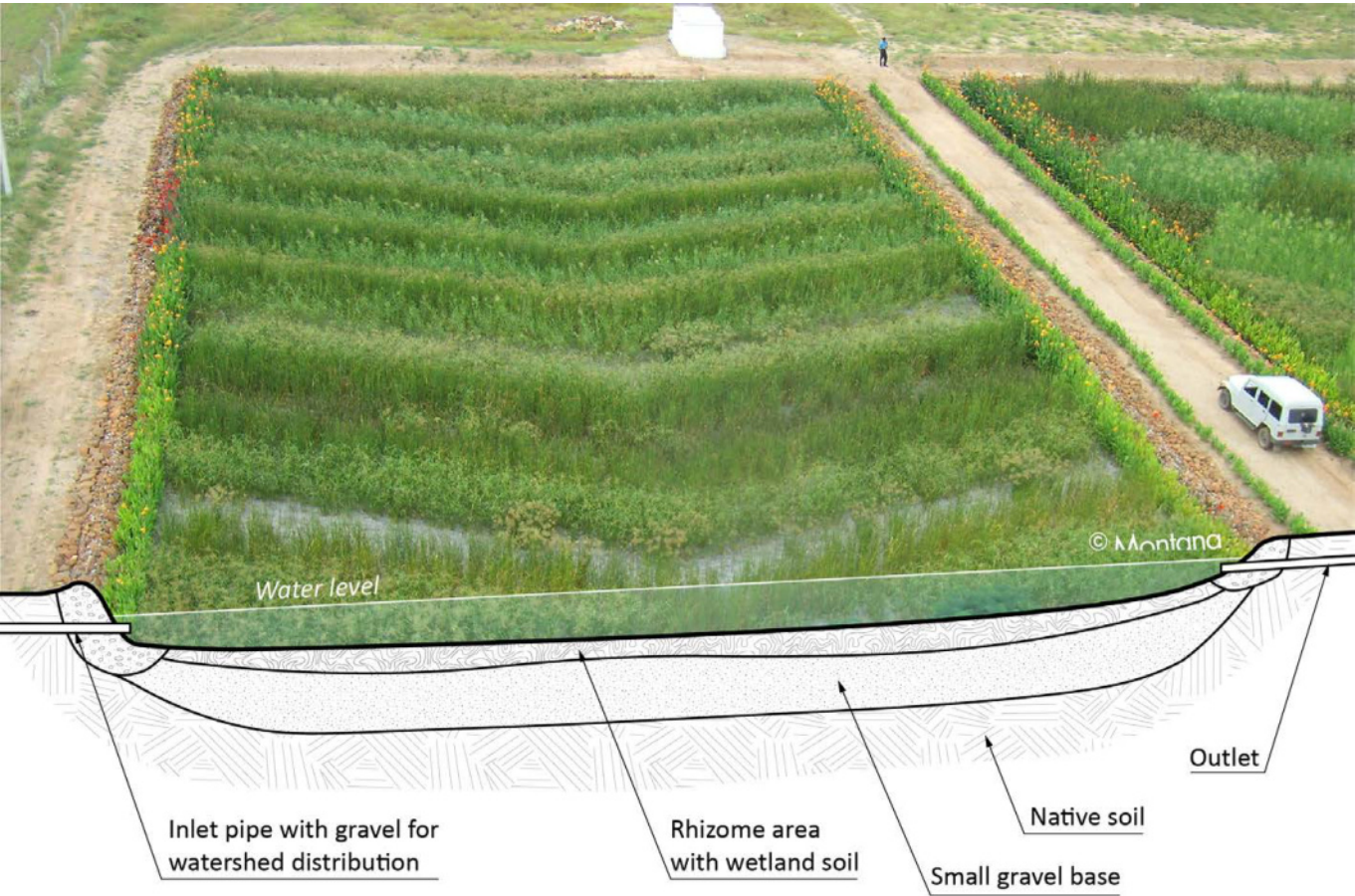
Constructed wetlands

A constructed wetland is a man-made system **designed to mimic the functions of natural wetlands** for the purpose of treating wastewater, stormwater, or industrial effluents. Constructed wetlands can be a cost-effective

and technically viable method for wastewater treatment since they use phytodepuration systems. They are often **more affordable to construct than conventional wastewater treatment systems**, have low operating and maintenance costs, and can accommodate fluctuating water levels.

↓
Section of a wetland.
Section: Montana S.p.A.
Pic source: Montana S.p.A.

↓
Infographic: Montana S.p.A.
Pic source: Biomatrix Water



Bibliography and sitography

ABG Geosynthetics. (s.d.). ABG bluroof – Blue Roof System.

Adams, A., & autori vari. (2025). Sustainable urban environment through green roofs: A literature review. *Sustainability*, 15(22), 15976. <https://doi.org/10.3390/su152215976>

Ahiablame, L. M., & Engel, B. A. (2015). Design and performance of wet ponds for stormwater management: A review of their effectiveness in pollutant removal and aquatic habitat creation. *Journal of Environmental Management*, 154, 121-131. <https://doi.org/10.1016/j.jenvman.2015.03.002>

Agaton, C. D., & Guila, G. S. (2023). Phytodepuration systems in urban landscapes: Role in wastewater treatment and biodiversity enhancement. *Environmental Management*, 68(3), 423-433. <https://doi.org/10.1007/s00267-023-01479-9>

Alberini, A., et al. (2023). The impact of infiltration-based solutions on urban biodiversity: A comparative study. *Environmental Science & Policy*, 131, 245–255. <https://doi.org/10.1016/j.envsci.2023.01.014>

Alonzo, D., et al. (2024). The role of tree filter boxes in mitigating urban heat island effects: A case study on street scale temperature reduction. *Urban Climate*, 46, 100428. <https://doi.org/10.1016/j.uclim.2024.100428>

Amani, M., et al. (2025). The role of pervious paving in mitigating urban heat islands: A comprehensive study. *Journal of Urban Climate*, 38, 100975. <https://doi.org/10.1016/j.uclim.2025.100975>

Ampatzidis, Y., et al. (2023). Urban cooling and environmental benefits of detention ponds: Performance analysis and design considerations. *Urban Climate*, 38, 100958. <https://doi.org/10.1016/j.uclim.2023.100958>

Antunes, A., et al. (2018). The economic and environmental benefits of pervious paving: A cost-benefit analysis of long-term performance. *Sustainable Cities and Society*, 42, 365–376. <https://doi.org/10.1016/j.scs.2018.08.013>

Arian, S., et al. (2025). The role of floodable parks in urban flood resilience and water quality improvement. *Urban Water Management*, 24(1), 33–42. <https://doi.org/10.1016/j.uwm.2024.12.001>

Author(s) unknown. (2025). Assessing the hydrological performance of a modular blue roof over time. *Journal of Water Management Research*, (volume/issue). Recuperato da <https://www.sciencedirect.com/science/article/pii/S0022169425013605>

Autodesk Water (2025, June 23). What is a bioretention system and how does it help control stormwater runoff? Autodesk Blog.

Barman, S., et al. (2024). The role of phytodepuration wetlands in supporting biodiversity: Habitat creation and ecological services. *Ecological Engineering*, 176,

Barros, L., Oliveira, F., & Silva, T. (2025). The role of detention basins in sustainable stormwater management: Multi-objective strategies and water quality enhancement. *Journal of Environmental Management*, 67(3), 235-249. <https://doi.org/10.1016/j.jenvman.2025.01.032>

Beeson, P. M., & Doyle, M. W. (2006). Riparian buffers and their role in water quality and stream health. *Environmental Management*, 38(6), 840-848. <https://doi.org/10.1007/s00267-006-0155-0>

BEMExpert. (2025). Blue roofs – A smart solution for stormwater management and resilient buildings. Recuperato da <https://bem.expert/blue-roofs-a-smart-solution-for-stormwater-management-and-resilient-buildings>

Berndtsson, J. C. (2010). Green roof performance

towards management of runoff water quantity and quality: A review. *Ecological Engineering*, 36(4), 351–360. <https://doi.org/10.1016/j.ecoleng.2009.12.014>

Bessette, A. (2023). The role of rain gardens in enhancing urban green spaces: Social, environmental, and health benefits. *Journal of Urban Environmental Management*, 56(2), 88-99. <https://doi.org/10.1016/j.juem.2023.01.014>

Bianchini, F., & Hewage, K. (2012). Probabilistic social cost-benefit analysis for green roofs: A lifecycle approach. *Building and Environment*, 58, 152–162. <https://doi.org/10.1016/j.buildenv.2012.07.005>

Biggs, H., et al. (2024). Wet ponds as ecological refuges and connectors in urban pondscapes: Promoting biodiversity and ecological function. *Landscape and Urban Planning*, 212, 104087. <https://doi.org/10.1016/j.landurbplan.2021.104087>

BioSwales | Urban Green-Blue Grids. (n.d.). Bioswales as stormwater management and ecological corridors in urban settings. Retrieved from <https://www.urbangreenbluegrids.com/bioswales>

Blokhuis, E., & autori vari. (2023). Rainwater harvesting and treatment: State of the art and future directions. *Water*, 15(8), 1518. <https://doi.org/10.3390/w15081518>

BlueRoofs.com. (s.d.). The Challenges of Implementing Blue Roofs. Recuperato da <https://bluroofs.com/the-challenges-of-implementing-blue-roofs>

Blue Roofs. (s.d.). Blue Roof Systems – Blue Roofs. Recuperato da <https://bluroofs.com/blue-roof-systems>

Boguniewicz-Zabłocka, J., & Łukasiewicz, E. (2025). Blue-green infrastructure effectiveness for urban stormwater management: A multi-scale residential case study. *Land*, 14(7), 1340. <https://doi.org/10.3390/land14071340>

Bonciarelli, L., Orlandi, F., Muscas, D., & Fornaciari, M. (2025). Sustainable stormwater management and bioretention: An overview of reviews of

the last 10 years. *Land*, 14(4), 736. <https://doi.org/10.3390/land14040736>

Bowler, D., Buyck, C., & Cassidy, E. (2012). Vegetation effects on urban microclimates: Cooling effects of filter strips and green infrastructure. *Urban Ecology*, 56(4), 821–833. <https://doi.org/10.1080/00220973.2012.694245>

Brix, H. (1994). The use of constructed wetlands for wastewater treatment in cold climates. *Water Science and Technology*, 30(2), 149-157. <https://doi.org/10.2166/wst.1994.0592>

Brudler, S., et al. (2016). Life-cycle analysis of underground detention systems: Energy use, material consumption, and environmental benefits. *Environmental Science & Technology*, 50(5), 2722–2730. <https://doi.org/10.1021/acs.est.5b06187>

Cai, W., et al. (2023). The cooling effects of urban floodable parks: A study of La Marjal in Alicante. *Urban Climate*, 39, 100938. <https://doi.org/10.1016/j.uclim.2023.100938>

Cameron, R., & Simpson, A. (2023). Bioretention areas and their role in stormwater management: Design, performance, and challenges. *Water*, 15(4), 567. <https://doi.org/10.3390/w15040567>

Campisano, A., Raffaele, R., & Lanza, L. (2020). Rainwater harvesting for urban water management: A critical review of policies, technologies, and applications. *Water*, 12(11), 3187. <https://doi.org/10.3390/w12113187>

Canedoli, C., et al. (2018). The role of urban trees in supporting biodiversity and ecological connectivity in city environments. *Urban Forestry & Urban Greening*, 34, 78-87. <https://doi.org/10.1016/j.ufug.2018.03.008>

Carlyle-Moses, D. E., et al. (2020). Urban trees as decentralized stormwater infrastructure: Hydrological benefits and challenges. *Urban Water Journal*, 17(3), 276-286. <https://doi.org/10.1080/1573062X.2020.1799656>

Castelle, A. J., & Johnson, A. W. (2009). Riparian buffer zones: Functions and importance in stream and water quality management. *Water Resources Bulletin*, 45(2), 211-219. <https://doi.org/10.1111/j.1752-1488.2008.00211.x>

org/10.1111/j.1752-1688.2009.00323.x

Castleton, H. F., Stovin, V., Beck, S. B. M., & Davison, J. B. (2010). Green roofs; building energy savings and the potential for retrofit. *Energy and Buildings*, 42(10), 1582–1591. <https://doi.org/10.1016/j.enbuild.2010.05.004>

Center for Neighborhood Technology. (2020). The benefits of urban greening: Tree filter boxes for sustainable water management and community enhancement. Center for Neighborhood Technology.

Chen, S., Zeng, H., Sun, H., Liu, S., & Yang, Y. (2023). How to determine the cistern volume of a rainwater harvesting system: An analytical solution based on roof areas and water demands. *Environment, Development and Sustainability*, 26, 20413–20438. <https://doi.org/10.1007/s10668-023-03480-x>

Chiquet, A., Francis, M., & Chadwick, C. (2018). Green walls and biodiversity: The role of vertical vegetation in ecological connectivity. *Landscape and Urban Planning*, 175, 48–57. <https://doi.org/10.1016/j.landurbplan.2018.03.004>

Comparative analysis of bioretention design strategies for urban runoff: effectiveness in quantity and quality control. (2024). *Journal of Urban Water Management / Environmental Pollution* (diversi autori)

Cristiano, E., Annis, A., Apollonio, C., Pumo, D., Urru, S., Viola, F., Deidda, R., Pelorosso, R., Petroselli, A., Tauro, F., Grimaldi, S., Francipane, A., Alongi, F., Noto, L. V., Hoes, O., Klapwijk, F., Schmitt, B., & Nardi, F. (2022). Multilayer blue-green roofs as nature-based solutions for water and thermal insulation management. *Hydrology Research*, 53(9), 1129–1149. <https://doi.org/10.2166/nh.2022.201>

Cristiano, E., Carucci, A., Piredda, M., Dessi, E., Urru, S., Deidda, R., & Viola, F. (2023). The effects of multilayer blue-green roof on the runoff water quality. *Heliyon*, 9(11), e21966. <https://doi.org/10.1016/j.heliyon.2023.e21966>

da Costa, L., et al. (2022). Assessing the financial benefits of rainwater harvesting: Economic analysis for urban sustainability. *Resources*,

Conservation & Recycling, 179, 106129. <https://doi.org/10.1016/j.resconrec.2021.106129>

Dalvit, M. (2024). Case study of multifunctional parks built over underground detention systems: A model for urban resilience. *Urban Planning & Development*, 150(3), 45–56. [https://doi.org/10.1061/\(ASCE\)UP.1943-5444.0000624](https://doi.org/10.1061/(ASCE)UP.1943-5444.0000624)

Daraojimba, J. (2024). Urban parks as green infrastructure for air quality improvement: Case studies on floodable parks. *Environmental Pollution*, 270, 116219. <https://doi.org/10.1016/j.envpol.2024.116219>

Davis, M. H., et al. (2025). The role of riparian buffers in enhancing species richness and supporting ecosystem services. *Ecological Restoration*, 33(2), 187–198. <https://doi.org/10.1016/j.jecorest.2025.03.002>

de Gois, J., et al. (2021). Economic and environmental impacts of rainwater harvesting for urban resilience. *Sustainability*, 13(24), 13011. <https://doi.org/10.3390/su132413011>

Delle Grazie, M., & Gill, T. (2022). Wetlands as the kidneys of the landscape: Their role in water purification, flood regulation, and ecosystem services. *Environmental Science & Policy*, 123, 127–138. <https://doi.org/10.1016/j.envsci.2022.03.014>

de Oliveira, S., et al. (2025). Reducing energy consumption in urban water management systems through decentralised rainwater harvesting: A case study in metropolitan areas. *Energy and Buildings*, 275, 112424. <https://doi.org/10.1016/j.enbuild.2024.112424>

Dierkes, C., & Stahlschmidt, F. (2012). Sand filters for stormwater treatment: Design criteria, performance, and maintenance. *Environmental Management*, 50(4), 837–847. <https://doi.org/10.1007/s00267-012-9935-9>

Di Stasio, G., et al. (2025). Phytoremediation of brownfields: Enhancing biodiversity and reducing environmental contaminants. *Ecological Engineering*, 205, 105939. <https://doi.org/10.1016/j.ecoleng.2024.105939>

Dobson, A., & Mallett, P. (2019). Urban trees and

the ecosystem services they provide: A study of pocket forests and their role in pollution control and water management. *Urban Forestry & Urban Greening*, 40, 88–98. <https://doi.org/10.1016/j.ufug.2019.03.004>

Dotson, A. (2008). Underground detention systems: Design, performance, and environmental benefits. *Journal of Environmental Management*, 88(4), 753–763. <https://doi.org/10.1016/j.jenvman.2007.06.014>

Duan, X., et al. (2024). Phytoremediation systems for the removal of volatile organic compounds and particulate matter: Mechanisms and applications. *Environmental Science & Technology*, 58(5), 2906–2915. <https://doi.org/10.1021/acs.est.3c08571>

Eniola, A. A., & Sizirici, A. (2024). Enhancing biosand filter performance for water treatment: The role of iron oxide and biochar in improving heavy metal and bacteria removal. *Journal of Environmental Management*, 254, 109743. <https://doi.org/10.1016/j.jenvman.2023.109743>

Euronews Green. (2025). Pocket forests: Urban solutions for cooling and environmental health. Euronews Green.

European Environment Agency. (2020). Riparian buffers for water quality protection and ecosystem restoration. European Environment Agency.

European Environment Agency. (2024). The cooling effects of riparian buffers on urban heat islands. European Environment Agency.

Fahey, T., & McHale, M. (2020). The role of urban forests in erosion control and water quality improvement. *Environmental Management*, 60(2), 234–245. <https://doi.org/10.1007/s00267-019-01299-w>

Fares, A., et al. (2019). Air quality improvement and dust suppression in agricultural landscapes through riparian buffer zones. *Environmental Pollution*, 252, 909–919. <https://doi.org/10.1016/j.envpol.2019.06.012>

Fernandes, L., et al. (2023). Energy efficiency in urban water services: The role of rainwater

harvesting and decentralized systems. *Renewable and Sustainable Energy Reviews*, 163, 112423. <https://doi.org/10.1016/j.rser.2022.112423>

Ferreri, A. (2025, 03 dicembre). Tetti verdi: tipologie, struttura tecnica, benefici e criticità per la progettazione. Ediltecnico. <https://ediltecnico.it/tetti-verdi-struttura-benefici-criticita/>

Forest Research. (2021). Sustainable urban drainage systems (SuDS): Cost-effectiveness and environmental benefits. Forest Research.

Forest Research. (2023). The role of trees in improving urban air quality and public health: An overview. Forest Research.

Francis, M., & Chadwick, C. (2012). Green walls in urban environments: Planning and design for biodiversity. *Urban Ecology*, 34(2), 227–240. <https://doi.org/10.1080/00039157.2012.683230>

Frontier Foam. (2025, settembre 13). Comprehensive Guide to Blue Roof Systems for Urban Stormwater Management. Recuperato da <https://frontierfoam.com/blue-roof-systems-urban-stormwater-management>

Fuller, M. J., et al. (2022). Riparian buffers and their role in reducing thermal stress on aquatic species: Cooling effects of tree-lined riparian zones. *Journal of Environmental Management*, 300, 113673. <https://doi.org/10.1016/j.jenvman.2021.113673>

Fundación Aquae. (2024). Floodable parks as tools for urban regeneration and flood control. Fundación Aquae.

Gallardo-López, I., et al. (2024). Tree filter boxes in urban streetscapes: Supporting biodiversity and enhancing ecological connectivity. *Urban Ecosystems*, 47(1), 53–64. <https://doi.org/10.1007/s11252-023-01435-2>

Garbisu, C., & Alkorta, I. (2003). Phytoremediation: A cost-effective technology for the removal of heavy metals from the environment. *Biotechnology Advances*, 21(3), 203–221. [https://doi.org/10.1016/S0734-9750\(03\)00009-1](https://doi.org/10.1016/S0734-9750(03)00009-1)

García, J., & García, F. (2019). Phytodepuration

systems for wastewater treatment: An overview of methods and applications. *Environmental Science and Pollution Research*, 26(7), 6891-6905. <https://doi.org/10.1007/s11356-019-04265-4>

Gascon, M., et al. (2017). Green spaces, urban river corridors, and their association with better self-reported well-being and physical activity. *Environmental Health Perspectives*, 125(6), 690-698. <https://doi.org/10.1289/EHP1767>

Gascon, M., et al. (2017). The health benefits of urban green spaces: A systematic review of green and blue spaces in urban environments. *Environmental Health Perspectives*, 125(9), 097017. <https://doi.org/10.1289/EHP1470>

Geosyntec. (s.d.). Rooftop Detention (Blue Roofs). In NPS Manual.

Ghermandi, A., & Fichtman, D. (2015). The value of urban water features: Enhancing environmental education and social benefits. *Environmental Management*, 56(4), 803-815. <https://doi.org/10.1007/s00267-015-0599-3>

Gong, S., et al. (2020). Wetlands and urban heat-island mitigation: Cooling effects and temperature regulation in urban ecosystems. *Landscape and Urban Planning*, 200, 103827. <https://doi.org/10.1016/j.landurbplan.2020.103827>

Gorjian, S. (2025). Economic and social benefits of integrating floodable parks into urban landscapes. *Sustainable Cities and Society*, 58, 102282. <https://doi.org/10.1016/j.scs.2025.102282>

Green roofs | Urban Green-blue Grids. (n.d.). <https://urbangreenbluegrids.com/measures/green-roofs/>

Greenwald, D., Freeman, A., & Tripp, S. (2024). Enhancing local air quality with vegetative barriers: The role of filter strips in roadside pollution mitigation. *Environmental Pollution*, 276, 116752. <https://doi.org/10.1016/j.envpol.2021.116752>

Green walls: vertical greening systems for building envelopes. (2011). Greening the building envelope, façade greening and living wall systems. *Open Journal of Ecology*. <https://doi.org/10.4236/oje.2011.11002>

[org/10.4236/oje.2011.11002](https://doi.org/10.4236/oje.2011.11002)

Groffman, P. M., & Crawford, A. L. (2013). Riparian buffers for nutrient management and pollution control: A review of their function in the landscape. *Science of the Total Environment*, 463, 520-530. <https://doi.org/10.1016/j.scitotenv.2013.06.026>

Guidi Nissim, W., et al. (2023). The role of phytoremediation in restoring ecological communities and mitigating contaminants in urban landscapes. *Environmental Management*, 67(4), 521-534. <https://doi.org/10.1007/s00267-023-01532-4>

Gunay, H., & Apul, D. (2021). Bioswales and their effect on urban stormwater runoff quality and quantity. *Journal of Hydrology*, 595, 125853. <https://doi.org/10.1016/j.jhydrol.2021.125853>

Gungor, N., et al. (2018). Wetland complexes as urban “cool islands”: Impacts on local temperature regulation and climate adaptation. *Environmental Management*, 61(3), 421-430. <https://doi.org/10.1007/s00267-018-1083-9>

Haddaway, N., Haines, L., & Swain, S. (2018). Filter strips as wildlife corridors: The role of vegetation in enhancing biodiversity and ecological connectivity. *Landscape and Urban Planning*, 173, 79-90. <https://doi.org/10.1016/j.landurbplan.2018.01.013>

Hanumesh, S., et al. (2025). Enhancing urban ecological connectivity: The role of rain gardens in providing habitat and supporting biodiversity. *Urban Ecosystems*, 48(3), 459-471. <https://doi.org/10.1007/s11252-025-00931-1>

Hassall, C., & Anderson, P. (2015). Urban ponds and their role in supporting biodiversity and maintaining ecological connectivity. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 25(6), 858-868. <https://doi.org/10.1002/aqc.2535>

Hassall, C., & Anderson, C. (2015). Urban wetlands and their ecological functions: Role in biodiversity enhancement and water quality management. *Ecological Engineering*, 75, 84-94. <https://doi.org/10.1016/j.jecoleng.2014.12.025>

Heaney, J. P., & Pitt, R. (2020). Wet pond

management for water quality enhancement: Techniques for maintaining aerobic conditions and preventing eutrophication. *Water Research*, 158, 428-436. <https://doi.org/10.1016/j.watres.2019.05.084>

Health Canada. (2023). Guidelines for implementing nature-based solutions for environmental health in urban spaces. Health Canada.

Hill, S., et al. (2017). The role of aquatic vegetation in enhancing detention pond biodiversity and ecosystem services. *Environmental Pollution*, 223, 337-347. <https://doi.org/10.1016/j.envpol.2017.01.042>

Hogarh, J. N., et al. (2015). Socioeconomic benefits of biosand filters: Improving public health and reducing household costs in rural communities. *Environmental Science & Technology*, 49(3), 1567-1574. <https://doi.org/10.1021/es505225v>

Huang, J., et al. (2022). Green and blue spaces for mental health: Evidence from large-scale urban park studies. *International Journal of Environmental Research and Public Health*, 19(11), 7267. <https://doi.org/10.3390/ijerph19117267>

Hunt, W. F., et al. (2008). Performance of rain gardens for stormwater management: A critical review. *Environmental Management*, 42(5), 786-793. <https://doi.org/10.1007/s00267-008-9174-3>

Hussain Bhat, A., & Sharma, S. K. (2025). Pervious concrete pavements: A comprehensive review of materials, performance, and sustainability. *Innovative Infrastructure Solutions*, 10, 326.

Imran, M., et al. (2019). The cooling effect of rain gardens on urban microclimates: Implications for urban heat island mitigation. *Urban Climate*, 27, 100443. <https://doi.org/10.1016/j.uclim.2018.11.002>

Infobuildenergia. (2025, 29 ottobre). Tetti verdi: efficienza e sostenibilità ambientale. <https://www.infobuildenergia.it/approfondimenti/tetti-verdi-tipologie-tecniche-costruttive-e-vantaggi/>

Integrating greening systems to improve energy efficiency: green roofs and green walls. (2025).

Article on integrating green roofs and walls for thermal performance and energy savings.

Interreg Europe. (2023). La Marjal floodable park: A case study on biodiversity and ecosystem connectivity. Retrieved from <https://www.interregeurope.eu>

Irwin, R., et al. (2017). Integrating detention ponds with urban landscapes: Public engagement and social benefits. *Landscape and Urban Planning*, 157, 67-76. <https://doi.org/10.1016/j.landurbplan.2016.07.008>

Jain, A. (2024). Pollution reduction in urban environments: The role of floodable parks in capturing particulate matter and improving air quality. *Journal of Environmental Quality*, 53(2), 132-143. <https://doi.org/10.2134/jeq2023.06.0180>

Jayasooriya, V. M., Ng, A. W. M., Muthukumaran, S., & Perera, B. J. C. (2017). Green infrastructure practices for improvement of urban air quality. *Urban Forestry & Urban Greening*, 21, 34-47. <https://doi.org/10.1016/j.ufug.2016.11.007>

Jeon, H., et al. (2021). Performance of detention ponds in urban stormwater management: Removal efficiency of pollutants. *Science of the Total Environment*, 762, 143118. <https://doi.org/10.1016/j.scitotenv.2020.143118>

Johansson, M. (2025). Social and environmental benefits of urban green spaces: Detention ponds as multifunctional assets. *Environmental Science & Policy*, 105, 68-75. <https://doi.org/10.1016/j.envsci.2024.12.001>

Jones, F., & Hendrix, C. (2019). Rainwater harvesting for stormwater management and alternative water supply (BSE-274 Fact Sheet). Virginia Cooperative Extension, Virginia Tech.

Jones, R., & White, S. (2024). The role of bioswales in sustainable urban drainage systems. *Water Resources Management*, 38, 1041-1052. <https://doi.org/10.1007/s11269-024-04011-5>

Kadlec, R. H., & Knight, R. L. (1996). *Treatment wetlands*. CRC Press.

Kalantari, S., Rashedi, M. R., Ehsani, R., & Tehrani,

F. M. (2023). A lifecycle analysis approach to the impact of green roofs on the structural and thermal performances of buildings. In F. Biondini & D. M. Frangopol (Eds.), *Life-cycle of structures and infrastructure systems* (pp. 501–508). CRC Press. <https://doi.org/10.1201/9781003323020-59>

Karabay, M., et al. (2024). The effectiveness of rain gardens in managing urban runoff: A case study of their impact on water quality and flood control. *Science of the Total Environment*, 799, 149124. <https://doi.org/10.1016/j.scitotenv.2021.149124>

Kennen, J., & Kirkwood, D. (2015). Effectiveness of bioretention systems in removing pollutants from stormwater: A critical review. *Environmental Science & Technology*, 49(5), 3502–3511. <https://doi.org/10.1021/es505508>

Kent Wildlife Trust. (2018). Nature-based solutions for urban spaces: The role of filter strips in improving biodiversity. Kent Wildlife Trust.

Kim, Y., & Song, J. (2019). The role of bioretention systems in enhancing urban biodiversity and ecological connectivity. *Landscape and Urban Planning*, 181, 1–10. <https://doi.org/10.1016/j.landurbplan.2018.09.004>

Koch, D., et al. (2020). The effect of living walls on urban microclimates: Temperature and air quality improvements. *Environmental Pollution*, 265, 114423. <https://doi.org/10.1016/j.envpol.2020.114423>

Kõiv-Vainik, M., Kill, K., Espenberg, M., Uemaa, E., Teemusk, A., Maddison, M., ... Scholz, M. (2022). Urban stormwater retention capacity of nature-based solutions at different climatic conditions. *Nature-Based Solutions Journal*, 2(1), 100038. <https://doi.org/10.1016/j.nbsj.2022.100038>

Kondo, M. C., et al. (2021). Green spaces and mental health: The role of urban trees in promoting well-being and reducing stress. *Environmental Health Perspectives*, 129(2), 22001. <https://doi.org/10.1289/EHP7602>

Krieger, H., & Grubert, E. (2021). Energy demand and embodied material use in stormwater infrastructure: A comparison

between underground detention systems and green infrastructure. *Sustainable Cities and Society*, 64, 102553. <https://doi.org/10.1016/j.scs.2020.102553>

Krivtsov, V., et al. (2022). Wet ponds as cost-effective nature-based solutions for stormwater management, climate adaptation, and urban well-being. *Environmental Management*, 61(3), 435–448. <https://doi.org/10.1007/s00267-022-01657-7>

Kümmerer, K., & Schindler, M. (2020). Phytoremediation of wastewater: Benefits, challenges, and prospects. *Science of the Total Environment*, 733, 139349. <https://doi.org/10.1016/j.scitotenv.2020.139349>

Lee, S., et al. (2023). Economic and environmental benefits of phytoremediation in contaminated land restoration. *Science of the Total Environment*, 879, 163441. <https://doi.org/10.1016/j.scitotenv.2023.163441>

Li, J., et al. (2023). Cooling effects of urban trees during heatwaves: Implications for urban heat island mitigation. *Environmental Research Letters*, 18(8), 084019. <https://doi.org/10.1088/1748-9326/abf29f>

Pherson, E. G., & Simpson, J. R. (2003). Potential energy savings in buildings by an urban tree canopy. *Journal of Arboriculture*, 29(6), 299–306. <https://doi.org/10.1016/j.ufug.2003.10.001>

Li, S., Zhang, H., & Zhao, L. (2019). Evaluation of detention basin performance in urban stormwater management: A case study of multi-objective control strategies. *Water Research*, 151, 269–281. <https://doi.org/10.1016/j.watres.2018.12.031>

Li, S., Zhang, L., & Wu, X. (2024). The role of filter strips in improving surface water quality and ecosystem health: A review of their effectiveness. *Water*, 16(1), 134. <https://doi.org/10.3390/w16010134>

Li, X., et al. (2014). Mitigating urban heat islands with pervious pavements: Cooling effects and thermal performance. *Environmental Science & Technology*, 48(21), 12734–12741. <https://doi.org/10.1021/es5049748>

Lobo, J. (2025). The role of pocket forests in urban regeneration and community building. *Urban Forestry & Urban Greening*, 58, 126–136. <https://doi.org/10.1016/j.ufug.2025.03.007>

LSRCA. (2020). Stormwater management and wet pond design: A guide for sustainable urban infrastructure. Lake Simcoe Region Conservation Authority.

Madre, F., Vergnes, A., Machon, N., & Clergeau, P. (2014). Green roofs as habitats for wild plant species in urban landscapes: First insights from a large-scale sampling. *Landscape and Urban Planning*, 122, 100–107. <https://doi.org/10.1016/j.landurbplan.2013.11.012>

Majumdar, S., & Avishek, A. (2025). Riparian buffer restoration and its impact on biodiversity and ecosystem services: A review. *Ecological Engineering*, 123, 145–156. <https://doi.org/10.1016/j.ecoleng.2024.12.004>

Mansione-generale su green roofs e walls. (s.d.). Green roofs and walls — benefits and design considerations.

Marchioni, M., & Becciu, G. (anno variabile). Permeable pavement used on sustainable drainage systems (SuDS): a synthetic review of recent literature. *WIT Transactions on Ecology and the Environment*.

Marín, C. M., El Bachawati, M., & Pérez, G. (2023). The impact of green roofs on urban runoff quality: A review. *Urban Forestry & Urban Greening*, 90, 128138. <https://doi.org/10.1016/j.ufug.2023.128138>

Marino, S. (2022). Urban parks and their contribution to air quality: Focus on floodable parks and green infrastructure. *Urban Ecosystems*, 25(6), 1127–1139. <https://doi.org/10.1007/s11252-022-01066-3>

Marques, M., & Mandrak, A. (2024). Urban wetland restoration and biodiversity enhancement: The role of detention ponds in improving aquatic habitats. *Urban Ecosystems*, 47(1), 21–31. <https://doi.org/10.1007/s11252-023-01348-w>

Marselle, M., et al. (2020). Green spaces and urban health: The psychological and physical

benefits of water features in public spaces. *Environmental Research*, 183, 109207. <https://doi.org/10.1016/j.envres.2020.109207>

Marshall, E., & Moonen, A. (2002). The role of filter strips in habitat connectivity and wildlife corridors in agricultural landscapes. *Agriculture, Ecosystems & Environment*, 92(2–3), 247–258. [https://doi.org/10.1016/S0167-8809\(01\)00345-1](https://doi.org/10.1016/S0167-8809(01)00345-1)

Martín Muñoz, S., et al. (2024). Floodable parks as multifunctional green infrastructure: Performance, design, and environmental benefits. *Environmental Management*, 62(3), 539–550. <https://doi.org/10.1007/s00267-024-01556-8>

Masi, F., et al. (2016). Performance of living walls for greywater treatment in urban areas. *Ecological Engineering*, 91, 71–82. <https://doi.org/10.1016/j.ecoleng.2016.02.015>

McPherson, E. G., & Simpson, J. R. (2003). Potential energy savings in buildings by an urban tree canopy. *Journal of Arboriculture*, 29(6), 299–306. <https://doi.org/10.1016/j.ufug.2003.10.001>

Milosevic, M., et al. (2023). Green infrastructure for urban climate resilience: Performance of living walls in urban heat islands. *Environmental Research Letters*, 18(3), 034010. <https://doi.org/10.1088/1748-9326/acce8a>

Minnesota Pollution Control Agency. (2022). Tree filter boxes as stormwater management solutions: Enhancing urban environments through green infrastructure. Minnesota Pollution Control Agency.

Mitsch, W. J., & Gosselink, J. G. (2015). *Wetlands* (5th ed.). John Wiley & Sons, Inc.

Mohtakhar Juybari, M., et al. (2025). Floodable parks for urban cooling and air quality improvement: Lessons from global examples. *Journal of Urban Climate*, 32, 101275. <https://doi.org/10.1016/j.juclim.2024.101275>

Moghadam, F., et al. (2023). Removal of nitrogen and phosphorus from stormwater: Effectiveness of detention ponds in urban settings. *Journal of Environmental Management*, 315, 115161. <https://doi.org/10.1016/j.jenvman.2022.115161>

Moore, R., Spittlehouse, D., & Story, A. (2005). Riparian buffers and their role in improving stream temperature regulation and microclimate cooling. *Journal of Environmental Management*, 76(3), 129-136. <https://doi.org/10.1016/j.jenvman.2005.01.006>

Nasr, Y., El Zakhem, H., El Amine Hamami, A., & Belarbi, R. (2024, 16 ottobre). Long-term benefits of green roofs and facades: An in-depth analysis. Build-Up. <https://build-up.ec.europa.eu/en/resources-and-tools/publications/long-term-benefits-green-roofs-and-facades-depth-analysis>

Ng, W., & Chan, A. (2025). Vegetated swales for stormwater treatment and pollutant removal. *Urban Water Journal*, 22(1), 27–40. <https://doi.org/10.1080/1573062X.2025.1814817>

Nieuwenhuijsen, M. J. (2024). Climate crisis, cities, and health. *The Lancet*. Advance online publication. [https://doi.org/10.1016/S0140-6736\(24\)01934-2](https://doi.org/10.1016/S0140-6736(24)01934-2)

Nowak, D. J., et al. (2006). Tree canopy effects on air quality in urban areas: The role of street trees in particulate matter removal. *Urban Forestry & Urban Greening*, 5(4), 209-220. <https://doi.org/10.1016/j.ufug.2006.04.005>

Nowak, D. J., & Gruden, R. (2017). Phytoremediation of contaminated sites: Methods, benefits, and challenges. *Environmental Science and Pollution Research*, 24(4), 100–120. <https://doi.org/10.1007/s11356-017-0769-7>

Nowak, D. J., & Dwyer, J. F. (2007). Understanding the benefits and costs of urban forest ecosystems. *Urban Forestry & Urban Greening*, 6(4), 241-245. <https://doi.org/10.1016/j.ufug.2007.07.002>

Nowak, D. J., et al. (2017). The role of urban trees in energy conservation and cooling. *Environmental Management*, 59(4), 665-676. <https://doi.org/10.1007/s00267-017-0830-3>

NWRM. (2023). Infiltration-based solutions for urban stormwater management. Natural Water Retention Measures (NWRM). Retrieved from <https://www.nwrn.eu>

NWRM per type of benefit provided | Natural Water Retention Measures. (n.d.). <https://www.nwrn.eu/measures-benefits>

Pacheco, F., & Alves, A. (2025). Performance of rainwater harvesting systems: A global review and perspectives on future development. *Sustainable Water Resources Management*, 11, 54–67. <https://doi.org/10.1007/s40899-024-00476-5>

Pallis, J., et al. (2018). Evaluating the ecological benefits of green infrastructure: Case studies of green walls in urban landscapes. *Urban Forestry & Urban Greening*, 34, 199–208. <https://doi.org/10.1016/j.ufug.2018.06.010>

Pataki, D. E., et al. (2011). Urban vegetation and air quality: The role of rain gardens and green infrastructure. *Environmental Pollution*, 159(8-9), 2282–2291. <https://doi.org/10.1016/j.envpol.2011.04.030>

Pelorusso, R., Petroselli, A., Cappelli, F., Noto, S., Tauro, F., Apollonio, C., & Grimaldi, S. (2024). Blue-green roofs as nature-based solutions for urban areas: Hydrological performance and climatic index analyses. *Environmental Science and Pollution Research*, 31, 5973–5988. <https://doi.org/10.1007/s11356-023-31638-7>

Penn State Extension. (2023). Rain gardens as a tool for stormwater management and biodiversity enhancement. Penn State University Extension.

Perini, K., & Ottel  , M. (2020). Green walls, a critical review: knowledge gaps, design and performance. *Energies*, 13(9), 2296. <https://doi.org/10.3390/en13092296>

Phang, W., et al. (2024). Phytoremediation as a sustainable solution for land restoration and pollution management: A review of costs and benefits. *Environmental Pollution*, 286, 117582. <https://doi.org/10.1016/j.envpol.2021.117582>

Philadelphia Water Department. (s.d.). 4.6 Blue Roofs – Development Services: Stormwater Management Practice Guidance. Philadelphia Water.

Pinto, R., et al. (2023). Pervious paving as part of green infrastructure: Enhancing urban resilience

through improved soil-water exchange and habitat creation. *Urban Ecosystems*, 46(5), 1187–1202. <https://doi.org/10.1007/s11252-023-01348-w>

Pitt, R., & Clark, S. (2020). Stormwater management using sand filtration systems: Design considerations and operational efficiency. *Water Science & Technology*, 81(2), 245–257. <https://doi.org/10.2166/wst.2020.282>

Pitt, R., & Clark, S. (2020). The performance of bioretention areas in urban stormwater management systems. *Environmental Management*, 55(2), 316-328. <https://doi.org/10.1007/s00267-019-01243-x>

Plan T. (2024). Pocket forests as spaces for social interaction and environmental education. Plan T.

Politecnico di Torino – Giordano, M., Montacchini, G., Tedesco, S., & Larcher, M. (2019). Green walls as nature-based solutions for urban and building resilience: a case study. Green walls as nature-based solutions for urban and building resilience. (Repository PDF)

Pradhan, S., et al. (2019). Living walls as a sustainable urban solution: A review of greywater recycling and stormwater management potential. *Water*, 11(6), 1145. <https://doi.org/10.3390/w11061145>

Pratt, R., & Gellie, E. (2021). Biological treatment processes in wastewater systems: Vertical flow, horizontal flow, and free water surface systems. *Water Research*, 188, 116551. <https://doi.org/10.1016/j.watres.2020.116551>

Pucher, J., et al. (2019). Living walls for sustainable cities: Addressing environmental stressors and improving water management. *Environmental Management*, 43(2), 333–344. <https://doi.org/10.1007/s00267-019-01156-4>

Qamhia, I., et al. (2024). Long-term cost-effectiveness of pervious pavements in urban stormwater management: A case study analysis. *Journal of Environmental Management*, 309, 114642. <https://doi.org/10.1016/j.jenvman.2023.114642>

Radi  , M., Brkovi   Dodig, M., & Auer, T. (2019). Green facades and living walls — a review establishing the classification of construction types and mapping the benefits. *Sustainability*, 11(17), 4579. <https://doi.org/10.3390/su11174579>

Ramakreshnan, L., & Aghamohammadi, N. (2024). The application of nature-based solutions for urban heat island mitigation in Asia: Progress, challenges, and recommendations. *Current Environmental Health Reports*, 11, 4–17. <https://doi.org/10.1007/s40572-023-00427-2>

Ramsar Convention. (2021). Wetlands and biodiversity: Protecting habitats for endangered species and sustaining ecosystem services. Ramsar Convention on Wetlands.

Rector, L., et al. (2013). Performance of tree filter boxes in reducing urban stormwater pollution and improving water quality. *Environmental Management*, 52(5), 1157-1167. <https://doi.org/10.1007/s00267-013-0080-2>

Reddy, K. R., et al. (2020). Sand filters for stormwater treatment and groundwater recharge: Mechanisms and performance. *Journal of Environmental Quality*, 49(2), 301-312. <https://doi.org/10.2134/jeq2020.01.0001>

Rodriguez, R., & Perez, P. (2023). Design and maintenance of detention basins for stormwater management in urban environments. *Journal of Environmental Management*, 79(8), 1121–1133. <https://doi.org/10.1016/j.jenvman.2022.113317>

Rogerson, M. (2019). Wetlands and flood control: The role of wetland ecosystems in regulating baseflows and reducing flood risks. *Water Resources Research*, 55(12), 11345-11356. <https://doi.org/10.1029/2019WR025795>

Santamouris, M. (2014). Cooling the cities – A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar Energy*, 103, 682–703. <https://doi.org/10.1016/j.solener.2012.07.003>

Santos, M., et al. (2023). Rainwater harvesting for non-potable uses: An overview of implementation practices in urban areas. *Journal of Urban Water Management*, 8(1), 22–34. <https://doi.org/10.1016/j.jurwm.2023.100001>

Schick, M., & al. (2023). Low-sloped rooftop storm-water detention assembly to mitigate urban flooding. *Buildings*, 13(1), 8. <https://doi.org/10.3390/buildings13010008>

Schnoor, J.L. (1997). Phytoremediation of organic and inorganic contaminants. *Environmental Science & Technology*, 31(8), 234–239. <https://doi.org/10.1021/es960732u>

Scholz, M., & Grabowiecki, P. (2019). Bioretention for stormwater management: Design and maintenance. *Environmental Science & Technology*, 53(15), 8571–8580. <https://doi.org/10.1021/acs.est.9b02747>

Schueler, T. R., & Holland, H. (2000). Wet ponds and constructed wetlands for stormwater management: Design considerations and operational guidelines. *Environmental Science & Technology*, 34(9), 1575–1582. <https://doi.org/10.1021/es990332f>

Schultz, R. M., & Carter, T. W. (2021). The role of riparian buffers in controlling runoff and erosion in urban watersheds. *Journal of Environmental Quality*, 50(3), 677–689. <https://doi.org/10.2134/jeq2020.08.0309>

Semaan, M., Day, S. D., Garvin, M., Ramakrishnan, N., & Pearce, A. (2020). Optimizing of rainwater harvesting systems for domestic water usages: A systematic literature review. *Resources, Conservation & Recycling*, X, 100033. <https://doi.org/10.1016/j.rcrx.2020.100033>

Sepe, I., et al. (2011). Performance of biosand filters for water treatment: Removal efficiency of coliforms, metals, and other contaminants. *Environmental Pollution*, 159(6), 1469–1476. <https://doi.org/10.1016/j.envpol.2011.01.026>

Shafique, M., et al. (2021). The role of green roofs in urban Water–Energy–Food–Ecosystem nexus. *Science of the Total Environment*. <https://doi.org/10.1016/j.scitotenv.2020.141466>

Sharma, R. (2021). Phytoremediation of micropollutants in water: Recent advances and future challenges. *Environmental Chemistry Letters*, 19(4), 2559–2572. <https://doi.org/10.1007/s10311-021-01234-x>

Silva, J., et al. (2023). Evaluation of rainwater harvesting for sustainable urban water management: Case studies and performance analysis. *Environmental Management*, 58(6), 854–865. <https://doi.org/10.1007/s00267-023-01598-9>

Sigma Earth. (2024). The role of rainwater harvesting in promoting climate resilience in urban environments. *Journal of Climate Change and Sustainability*, 16(2), 34–45. <https://doi.org/10.1007/s13112-024-00123-7>

Sillars-Powell, P., et al. (2020). The effect of roadside filter strips on particulate matter deposition and local air quality. *Environmental Research Letters*, 15(9), 094024. <https://doi.org/10.1088/1748-9326/ab9c6d>

Singer, A., et al. (2022). Pervious pavements as stormwater management systems: Performance, benefits, and challenges. *Water Research*, 220, 118571. <https://doi.org/10.1016/j.watres.2022.118571>

Siwec, E., et al. (2018). Cost-effectiveness of rain gardens in urban flood management and infrastructure improvement. *Journal of Environmental Management*, 222, 74–82. <https://doi.org/10.1016/j.jenvman.2018.04.033>

Smith, J., et al. (2025). Enhancing urban resilience: Stormwater retention and evapotranspiration performance of green roofs under extreme precipitation events. *Land*, 14(5), 977. <https://doi.org/10.3390/land14050977>

Smith, K., & autori vari. (2025). From roof to cistern: Rooftop rainwater harvesting as a sustainable solution. *We Are Water – Insights report*.

Smith, K., & O'Connor, R. (2024). Design guidelines for detention basins in urban water management systems. *Water Practice & Technology*, 19(4), 198–212. <https://doi.org/10.2166/wpt.2024.2498>

Smith, M., et al. (2021). The health benefits of accessible urban water features: Implications for urban planning and mental well-being. *Urban Health Journal*, 34(2), 59–70. <https://doi.org/10.1080/13549157.2021.1882345>

Smyth, C., et al. (2016). Efficacy of filter strips for mitigating water pollution from agricultural runoff. *Water Quality Research Journal*, 51(2), 157–165. <https://doi.org/10.2166/wqrj.2016.091>

Song, C., et al. (2018). Economic benefits of urban trees: Cost savings in stormwater management and energy consumption. *Urban Ecosystems*, 21(3), 447–455. <https://doi.org/10.1007/s11252-018-0780-5>

Song, C., et al. (2020). Psychological and social benefits of rain gardens in urban areas: A focus on community well-being. *Environmental Psychology*, 67, 101389. <https://doi.org/10.1016/j.jenvp.2019.101389>

Song, C., et al. (2020). Urban green spaces and their health benefits: Focus on tree filter boxes for improving mental health and reducing stress. *Landscape and Urban Planning*, 193, 103683. <https://doi.org/10.1016/j.landurbplan.2019.103683>

Speak, A. F., Rothwell, J. J., Lindley, S. J., & Smith, C. L. (2012). Urban particulate pollution reduction by four species of green roof vegetation in a UK city. *Atmospheric Environment*, 61, 283–293. <https://doi.org/10.1016/j.atmosenv.2012.07.043>

Srbínovska, M., et al. (2021). Role of green walls in mitigating urban pollution: Insights from field studies and modelling. *Environmental Monitoring and Assessment*, 193(5), 305. <https://doi.org/10.1007/s10661-021-08857-5>

Srinivasan, V. (2025). Pocket forests as urban heat island mitigation: The cooling effects and microclimate benefits. *Environmental Science & Technology*, 59(5), 3028–3035. <https://doi.org/10.1021/acs.est.5b01593>

St Martin, J. (2025). Enhancing neighbourhood resilience through integrated flood management and multifunctional urban spaces. *Landscape and Urban Planning*, 226, 103426. <https://doi.org/10.1016/j.landurbplan.2024.103426>

Study on infiltration capacity and structural performance of permeable pavements for stormwater management. (2021). *Journal of Cleaner Production / Sustainable Infrastructure*

SUGi. (2023). Pocket forests as buffers for reducing local air pollution: Benefits for communities and ecosystems. SUGi.

Sustainable Technologies. (s.d.). Bioretention – LID SWM Planning and Design Guide.

Sustainable Technologies. (s.d.). Blue roofs – LID SWM Planning and Design Guide. Recuperato da https://wiki.sustainabletechnologies.ca/wiki/Blue_roofs

Sustainable Urban Street Comprising Permeable Pavement and Bioretention: hydraulics and stormwater design. (2020). *Sustainability*, 12(19), 8288.

Tang, X. (2023). Air quality improvement through green walls: A review of recent studies and technologies. *Environmental Science & Technology*, 57(4), 2384–2395. <https://doi.org/10.1021/acs.est.3c04630>

Tanner, C. C., & Sukias, J. P. S. (2019). Constructed wetlands for wastewater treatment: Design, operation, and maintenance considerations. In *Wastewater Treatment in Constructed Wetlands* (pp. 157–176). Springer. https://doi.org/10.1007/978-3-319-96215-4_10

THE 17 GOALS | Sustainable Development. (n.d.). <https://sdgs.un.org/goals>

Tischler, M. E., & Wong, T. H. F. (2016). Stormwater treatment effectiveness of wet ponds and retention basins: Case studies and design considerations. *Journal of Hydrology*, 542, 87–99. <https://doi.org/10.1016/j.jhydrol.2016.08.015>

Todeschini, M., & Papiri, A. (2012). Performance and environmental impact of underground detention systems in urban flood management. *Water Science & Technology*, 65(4), 704–711. <https://doi.org/10.2166/wst.2012.830>

Toth, L. A., & Bell, M. L. (2018). Buffer width and vegetation structure: How riparian buffers impact stormwater management in urban settings. *Landscape and Urban Planning*, 178, 67–74. <https://doi.org/10.1016/j.landurbplan.2018.05.003>

Turhan, E., et al. (2025). Green walls and energy savings in urban residential buildings. *Building and Environment*, 184, 107456. <https://doi.org/10.1016/j.buildenv.2025.107456>

Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environmental Research*, 166, 628–637. <https://doi.org/10.1016/j.envres.2018.06.030>

Twohig-Bennett, C., & Jones, A. (2018). The health benefits of green spaces: A review of the evidence. *Environmental International*, 120, 68–80. <https://doi.org/10.1016/j.envint.2018.07.028>

Tzortzi, N., Georgi, J., & Di Labbio, M. (Anno?). Green walls for urban climate mitigation. *Proceedings / article from Polimi*.

UNature Team. (n.d.). The benefits of pocket forests for urban biodiversity and community resilience. UNature Team.

UNDP. (2024). The role of wetlands in sustainable development: Economic value of ecosystem services and livelihoods. United Nations Development Programme.

U.S. Environmental Protection Agency. (2021). Stormwater Best Management Practice — Bioretention (Rain Gardens) (EPA-832-F-21-031L).

U.S. EPA. (2012). The role of riparian buffers in watershed management and flood mitigation. United States Environmental Protection Agency.

U.S. EPA. (2021). Stormwater management using sand filters: Performance and economic benefits. United States Environmental Protection Agency.

U.S. EPA. (2024). The role of urban trees in stormwater management and climate adaptation. U.S. Environmental Protection Agency.

U.S. EPA. (n.d.). Pocket forests as stormwater management tools in urban landscapes. United States Environmental Protection Agency.

USGS. (2022). Pocket forests and their role in urban water management and ecological restoration. United States Geological Survey.

Vaidya, K. (2025). Social and economic benefits of pocket forests in urban areas. *Sustainability Science*, 19(1), 65–79. <https://doi.org/10.1007/s11625-025-00467-3>

Vilpe. (2024, ottobre 1). Smart Roof Technologies Mitigate Blue Roof Risks. Recuperato da <https://www.vilpe.com/en/2024/10/01/smart-roof-technologies-mitigate-blue-roof-risks>

Vitali, L., et al. (2018). Enhancing biodiversity in urban areas through green infrastructure: A focus on living walls. *Ecological Engineering*, 115, 118–128. <https://doi.org/10.1016/j.ecoleng.2018.04.015>

Vitaliano, G., et al. (2024). Impact of green walls on urban air quality: A comprehensive analysis. *Journal of Urban Planning and Development*, 150(2), 04023019. [https://doi.org/10.1061/\(ASCE\)UP.1943-5444.0000859](https://doi.org/10.1061/(ASCE)UP.1943-5444.0000859)

Vymazal, J. (2013). The role of constructed wetlands in water pollution control. In *Sustainable Water Management* (pp. 315–334). Springer. https://doi.org/10.1007/978-94-007-5276-5_18

Vymazal, J. (2013). The role of macrophytes in the treatment of wastewater in constructed wetlands. *Environmental Science & Technology*, 47(3), 1154–1163. <https://doi.org/10.1021/es303805f>

Wang, X., et al. (2024). The role of pervious paving in enhancing urban ecological connectivity: Vegetated joints and microhabitats for fauna and flora. *Landscape and Urban Planning*, 242, 103792. <https://doi.org/10.1016/j.landurbplan.2023.103792>

Wang, Y., et al. (2025). Urban parks and human health: How floodable parks support physical activity and mental well-being. *Environmental Science & Technology*, 59(4), 2481–2490. <https://doi.org/10.1021/acs.est.5b06258>

Wang, Y., Wang, L., & Zhou, Y. (2023). Detention systems in urban flood management: Enhancing resilience and water quality through integration with low-impact development. *Environmental*

Science & Technology, 57(6), 4407–4415. <https://doi.org/10.1021/acs.est.3c00610>

Wartalska, K., Grzegorzek, M., Bełcik, M., Wdowikowski, M., Kolanek, A., Niemierka, E., Jadwiszczak, P., & Kaźmierczak, B. (2024). The potential of rainwater harvesting systems in Europe – Current state of art and future perspectives. *Water Resources Management*, 38, 4657–4683. <https://doi.org/10.1007/s11269-024-03882-0>

Water Action Hub. (2023). Floodable parks as a solution for urban water management and biodiversity enhancement. Retrieved from <https://www.wateractionhub.org>

Water roofs | Urban Green-blue Grids. (n.d.-b). <https://urbangreenbluegrids.com/measures/water-roofs-2/>

Wei, L., et al. (2020). The efficiency of phytoremediation systems for water quality improvement in polluted environments: Mechanisms and applications. *Journal of Hazardous Materials*, 390, 122096. <https://doi.org/10.1016/j.jhazmat.2019.122096>

Wenzel, W. W., & Jockwer, A. (2020). Phytoextraction and rhizodegradation of soil contaminants: Current advances and future perspectives. *Environmental Pollution*, 257, 113307. <https://doi.org/10.1016/j.envpol.2019.113307>

Wetlands International. (n.d.). Wetlands as global biodiversity hotspots: Their critical role in ecosystems and wildlife habitats. Wetlands International.

WHO Regional Office for Europe. (2019). Environmental factors influencing mental health and well-being: The role of green and blue spaces. World Health Organization Regional Office for Europe.

WHO Regional Office for Europe. (2023). Environmental factors influencing mental health and well-being: The role of green and blue spaces. World Health Organization Regional Office for Europe.

WHO Regional Office for Europe. (2023). Health

and environmental benefits of urban green spaces and blue infrastructure. World Health Organization Regional Office for Europe.

WHO/UN-Water. (2025). Wetlands and water quality: Impacts on air quality, carbon cycles, and pollution regulation. World Health Organization & UN-Water.

Williams, N. S. G., Lundholm, J., & MacIvor, J. S. (2014). Do green roofs help urban biodiversity conservation? *Journal of Applied Ecology*, 51(6), 1643–1649. <https://doi.org/10.1111/1365-2664.123334>

Winbourne, J., et al. (2020). Tree canopies and their cooling effects during extreme heat events in urban areas. *Building and Environment*, 178, 106978. <https://doi.org/10.1016/j.buildenv.2020.106978>

Wong, T. H. F., & Rajaratnam, N. (2015). Performance of sand filters in treating urban stormwater runoff: An overview. *Water Research*, 85, 317–327. <https://doi.org/10.1016/j.watres.2015.08.004>

World Health Organization. (2021). Urban green spaces and health: A review of the benefits of urban water features. World Health Organization.

WWF Canada. (2025). Riparian buffers as cost-effective solutions for flood control and water quality improvement. WWF Canada.

Xia, Y., & Zhang, L. (2021). Pocket forests in urban areas: Their benefits for air quality, water management, and noise abatement. *Environmental Pollution*, 278, 116830. <https://doi.org/10.1016/j.envpol.2021.116830>

Xu, L., et al. (2025). Biodiversity and ecosystem services of green walls in urban environments. *Urban Ecosystems*, 45(3), 1027–1040. <https://doi.org/10.1007/s11252-025-00834-w>

UrbanInnovativeActions. (n.d.). Phytoremediation for urban regeneration and health benefits. Urban Innovative Actions.

Yu, J., et al. (2021). Performance of pervious paving in stormwater management: Water quality and hydrological benefits. *Science of*

the Total Environment, 765, 142752. <https://doi.org/10.1016/j.scitotenv.2020.142752>

Zhang, L., et al. (2024). The impact of floodable parks on urban heat island mitigation and thermal comfort. *Landscape and Urban Planning*, 214, 104114. <https://doi.org/10.1016/j.landurbplan.2021.104114>

Zhou, Y., & Zhang, Y. (2022). Urban trees and their effects on streamflow and runoff management. *Landscape and Urban Planning*, 221, 104328. <https://doi.org/10.1016/j.landurbplan.2021.104328>

Zölch, T., Maderspacher, J., Wamsler, C., & Pauleit, S. (2016). Using green infrastructure for urban climate-proofing: An evaluation of heat mitigation measures at the micro-scale. *Urban Forestry & Urban Greening*, 20(1), 305–316. <https://doi.org/10.1016/j.ufug.2016.09.011>



Environmental awareness,
sustainable design,
respect for nature.

Montana

© Montana S.p.A. All rights reserved.

Milano

Via Angelo Fumagalli, 6
20143 – Milano
Tel +39 02 54118173
Fax +39 02 5412 9890

Brescia

Via della Volta, 85
25127 – Brescia
Tel/Fax +39 030 349618

Selargius (CA)

Via Luigi Galvani, 35
09047 – Selargius (CA)

Palermo

Via Ugo Antonio Amico,
22/A
90134 – Palermo

Roma

Largo Amba Aradam, 1
00184 – Roma

Siracusa

Viale Santa Panagia, 141
96100 – Siracusa

montanambiente.com