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D1.1.1 Typology and criteria for planning CCI/GI/NBS on the local level

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Executive summary

Given the escalating effects of climate change and their widespread consequences, the significance of taking actions to adapt and mitigate these impacts cannot be emphasized enough. As conventional methods face difficulties in dealing with the problems presented by a warming planet, utilizing the potential of nature presents an appealing substitute. In light of this, the green adaptation measures have emerged, the Nature-based Solutions (hereinafter NbS) and Green Infrastructure (hereinafter GI) that offer innovative and sustainable strategies to address climate change impacts while enhancing the resilience and liveability of urban areas.

This deliverable aims to outline various typologies of NBS and GI applicable in the urban context, highlighting the essential criteria to consider when planning such green measures. It explores the definitions, importance, and practical adoption of NBS and GI in addressing climate change, with a specific focus on the GreenScape CE pilot cities. These pilot areas, comprising Zagreb, the Metropolitan area of Milan, Ptuj, Szegedin, and Warsaw, face unique climate challenges and by working collaboratively and harnessing the potential of nature-based approaches, we can pave the way for a greener and more prosperous tomorrow. Through the exploration of NbS and GI within the context of the GREENSCAPE CE pilot areas, the deliverable endeavours to empower these cities with the knowledge and strategies necessary to build a resilient, sustainable, and climate-ready future.

The deliverable is structured as follows:

<u>Definition and importance of NbS/ GI/ CCI in addressing climate change</u>

In this section, we will provide a clear and concise definition of Nature-Based Solutions and Green Infrastructure, illustrating their roles as transformative tools in the fight against climate change. We will explore how NBS and GI leverage natural processes and ecosystem services to mitigate the impacts of climate change, enhance adaptive capacity, and contribute to sustainable urban development. By highlighting their environmental, social, and economic benefits, we aim to emphasize the importance of integrating NBS and GI into climate action strategies.

<u>Pilot cities, challenges and potentials</u>

This section will introduce the five GrenScape CE pilot cities and provide an overview of their unique profiles, geographic characteristics, and demographic dynamics. Each city, including Zagreb, the Metropolitan area of Milan, Ptuj, Szegedin, and Warsaw, faces distinct climate challenges driven by their diverse urban landscapes and regional climates. The challenges presented here are based on the valuable insights gathered through a comprehensive questionnaire compiled by each city, shedding light on their specific needs and priorities in the face of climate impacts.

<u>Typologies and Criteria of NbS - Schemes for each NbS/ GI</u>

In this section, we will explore various typologies of Nature-Based Solutions and Green Infrastructure, considering their suitability for the GREENSCAPE CE pilot areas. For each typology, we will present comprehensive criteria that encompass ecological, economic, and social aspects, ensuring that the implementation of NBS and GI aligns with the specific needs and goals of each city. Through detailed schemes and guidelines, we intend to facilitate the adoption of NBS and GI in a manner that maximizes their potential benefits while minimizing potential challenges.

1. Definition and importance of NbS/ CCI/ GI in addressing climate change

In a unified endeavor, a multitude of actors ranging from the European Union and the United Nations to individual nations are fervently directing their efforts towards nature-based solutions as a robust strategy to confront the pressing trials posed by climate change. This collaborative approach spans global and national spheres, as countries worldwide actively implement measures that capitalize on the inherent resilience of nature to build a sustainable future for all. They are taking different Climate Change Initiatives (hereinafter CCI) and forming various coalitions to speed the pace of climate action.

Urban areas stand at the forefront of climate change consequences, grappling with escalating challenges that demand immediate attention. Amid this crisis, the potential of nature-based solutions as a compelling response option. Introduced firstly around the end of 2000s by the World Bank (2008[1]) and IUCN (2009[2]), the nature-based solutions have been rooted from the beginning in the climate change mitigation and adaptation with a strong emphasis on biodiversity conservation and at the same time also addressing policy objectives.

NbS are defined by the European Commission[3] as "*Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. NbS must therefore benefit biodiversity and support the delivery of a range of ecosystem services*".

Their application is very broad and can be considered as an encompassing concept that include also other approaches such as ecosystem-based adaptation (hereinafter EbA), eco-disaster risk reduction (hereinafter eco-DRR), green infrastructure (hereinafter GI) and natural climate solutions (hereinafter NCS) (Paileit et.al., 2017[4]). Each approach differs slightly, while NbS work towards solutions and in creating new ones on the ground. These solutions work in harmony with nature, providing a range of benefits beyond just carbon sequestration, including biodiversity conservation, water management, and enhanced ecosystem services.

In GreenScape CE, nature-based solutions are deployed as **solutions** that use the power of nature to address environmental challenges of the pilot cities, and as **strategies** to provide guarantees for social and environmental sustainability in pilot cities. Whiles the nature-based solutions are individual multi-beneficial small or large-scale interventions, Green Infrastructure refer to the **interconnected networks** of all green spaces. While both NBS and GI share the overarching goal of leveraging nature to address climate change and environmental challenges, they differ in their scale and application:

- NbS is broader and can include large-scale ecosystem-based interventions, such as reforestation and wetland restoration, which target carbon sequestration and ecosystem restoration. In contrast, GI often focuses on localized, urban or peri-urban green spaces and infrastructure to enhance urban resilience and quality of life.
- NbS is more oriented towards preserving and restoring natural ecosystems, which, in turn, offer a range of ecosystem services and climate benefits. GI emphasizes incorporating green elements into urban

[1]Leary, Neil, James Adejuwon, Vicente Barros, Ian Burton, Jyoti Kulkarni, and Rodel Lasco, Biodiversity, Climate Change and Adaptation, Climate Change and Adaptation, 2008.

[2] https://www.iucn.org/sites/default/files/import/downloads/iucn_position_paper_unfccc_cop_15_1.pdf (accessed 07/2023)

[3] https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en (accessed 07/2023)

[4] Pauleit, Stephan, Teresa Zölch, Rieke Hansen, Thomas B. Randrup, and Cecil Konijnendijk van den Bosch, "Nature-Based Solutions and Climate Change – Four Shades of Green", 2017, pp. 29–49. http://link.springer.com/10.1007/978-3-319-56091-5_3.

planning and infrastructure to mitigate the negative impacts of urbanization and improve overall urban environmental conditions.

Both NBS and GI play crucial roles in the fight against climate change and offer a range of benefits:

- Carbon Sequestration: NbS which involve practices like afforestation and reforestation. These activities effectively capture carbon dioxide from the atmosphere, playing a vital role to reduce greenhouse gas emissions.
- Enhanced Resilience: GI helps cities and communities become more resilient to the impacts of climate change, such as extreme weather events, floods, and heatwaves, by providing natural buffers and regulating water flows.
- Biodiversity Conservation: NBS fosters biodiversity by preserving and restoring natural habitats, protecting endangered species, and maintaining ecological balance.
- Improved Air and Water Quality: Both NBS and GI contribute to improved air quality by absorbing pollutants and reducing the urban heat island effect. They also aid in filtering and purifying water, promoting healthier ecosystems and water resources.
- Sustainable Urban Development: GI promotes sustainable urban planning and development, creating healthier and more livable cities with better access to green spaces and recreational areas.

Both the concepts are used in GreenScape CE to support cities choose solutions and measures that will be part of their action plans and of the Joint Strategy on strengthening their implementation in Central Europe (hereinafter CE) cities. While the term Climate Change Initiatives (CCI) will refer to all the actions or networks mutually co-created by the GreenScape CE stakeholders through the deployment of NbS and/or GI.

2. Pilot cities, challenges and potentials

The GreenScape CE project is centered around five CE pilot cities, each facing distinct climate challenges that demand innovative and nature-based solutions. These pilot cities, comprising Zagreb, the Metropolitan area of Milan, Ptuj, Szegedin, and Warsaw, have collectively embarked on a mission to tackle their environmental concerns through the implementation of Green Infrastructure (GI) and Nature-Based Solutions (NBS).

To gain a comprehensive understanding of their specific challenges, the pilot cities compiled a questionnaire that served as a platform for identifying and prioritizing their key environmental concerns. The cities were presented with seven fundamental challenges:

- **Flood Management**: Addressing the issues of river flooding and pluvial flooding to safeguard communities and infrastructure from the devastating impacts of extreme weather events.
- **Water Scarcity**: Confronting the growing scarcity of water resources, ensuring sustainable water management, and securing water availability for current and future generations.
- **Urban Heat Island and Heat Waves**: Alleviating the urban heat island effect and preparing for heatwaves to enhance public health and well-being during extreme heat events.
- **Air Pollution**: Mitigating air pollution levels to improve air quality and promote a healthier living environment for citizens.
- **Loss of Biodiversity**: Preserving and enhancing biodiversity to conserve natural habitats and foster ecological balance within urban landscapes.
- **Green Space Deprivation**: Revitalizing and improving the quality of existing green spaces to ensure that they are safe, functional, and inviting for community use as well as creating new green spaces.
- **Habitat Fragmentation**: Mitigating habitat fragmentation by creating green infrastructure - wildlife corridors or interconnected pocket and large green spaces.
- **Socio-economic Inequalities**: Increasing the availability of green spaces in the deprived areas and improving the access, safety, and security for the people to use them.

Each pilot area was asked to select up to three challenges from the list, indicating their priority concerns. Additionally, the cities provided concise explanations outlining their specific needs and aspirations in addressing the chosen challenges. Through this questionnaire, the GreenScape CE project gained invaluable insights into the cities' environmental priorities, laying the groundwork for the development of tailored and effective GI/NBS measures.

The findings, as depicted in Figure 1, highlight the predominant challenges encountered by our pilot cities. Foremost among these challenges are the 'Urban Heat Island effect and heat waves,' as well as 'Green space deprivation.' Nearly all pilot cities have identified these two issues as central concerns. Following closely are two compelling challenges: 'Flood management' and 'Air pollution,' which are prevalent among the majority of pilot cities, and ‘Water scarcity’ for two cities. Notably, 'Habitat fragmentation' emerges as a particularly significant challenge for Warsaw.

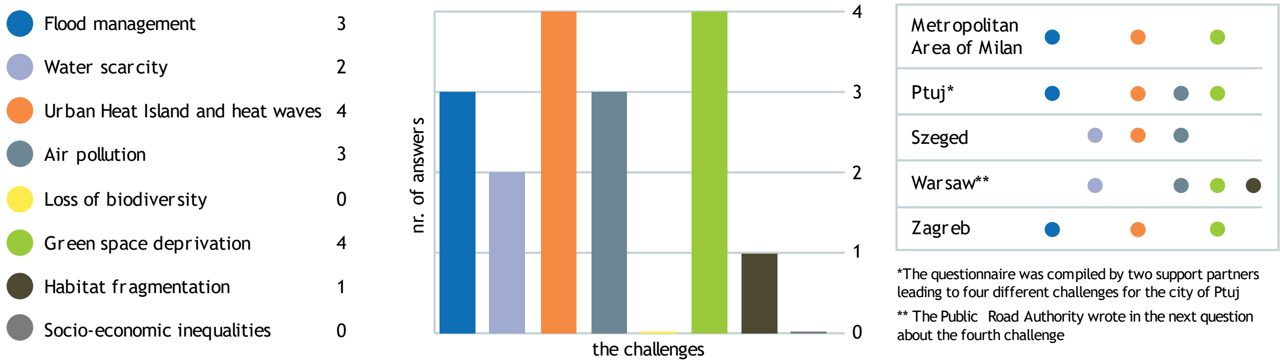

Figure 1. The most relevant challenges of GreenScape CE pilot cities

Metropolitan Area of Milan, Italy

The Metropolitan City of Milan stands as one of the most densely populated urban regions in Europe, boasting a density of 2,000 inhabitants per square kilometer. With a resident populace exceeding three million, it ranks as the third most populous area on the continent, trailing only London and Paris. A notable demographic aspect is that 22% of this population is aged 64 or older.

Encompassing an approximate area of 1,600 square kilometers across 133 Municipalities, including the city of Milan, the metropolitan domain comprises 41% urbanized expanses and infrastructure, 50% agricultural zones, and a mere 8% woodland areas. Characterized by its predominantly flat terrain, the region accommodates a cluster of regional parks acknowledged for their protected for their high natural-ecological value. The principal among these parks, spanning 61 municipalities, covers a vast expanse of approximately 47,000 hectares.

Established in 2014, the Metropolitan City of Milan is a local public authority of moderate jurisdiction and oversees the largest metropolitan urban area in Italy. Integral to the adaptation process, the Metropolitan City of Milan plays a pivotal role in devising a comprehensive strategy across its territory, promoting the integration of adaptation measures at the local level, while harmonizing diverse planning and operational frameworks.

The Metropolitan Area of Milan has identified three challenges: ‘Flood management’, ‘Green space deprivation’, and the pressing concerns of ‘Uban Heat Islands and heatwaves’. Recognizing the gravity of these challenges, the region is committed to addressing them through a concerted effort. To effectively tackle these issues, the Metropolitan Area of Milan acknowledges in the questionnaire the necessity of having available spatial and economic planning tools that consider and integrate climate change phenomena in order to implement effective solutions on the ground and subsequently monitor the impacts of the measures implemented.

Ptuj, Slovenia

Located in northeastern Slovenia, the city of Ptuj is one of the country's oldest settlements, boasting a rich history and cultural heritage. Situated along the Drava River, Ptuj's geographic characteristics contribute to its appeal, with picturesque landscapes and a temperate continental climate. The city is surrounded by rolling hills and fertile plains, making it an ideal location for agricultural activities and tourism. Its historic center showcases well-preserved architecture, including the prominent Ptuj Castle.

In terms of demographic dynamics, Ptuj has a population of approximately 20,000 residents. Over the years, the city has witnessed a gradual growth in its population, attributed to a combination of natural population increase and migration. The inhabitants of Ptuj primarily engage in various sectors, including manufacturing, trade, and services, which form the backbone of the local economy.

However, like many other urban areas, Ptuj faces significant challenges in combatting climate change. The city experiences the challenges of global warming, including 'Air pollution' 'Urban Heat Island and heatwaves', 'Flood management', and 'Green space deprivation'. The latter because according to one support partner in GreenScape CE, the recent focus on city center investments has resulted in a significant reduction of green spaces, leading to various challenges for citizens. These challenges encompass the absence of shaded areas during warm days, a dearth of green recreational spots, and notably elevated temperatures within the city center, surpassing those on the outskirts. Consequently, the city center is facing a decline in activity, particularly evident during summer when it lacks visitors, operational shops, and bustling restaurants. Implementing green initiatives holds the potential to enhance the urban experience by providing more enjoyable city errands and contributing to temperature reduction in the central area during hot spells. Additionally, the city contends with heightened levels of airborne particulate matter, further underscoring the need for action.

By embracing natural-based solutions, the city aims to rejuvenate its central area with greenery, simultaneously working to improve air quality and create a more sustainable urban environment. The other supporting partner in the questionnaire emphasizes that because Ptuj is a medieval city, wrestles with limited green spaces in its historic core, making the preservation and enhancement of existing green infrastructure elements a key challenge.

Szegedin, Hungary

Situated in southern Hungary, Szeged is a vibrant city renowned for its rich history, cultural heritage, and picturesque surroundings. Nestled along the banks of the Tisza River, the city's geographic characteristics include fertile plains and a continental climate with hot summers and cold winters. Szeged is widely known for its stunning architecture, including the iconic Votive Church and the imposing Szeged University buildings.

In terms of demographic dynamics, Szeged has a population of around 170,000 residents. The city's population has remained relatively stable over the years, with a mix of locals and a growing number of international residents, especially due to the university's allure. Szeged's economy is diverse, encompassing sectors such as education, research, manufacturing, and agriculture.

Despite its appeal, Szeged faces challenges in combating climate change. Like many other cities, it experiences the impacts of global warming, including more frequent 'heatwaves and consequently also Urban Heat Island effect', 'Air pollution', 'flash floods but also droughts'. This last challenge, as acknowledged by the Municipality of Szeged in the questionnaire, the city is having a significant shift in precipitation patterns, where the overall amount of rainfall might not decrease significantly, but its distribution will undergo substantial change. Infrequent but intense rainfall events are projected, wherein several times the monthly precipitation could occur within a mere hour or two following prolonged hot and rain-deprived conditions. This forecasted pattern carries the potential for street inundation, resulting in flash floods, which then rapidly dissipate into the ground and drainage systems, leaving the city devoid of water once again. Managing this situation effectively presents challenges. An approach could involve harnessing rainfall as greywater for purposes like irrigation. Compounded by urban vegetation's existing vulnerability to heightened heat stress due to thermal insulation, the inability to provide adequate watering could render the months of drought and elevated temperatures untenable for city plants.

Warsaw, Poland

As the capital and largest city of Poland, Warsaw is a bustling metropolis located in the central part of the country. The city's history dates back to the 13th century, and it has since evolved into a vibrant hub of culture, commerce, and politics. Warsaw's geographic characteristics include its position along the Vistula River, which has historically played a significant role in the city's development and trade. The city experiences a temperate continental climate, with warm summers and cold winters. Warsaw's cityscape showcases a mix of architectural styles, with modern skyscrapers juxtaposed against historic landmarks like the Royal Castle and the Old Town, which is a UNESCO World Heritage site.

In terms of demographic dynamics, Warsaw is a melting pot of diversity. With a population of over 1.7 million residents, it is the most populous city in Poland. The city attracts people from various regions of the country and a growing number of international residents drawn to its economic opportunities and cultural attractions. Warsaw serves as a major center for business, education, research, and the arts, making it a vibrant and dynamic urban environment.

As in many major cities, Warsaw faces challenges in combating climate change. The city experiences the impacts of global warming, including 'Air pollution', 'Green space deprivation' and 'Habitat fragmentation'. The Public Roads Authority highlights in the questionnaire that the city of Warsaw confronts pronounced challenges concerning air pollution, with winter exacerbating the issue. Priority is placed on initiatives like furnace replacement programs and addressing concerns tied to internal combustion vehicle use. An evident shift in focus pertains to diminishing tiled surfaces, signifying a growing imperative. Indeed, measures are being implemented, recognizing that this is a lengthy process due to the scale of the challenge, demanding substantial temporal and financial commitments. Warsaw boasts a considerable expanse of green spaces, yet opportunities remain to enhance their connectivity. An illustrative instance is the widely discussed annual merganser migration route. Furthermore, rainwater collection poses a distinct challenge. Unlike excess water, Warsaw grapples with scarcity, especially during summer. Remedying this scarcity necessitates prompt and decisive action.

Zagreb, Croatia

Located in the heart of Croatia, Zagreb is the nation's capital and largest city. As a cultural and economic hub, Zagreb showcases a blend of historic charm and modern developments. Nestled between the southern slopes of the Medvednica mountain and the banks of the Sava River, the city enjoys a picturesque setting. Its geographic characteristics contribute to a continental climate with distinct seasons, hot summers, and cold winters. The cityscape boasts an architectural mix of medieval structures, Austro-Hungarian buildings, and contemporary designs, creating a unique urban fabric.

In terms of demographic dynamics, Zagreb is home to over 800,000 residents, making it the most populous city in Croatia. The population is diverse, comprising locals, immigrants, and expatriates drawn to the city's economic opportunities and vibrant cultural scene.

However, like many urban centers worldwide, Zagreb faces challenges in combating climate change. The city experiences the impacts of global warming. Indeed, as highlighted from the support partner, the City of Zagreb is confronted with a formidable confluence of challenges stemming from urbanization and the evolving climate landscape. This predicament is prominently manifested by the Urban Heat Island (UHI) effect and recurrent instances of urban flooding. The UHI effect particularly impacts the city center, contributing to elevated temperatures, while various sectors across the city grapple with the recurrent threat of flooding. This complex interplay between urbanization and climate shifts has also led to a scarcity of green spaces, an outcome directly linked to the intensification of urban development.

3. Typologies of NbS/ GI

Within this deliverable, we embark on a captivating journey through an array of nature-inspired typologies, each playing a pivotal role in enhancing urban resilience and sustainability. As cities strive to address the challenges posed by climate change and urbanization, the integration of NbS becomes increasingly paramount. Here, we present a diverse collection of typologies, carefully curated to foster a harmonious coexistence between urban landscapes and the natural world.

- Bioswales: Embracing the power of vegetation, bioswales provide an ingenious means to manage stormwater runoff, filtering and purifying it before it enters waterways. These vibrant green corridors also act as welcoming habitats for local wildlife, transforming streets into thriving ecosystems.
- Infiltration Trenches/Strips: Functioning as below-ground reservoirs, infiltration trenches and strips capture excess water and allow it to infiltrate the soil, replenishing groundwater and mitigating the risks of flooding.
- Bioretention Systems and Rain Gardens: Championing the concept of "nature as a sponge," bioretention systems combine indigenous plants and engineered structures to efficiently manage stormwater, ensuring its gradual release and purification.
- Tree Box Filters: Adorned with lush vegetation, tree box filters are nature's gift to urban air quality. These green installations absorb pollutants and carbon dioxide, promoting healthier and cleaner surroundings.
- Detention Basins: Artfully designed detention basins provide vital flood control, acting as elegant sanctuaries that temporarily hold excess water during heavy rainfall, minimizing damage to urban areas.
- Retention Ponds and Constructed Wetlands: Serenading us with their tranquil charm, retention ponds and constructed wetlands blend seamlessly into urban landscapes, offering vital flood control while nurturing diverse flora and fauna.
- Permeable Pavements: Paving the way for sustainable infrastructure, permeable pavements allow rainwater to seep through, reducing runoff and replenishing groundwater.
- Green Barriers: Standing tall as nature's guardians, green barriers mitigate noise pollution, improve air quality, and provide privacy and beauty to urban environments.
- Green Facades and Living Walls: Veils of green embellish the urban canvas as green facades and living walls weave their magic, reducing building energy consumption while boosting biodiversity and aesthetics.
- Vegetated Pergola and Pergola Pathways: Intertwining functionality and beauty, vegetated pergola paths invite pedestrians to traverse shaded walkways adorned with cascading greenery.
- Green Roofs (Intensive and Extensive): Redefining rooftops, green roofs enhance building insulation, conserve energy, and create biodiverse habitats, transforming concrete jungles into vibrant green oases.
- Balcony Gardens: Inspiring urban dwellers to embrace horticulture, balcony gardens nurture mini-green havens, connecting residents with nature amid the bustle of city life.
- Street Trees: Celebrated for their elegance and environmental prowess, street trees grace urban boulevards, offering shade, cooling effects, and improved air quality.
- Urban Forestation: Ushering nature into cityscapes, urban forestation endeavors to create vast green canopies, replenishing urban ecosystems and enriching lives.
- Community Gardens: Fostering a sense of community and pride, community gardens serve as bountiful spaces for urban farming, where neighbors grow fresh produce and forge lasting bonds.

- Pocket Parks and Parklets: Discovering hidden gems amidst urban confines, pocket parks and parklets provide much-needed recreational spaces, adding splashes of green amidst the concrete.
- Urban Farming and Urban Orchard: Embracing urban agriculture, cities transform vacant lots into vibrant farmlands, cultivating locally sourced produce and promoting sustainable practices.

Amidst this tapestry of typologies, we celebrate the beauty and efficacy of nature-based solutions in shaping cities that are both resilient and environmentally conscious. These typologies serve as beacons of hope, guiding us towards a future where urban landscapes thrive in harmony with the natural world.

Bioswales

Figure 2. Bioswale along the road (© Rich Blankenship, www.holemanlandscape.com, 2015)

Definition

Bioswales and rain gardens are designed to manage a volume of runoff from a large impermeable area, such as a parking lot or a road. They absorb, store, and convey the flow of surface water, while also removing pollutants and sediment as the water passes through the vegetation and soil layer. The selection of vegetation for vegetated channels is variable, but native rooted plants are common and preferred. Their widespread application represents a significant contribution to the management and local control of stormwater.

Description

Bioswales and rain gardens can be wet or dry and appear as open, shallow linear ditches with a trapezoidal or parabolic shape. The banks are covered with vegetation or plants resistant to floods and erosion. Within these channels, the water flow is attenuated, allowing it to move at a slower and controlled pace. They primarily function as a filtering medium and pollutant removal system by capturing the flow of rainwater.

The water flowing through the vegetated channel moves slowly along its length, passing through the grass that slows down and filters the surface water flow, enabling the infiltration of a portion of the water into the ground. This process also exerts a laminating effect, resulting in a reduction of water velocity. Water collected from the drained surface is temporarily stored and then released into a storage or drainage system.

They can be used as an alternative to traditional sewer pipes, allowing rainwater to be conveyed without the need for grates, curbs, or road pits. They are typically used for rainwater management, but it is essential to have an overflow pipe to handle intense weather events. There are two types of vegetated channels: dry and wet.

Project and technical guidelines

The sizing of vegetated channels must consider three elements:

- Adequate capacity to convey the design flow rate.
- Adequate management of the expected maximum flow rates, including the potential sizing of systems for collecting excess water.
- Emptying half of the drained water from vegetated channels within a maximum of 24 hours to ensure their functionality for subsequent weather events.

In the design of a dry vegetated channel, it is essential to determine the flow section concerning the maximum design flow rate first. This will define the geometric characteristics of the channel, such as width, length, and side slopes.

Knowing the groundwater depth is important to verify the feasibility of designing a dry channel and to understand whether it is possible to infiltrate part of the conveyed water (minimum distance 1 m). If it is necessary to protect the underlying aquifer, vegetated channels can be waterproofed with impermeable liners. It is suggested to use vegetated channels to convey rainwater drained from areas less than two hectares in size.

It is preferable to introduce water laterally into the vegetated channels rather than through single points of entry. If not possible, adequate energy dissipation systems should be implemented at the entry points (e.g., stone blocks)

To reduce the slope, small control barriers made of various materials that can also serve as decoration (e.g., wood, masonry, stones) should be provided. Downstream of the barriers, erosion control systems should be installed.

Attention must be given to the type of vegetation used in dry channels. It must be capable of withstanding prolonged periods of both drought and rainfall, as well as the accumulation of sediment and debris. The vegetation should also be tolerant of high salt concentrations if filter strips are used for rainwater from roads treated with anti-icing salt.

The same considerations for vegetation apply to wet channels. Preferably, native plant species of the site should be planted. Dense planting discourages the natural development of vegetation in the channel.

Vegetated channels should be positioned where there is enough space to accommodate additional storage depth and width.

Careful sizing of wet vegetated channels is necessary if they are planned to be implemented in densely populated residential areas to avoid generating stagnant zones and subsequent bad odors and mosquito proliferation.

Usage in particularly hot areas is not recommended to avoid forced irrigation, and in very cold areas to avoid dealing with high snow loads and significant freezing depths.

Additionally, attention must be paid not to position vegetated channels in excessively shaded areas to avoid limiting grass growth.

Advantages and disadvantages

The advantages are:

- Effectiveness in removing sediments due to the filtering action exerted by vegetation.
- Reduction of the volume of runoff water.
- Contribution to the reduction of impermeable surfaces.
- Contribution to the naturalization of the environment in which they are integrated.

The disadvantages are:

- Risk of erosion if not properly designed.
- In residential areas, potential issues with stagnant water if not properly designed.

Maintenance aspects

Regular checks and maintenance are necessary. These checks can be carried out by non-specialized labor, thus can be done simultaneously with the regular maintenance of public spaces or roads, resulting in minimal additional costs.

In the case of vegetated channels designed with high aesthetic value, maintenance interventions by gardeners should be considered.

Typically, the use of fertilizers for vegetated channels is not recommended and should be avoided, especially when the channels are located in areas with sensitive aquifers.

Periodically:

- Mowing of the grass and plantings.
- Removal of sediments.
- Inspection of the banks and bed to identify any erosive processes.
- Cleaning the channel from waste and debris deposits.

Annually:

- Examine the slope of the dry mud and the infiltration rate.

References

- B. W. Ballard, S. Wilson, H. Udale-Clarke, S. Illman, T. Scott, R. Ashley e R. Kellagher, «The SuDS Manual,» 2015. [Online]. Available: http://www.scotsnet.org.uk/documents/NRDG/CIRIA-report-C753-the-SuDS-manual-v6.pdf. [Accessed 03 2019].

Infiltration Trenches/ Strips

Figure 3. Infiltration trench with stones in urban area (© Andras Kis, Natural Water Retention Measure - NWRM Workshop, 2013)

Definition

Infiltration trenches are constructed with the aim of promoting the infiltration of runoff volumes through the top surface of the trench and their subsequent filtration into the subsoil through the sides and bottom of the trench. They are capable of removing a wide range of pollutants from rainwater through absorption, precipitation, filtration, chemical, and bacterial degradation. They are referred to as infiltration trenches when they are considered as a point element (accumulation and infiltration point). On the other hand, if the objective is to create a linear element to convey rainwater from point A to point B, they are typically equipped with a drain, and they are called filter drains.

Description

Infiltration trenches are composed of trench excavations, typically with a rectangular cross-section, filled with naturally inert, gravelly, and sandy material with high permeability. The infiltrated water is transported along the trench through the filling material or by using a draining pipe placed at the base of the trench. To prevent clogging of the drainage system by fine particles, the excavation can be completely lined with layers of non-woven fabric.

Project and technical guidelines

The trench is sized to achieve complete drainage of infiltrated water into the underlying soil within 12 to 24 hours after the end of the rainfall event. This design is based on the existing soil conditions at the intervention site, contributing to maintaining the water balance and recharging groundwater aquifers.

The design of infiltration systems should primarily consider:

- The permeability of the existing soil.
- The characteristics of the groundwater table.
- The possible pollution of rainwater.

The hydraulic sizing criteria of infiltration systems require comparing:

- The incoming flow rates to the system, considering short-term rainfall events of varying intensity (depending on the level of protection needed for the area).
- The soil's infiltration capacity.
- The potential storage volume in the system.

When infiltration trenches are designed to intercept runoff for frequent and low-intensity rain events downstream, they are typically sized to intercept up to 5 mm of rainwater falling on the drained area.

It is advisable to provide a pre-treatment device upstream of an infiltration trench, such as a sediment trap or a grille, to prevent sediment and coarse material from clogging the trench.

The base of the trench should be at least 1 meter away from the water table for the following reasons:

- To minimize the risk of contamination from rainwater.
- To reduce the risk of an increase in the water table level during rainfall events, resulting in reduced available volume for infiltration.
- To ensure a sufficient unsaturated area between the trench and the water table, maximizing the infiltration capacity.

Infiltration trenches are particularly suitable for both commercial and medium to high-density residential areas where the drained area is less than two hectares, and the soil type is permeable enough to ensure adequate infiltration rates.

There are no specific restrictions on the land use above the infiltration trench.

Advantages and disadvantages

The advantages are:

- Decent purification performance, mainly due to filtration and absorption mechanisms.
- Groundwater recharge.
- Limited maintenance activities.
- Low surface area requirement (typically less than 10% of the impermeable surface area of the drained basin).
- Good storage capacity.

The disadvantages are:

- Low detention capacity (limited ability to retain and slow down peak flows).
- Possibility of leakage of oily substances (unless a first flush diverter followed by an oil separator is installed at the inlet).
- Potential clogging in areas with high transport of sandy material during rainfall events.

Maintenance aspects

Ordinary Maintenance:

- Inspections and removal of accumulated sediments to prevent filter clogging.
- Removal of accumulated sediments and oils/grease from pre-treatment systems.
- Removal and replacement of the clogged fine gravel layer.

Annually:

- Cleaning and trimming of the grass species present on the grassed strip.

References

B. W. Ballard, S. Wilson, H. Udale-Clarke, S. Illman, T. Scott, R. Ashley e R. Kellagher, «The SuDS Manual,» 2015. [Online]. Available: http://www.scotsnet.org.uk/documents/NRDG/CIRIA-report-C753-the-SuDS-manual-v6.pdf. [Accessed 03 2019].

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Bioritention systems/ rain gardens

Figure 4. Bioritention basin (© Bluegrass Landscaping & Maintenance, 2018)

Definition

Bio-retention areas are shallow depressions in the ground covered with vegetation, designed for collecting and treating rainwater drained from surrounding impermeable surfaces through filtration and removal of pollutants.

These systems allow for a completely natural filtering and purification of collected water, with excellent removal rates for the main pollutants conveyed by stormwater: TSS:> 90%, Total P:> 80%, Total N: 50%, Metals (zinc, lead, cadmium):> 90%. Additionally, bio-retention areas have beneficial effects, such as reducing hydraulic risks, increasing biodiversity, and serving as urban design elements.

Description

Stormwater runoff is directed through surface flow to the vegetated bio-retention area. In the retention area, there is temporary storage and further deposition of transported materials. The filtering layer performs the initial filtration of stormwater and promotes the growth of microorganisms that degrade organic matter. The thickness of the gravel layer serves as the filtration system, with soil particles providing sites for pollutant adsorption. Vegetation ensures the stability of the bio-retention area and contributes to the retention of pollutants. For smaller bio-retention areas serving a single residence or building, they are often referred to as "rain gardens."

Project and technical guidelines

Bio-retention areas are typically sized at 2-4% of the drained area.

It is preferable to avoid impermeabilization of bio-retention areas and allow for the infiltration of treated rainwater into the subsoil. In this case, the following aspects should be considered during the design phase:

• Geological, geotechnical, and hydrogeological characteristics of the soil.

• Distance from the water table (minimum 1 m).

When bio-retention areas are designed to intercept frequent and low-intensity rainfall events downstream, they are typically sized to capture up to 5 mm of rainfall falling on the drained area or generally events with a return period of 1 year.

These vegetated filtering systems are designed to drain accumulated water within 24-48 hours after the rainfall event, ensuring sufficient residence time for pollutant removal and preventing water stagnation and insect proliferation.

Bio-retention areas are typically designed to treat runoff from frequent rain events (low return period). Therefore, it is recommended to include an overflow system to discharge water during intense rain events, ideally positioned near the point of entry of the water.

A horizontal surface is preferred to allow for a homogeneous distribution of rainwater across the entire useful area. For steep areas, small control barriers made of various materials that can also serve as decoration (e.g., wood, masonry, stones) are suggested. Erosion control systems should be implemented downstream of these barriers.

The filling medium typically consists of a mixture of gravelly sandy material with high infiltration capacity, with limited percentages of compost (maximum 25%) and site soil (maximum 25%).

Involvement of landscape architects, agronomists, or nursery experts is recommended for choosing the vegetation. Generally, the characteristics to consider for selecting vegetation to be planted are:

- Adaptation to both dry and wet conditions.
- Adaptation to the pollutant load conveyed by stormwater.
- Root penetration capability.
- Preference for native plants.
- Landscape integration.
- Availability of plants in nurseries near the site.
- Reduced maintenance requirements.
- Plant height (considered for roadside visibility reasons).

Bio-retention areas are typically designed to receive runoff without the need for traditional sewer systems but through specific openings positioned, for example, along road curbs (minimum 500 mm). Adequate energy dissipation systems (e.g., stone blocks) should be provided near these openings to limit the risk of erosion.

In the case of runoff with a high sediment load, it is advisable to provide a sediment trap, filter strips, or a pond before the water enters the bio-retention area. Alternatively, a densely vegetated area can be placed at the entrance of the bio-retention area.

Bio-retention areas can be easily integrated into urban areas due to their flexibility and adaptability to the landscape. They can have more natural shapes in low-density residential areas or more rigid shapes in high-density areas. For these reasons, they provide an excellent solution for retrofitting green areas in the context of Sustainable Drainage Systems (SuDS).

Regarding rain gardens, they can take the form of flowerbeds in the external green spaces of buildings.

Advantages and disadvantages

The advantages are:

- High pollutant removal capacity.
- Requires low maintenance.
- Reduces volume and peak flow.

- Reduces conveyance time.
- Potential urban design element.
- Increases biodiversity.
- Reduces heat islands.

The disadvantages are:

- Requires relatively large surface areas (although these areas can be used and contribute to the environmental integration).
- Susceptible to clogging if the surrounding landscape is not well managed.

Maintenance aspects

Regular checks and maintenance are necessary. These checks can be carried out by non-specialized labor, making them feasible alongside regular maintenance activities for public spaces or roads, with minimal additional costs.

In the case of bio-retention areas designed with high aesthetic value, maintenance interventions by gardeners should be considered.

It is typically not recommended to use fertilizers, herbicides, and pesticides for bio-retention areas, and it should be avoided in areas with sensitive aquifers.

Quarterly:

- Removal of waste/debris.
- Check the health of plants (diseases, poor growth, presence of invasive plants).
- Control and cleaning of the inlet/outlet.
- Check the proper filtration capacity.

Annually:

- Check and clean draining channels (if present).
- Trimming vegetation (frequency varies depending on the type of planted species).

Repair (typically after 20 years):

- Replacement of the mulch layer (if present) and any other layer subject to clogging.

References

B. W. Ballard, S. Wilson, H. Udale-Clarke, S. Illman, T. Scott, R. Ashley e R. Kellagher, «The SuDS Manual,» 2015. [Online]. Available: http://www.scotsnet.org.uk/documents/NRDG/CIRIA-report-C753-the-SuDS-manual-v6.pdf. [Accessed 03 2019].

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Tree Box/pits Filters

Figure 6. Tree pit (© StormForm™)

Figure 5. Tree pits in historic public spaces (© GreenBlue Urban ArborFlow 100 panel system)

Definition

Tree box filters are small biofiltration systems composed mainly of three elements: a box, soil, and a plant species. These systems allow for a completely natural filtering and purification of water, similar to bio-retention areas, while combining the major advantages provided by trees in urban environments, such as reducing heat islands and improving air quality.

Description

The boxes are buried and can be made of prefabricated concrete structures, and they can have either closed or open bottoms depending on whether water can infiltrate into the soil or not, for example, in clayey soils. The soil inside is composed of a special mixture of substrates and filtering materials formulated to filter the received water. Tree species, preferably native and capable of withstanding stress conditions resulting from alternating periods of rain and wet soil and periods of drought, are planted within the soil. The tree box filter system allows the removal of pollutants present in rainwater, filtering it before releasing it into the sewer system or groundwater.

Project and technical guidelines

The number and size of tree box filters are regulated based on the water flow they need to handle and the dimensional characteristics of the soil. Proper design of tree box filters ensures adequate conditions for tree development, including:

- Sufficient space for root growth.
- Adequate filling medium.
- Suitable gas exchange conditions.
- Proper drainage.
- Adequate water quantities.

Adequate water supply can be ensured by providing accumulation zones at the bottom of the box, accepting that the tree may experience brief periods of flooding. It is necessary to verify that the drained area can meet the water demand of the planted trees.

The filling medium should drain rainwater and provide sufficient nutrients to the tree. The required volume of filling material depends on the type of planted trees and is a crucial aspect to consider during design. For most trees used in urban environments, a depth of 2 meters is sufficient. Attention should also be given to the pH of the materials used to avoid any adverse effects on tree growth due to different pH values from the filling materials. With appropriately designed filling material, tree box filters can achieve pollutant removal rates similar to those obtained with vegetated bio-retention areas. Tree box filters are designed to drain accumulated water within 48 hours after the rainfall event to avoid compromising tree health. It is preferable to avoid impermeabilization of the infiltrating boxes and allow treated rainwater to infiltrate the subsoil. In this case, the following aspects should be considered during the design phase:

- Geological, geotechnical, and hydrogeological characteristics of the soil.
- Distance from the water table (minimum 1 m).

The choice of tree species depends on both technical (adaptation to dry/wet conditions) and aesthetic/landscape/fruitive components, and it should always be supported by a landscape architect or agronomist. Generally, the desired characteristics for trees in these systems include:

- Well-developed canopy.
- Long life expectancy.
- Rapid growth.
- Drought tolerance.
- Tolerance to short periods of flooding.
- Resistance to pollutants present in water and air in urban environments.
- Extensive root development.
- Rough bark.
- Opaque foliage.
- Vertical branch development.

Tolerance to saline water (in case of placement in areas at risk of winter frost, due to road salt use).

The box can be made from various materials (plastic, concrete, steel) and must be able to withstand the static and dynamic loads it may be subjected to, preventing compaction of the filling material. The vehicular load can also be distributed on internal grids inside the box (e.g., honeycomb grids in HDPE), reducing the thickness of the retaining walls while allowing sufficient space for root development and gas exchange. The top of the box typically has a grille to protect the system from debris and leaves. This grille primarily serves as a safety feature but also helps to filter some pollutants.

Tree box filters are typically designed to accumulate small amounts of water on the surface, typically no more than 5 mm of the drained area. Therefore, it is recommended to include an overflow system to discharge water during intense rain events, ideally positioned near the point of water entry. Water supply to tree box filters can be done in various ways, for example, through special openings in road curbs.

Tree box filters are highly adaptable and can be integrated into the surrounding environment. They can be used in all developments and under all soil and slope conditions. They improve the aesthetics of streets, neighborhoods, and parking areas where they are installed, increasing the available shade.

Advantages and disadvantages

The advantages are:

- Reduces the volume of rainwater runoff intercepted by the canopy.

- Improves water quality.
- Increases groundwater infiltration and recharge.
- Provides local control of flooding phenomena.
- Requires limited space, easy installation, and low maintenance.
- Reduces heat islands.
- Acts as an urban design element.
- Reduces noise.
- Increases biodiversity.
- Reduces CO_2 in the urban environment.

The disadvantages are:

- Higher maintenance in the first period after construction to allow tree establishment.
- Receives small volumes of water, therefore not suitable for managing intense rain events.

Maintenance aspects

Regular checks and maintenance are necessary. These checks can be carried out by non-specialized labor, making them feasible alongside regular maintenance activities for public spaces or roads, with minimal additional costs.

Much of the maintenance of tree box filters concerns the health of the tree and does not differ from regular maintenance interventions for urban trees.

Ordinary maintenance:

- Removal of any debris deposited on the surface.

Periodically:

- Periodic inspection of facilities and structural components.
- Cleaning of inflow and outflow mechanisms.
- Soil and substance checks to avoid the presence of pollutants harmful to vegetation.

Annually:

- Annual removal/replacement of mulch, manure.
- Pruning of trees.

Every 5 or 10 years:

- Tree replacement.

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B. W. Ballard, S. Wilson, H. Udale-Clarke, S. Illman, T. Scott, R. Ashley e R. Kellagher, «The SuDS Manual,» 2015. [Online]. Available: http://www.scotsnet.org.uk/documents/NRDG/CIRIA-report-C753-the-SuDS-manual-v6.pdf. [Accessed 03 2019].

Detention Basins

Figure 7. Detention basin (© susDrain)

Definition

Detention basins are shallow vegetated spaces designed for temporary surface storage and flow control of rainwater. They also facilitate some settling of particulate pollutants.

Description

They are areas consisting of small, permeable-bottomed reservoirs designed to remain dry most of the time. Their function is to receive and temporarily retain rainwater following weather events and then slowly release it within 24 hours through filtration systems installed to remove debris. They serve both to control surface water flow and to allow the settling of suspended solids in first-flush rainwater, so they must be sized to fulfill both functions. Essentially, they perform the function of retention basins but are integrated into an urban fabric with a multifunctional approach, also using them for recreational purposes.

Project and technical guidelines

Detention basins should be constructed without any lining of the bed and banks, except for those necessary to protect hydraulic structures. Typically, detention basins are not impermeable due to their large surfaces. Impermeabilization should only be considered in areas with high groundwater vulnerability. In non-impermeable basins, if possible, infiltration areas should be designed to infiltrate a volume of rain equivalent to 5 mm on the drained surface. It is advisable to provide a calm area at the entrance of the basin, delimited, for example, by a bank of permeable material (e.g., gravel), capable of reducing the inlet velocities and allowing for the sedimentation of solid materials conveyed by rainwater. It is recommended to always include an overflow system to discharge water during intense rain events above the design event (e.g., 200-year return period), ideally positioned near the point of water entry. The treatment capacity of runoff can be maximized by including small ponds and wetlands (Sheet T10) at the outlet of detention basins. Areas with a greater recreational vocation can be designed to be frequently flooded, with return periods of 1-5 years. Inlet and outlet structures should not be accessible to the public but only to maintenance personnel.

Adequate energy dissipation systems (e.g., stone blocks) should be provided near the entrance to limit the risk of erosion. At the outlet, a control structure is typically required, with pipes serving as calibrated outlets and an overflow system (e.g., spillway). It should also be considered to position energy dissipation systems at the outlet of the detention basin. Detention basins are typically vegetated with grass, but other species can be included to enhance the landscape value and biodiversity of the area. Plantations can be established on the banks to increase their stability. Some non-vegetated detention basins have been successfully implemented in highly urbanized areas, such as the Water Plaza in Rotterdam. A minimum of 100 mm of soil is necessary for vegetated detention basins.

Advantages and disadvantages

The advantages are:

- Able to handle a wide range of rainy events.
- Good reduction of peak flow.
- Simple system to design and construct.
- Requires little maintenance.

The disadvantages are:

- Detention depth is limited to inlet and outlet levels of the system.
- Extensive interventions requiring a large area.

Maintenance aspects

It is important to ensure safe access to detention basins for maintenance activities. Maintenance operations are mainly performed after intense weather events. These checks can be carried out by non-specialized labor, making them feasible alongside regular maintenance activities for public spaces or roads, with minimal additional costs.

Ordinary maintenance:

- Removal of debris and waste.
- Mowing vegetation.
- Inspection of inlet/outlet systems and possible cleaning.
- Monitoring and removal of sediment if necessary.

References

B. W. Ballard, S. Wilson, H. Udale-Clarke, S. Illman, T. Scott, R. Ashley e R. Kellagher, «The SuDS Manual,» 2015. [Online]. Available: http://www.scotsnet.org.uk/documents/NRDG/CIRIA-report-C753-the-SuDS-manual-v6.pdf. [Accessed 03 2019].

Retention Ponds and Constructed Wetlands

Figure 8. Retention pond (© Daryl Mitchell)

Definition

Retention ponds and constructed wetlands are basins with a permanent body of water where rainwater is conveyed and can be designed to serve multiple objectives, such as attenuation, rainwater treatment, increased biodiversity, and recreational potential of the area. When these systems are primarily designed for the treatment of first-flush rainwater from separate networks or the overflow from combined networks, they are referred to as phytodepuration (mainly with submerged flow). If used for treating combined sewer overflows, phytodepuration systems with submerged flow are preferred (i.e., without water remaining on the surface during dry periods); however, this does not preclude their integration into areas with high recreational value.

Description

Retention ponds and constructed wetlands can have areas at different depths to accommodate various plant species. They are called ponds when deeper free water areas prevail over vegetated areas, while they are referred to as wetlands when most of the area has a lower and vegetated depth. These systems can include raising the water level in case of rainwater attenuation. Similarly, the water level can be designed to fluctuate to accumulate rainwater for reuse purposes (e.g., irrigation of green areas). Through treatment systems, natural processes, and emergent and submergent aquatic vegetation, biological removal of pollutants occurs before the water is re-introduced into water bodies. If used for treating combined sewer overflows, phytodepuration systems with submerged flow are preferred (i.e., without water remaining on the surface during dry periods); however, this does not preclude their integration into areas with high recreational value.

Project and technical guidelines

It is advisable to plan natural-shaped forms, adaptable to the specific topography and soil conditions of the site, as well as its orientation, appearance, and proximity to other landscape features, buildings, etc. In general, the forms should be designed according to the following guidelines:

- Gradual water entry points, avoiding dead zones due to corners, maximizing sedimentation capacity by increasing flow section and reducing velocities.
- In the case of extensive ponds or wetlands, divide them into multiple sub-basins to optimize purification processes and facilitate management and maintenance operations.

- Provide wetland areas at different depths to maximize biodiversity, planting different plant species, with helophytes in shallower areas (maximum 40 cm in dry periods) and hydrophytes in deeper areas (typically 1 m).
- Include a calm zone at a greater depth at the water outlet point to prevent the risk of lifting deposited sediments.

It is recommended to provide a calm area at the entrance of the basin, delimited, for example, by a bank of permeable material (e.g., gravel), capable of reducing inlet velocities and allowing for the settling of solid materials conveyed by rainwater. Alternatively, in the case of more polluted waters or discharges from combined sewers, the use of an underground sedimentator as pre-treatment is recommended to reduce aesthetic impact (e.g., oils) and the risk of bad odors.

It is important, especially for wetlands with shallower water depths, to estimate a water balance to verify that the inputs are sufficient to compensate for evapotranspiration, thereby preventing the risk of waterless periods or excessively stagnant waters, which can promote insect proliferation.

It is advisable to always include an overflow system to discharge water during intense rain events above the design event (e.g., 200-year return period), ideally positioned near the point of water entry.

Ponds and wetlands are typically waterproofed with plastic geomembranes, unless there are favorable soil conditions (high clay content and minimal infiltration). Above the geomembrane, a layer of gravel is placed. Furthermore, the bottom of the surface flow wetlands is made by placing a layer of soil to allow the planting of vegetation. Due to the low nutrient load conveyed by rainwater, it is necessary to verify that the soil characteristics allow adequate support to vegetation in terms of nutrients.

The design is normally based on the storage of the estimated flood volume rather than water quality parameters. In this regard, an indicative value for pond design assumes a permanent volume equal to 10-15 mm of rain on the drained surface. In the case of sizing predominantly for the treatment of first-flush rainwater from separate sewage or discharges from combined sewers, such systems should be sized as phytodepuration systems, following the relevant texts and manuals (e.g., Kadlec and Wallace, 2009, "Treatment Wetlands. 2nd Edition"; Tondera et al., 2018, "Ecotechnologies for the Treatment of Variable Stormwater and Wastewater Flows"). In this case, it is advisable to use subsurface submerged flow solutions (typically gravel or sand) properly selected, without using soil.

Given their high multidisciplinary potential, it is advisable to include engineers, geologists, biologists, naturalists, and landscape architects in the design team.

For the choice of vegetation, the involvement of landscape architects, agronomists, or nurserymen is recommended. In general, the characteristics to consider when selecting vegetation for planting include:

- Different water depths
- Adaptation to the pollutant load conveyed by rainwater
- Preference for native plants
- Landscape integration
- Availability of plants in nurseries close to the site
- Reduced maintenance needs

The inlet and outlet structures should not be accessible to the public but only to maintenance personnel. Near the entrance, an adequate energy dissipation system (e.g., stone blocks) should be provided to limit the risk of erosion. At the outlet, a control structure with calibrated outlet pipes and an overflow system (e.g., spillway) is typically required. The positioning of energy dissipation systems at the outlet of the detention basin should also be evaluated. Typically designed for new development areas, they can be easily integrated into accessible public spaces, such as parks.

Advantages and disadvantages

The advantages are:

- High pollutant removal capacity, especially for wetlands
- Reduction of peak flow
- High recreational and landscape potential
- High potential for increased biodiversity
- Possibility of using them for rainwater storage for reuse purposes
- Ideal for environmental education activities

The disadvantages are:

- The risk of insect proliferation should be evaluated if exclusively fed by rainwater
- Extensive solutions that require a larger area for implementation

Maintenance aspects

It is important to ensure safe access to ponds and wetlands for maintenance activities. Maintenance operations are mainly performed after intense weather events. These checks can be carried out by non-specialized labor, making them feasible alongside regular maintenance activities for public spaces or roads, with minimal additional costs

References

R. Kadlec e S. Wallace, Treatment Wetlands, CRC Press; 2 edition, 2008.

K. Tondera, G.-T. Blecken, F. Chazarenc e C. Tanner, Ecotechnologies for the Treatment of Variable Stormwater and Wastewater Flows, Springer International Publishing, 2018.

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Permeable pavements

Figure 9. Grass pavers being used for a permeable driveway (© Nanda Sluijsmans, 2021)

Definition

A paving system made with permeable surfaces ensures the surface runoff of rainwater that permeates into the ground through modular elements, such as concrete blocks or reinforced plastic mats, characterized by voids or joints filled with permeable material (sand or gravel), allowing the infiltration of runoff water.

Description

Permeable pavements can be used for both new developments and for retrofitting or replacing old impermeable pavements. They offer numerous design solutions that allow for diversifying and characterizing the urban landscape. The variety of materials available on the market and in nature enables high-quality design for site enhancement. Different types of modules are commercially available, including porous pavers, grass-filled blocks or cubes with wide joints, grass-filled concrete grids, and plastic grass-filled grids.

Project and technical guidelines

For proper design, the following are necessary:

- An analysis of the geological characteristics of the original soil, subsoil, and, in particular, its permeability.
- An initial estimation of the amount of water that the pavement must be able to absorb.
- The volume of traffic that the pavement must support.

Permeable pavements are typically used to infiltrate water falling on the permeable surfaces themselves. However, due to the high infiltration capacity of some technical solutions, permeable pavements can be used to drain rainwater falling on adjacent impermeable surfaces (e.g., roofs). In such cases, it is suggested to maintain a maximum ratio of 2:1 between drained impermeable surfaces and permeable pavements for infiltration to avoid rapid clogging of the permeable surfaces.

Despite the high infiltration capacity of some technical solutions, it is recommended to always couple permeable pavements with an overflow sewer system. If there is a risk of groundwater contamination, slope instability, or excessive proximity to foundations, it is possible to waterproof the bottom of the permeable pavement, using the layers of the pavement for runoff storage and treatment. In this case, drains are placed on the top layer of the permeable pavement to convey the treated water to another discharge point.

Underground services should not be placed below permeable pavements. It must always be verified that the infiltration capacity of the permeable pavement is greater than the maximum rainfall intensity on the design surface. The infiltration capacity of permeable pavements varies depending on the technology and is usually provided by the manufacturing companies as technical data. Permeable pavements, even when correctly designed for the design loads, will experience a decrease in infiltration capacity over time due to the clogging of cracks or pores. Therefore, it is advisable to consider a long-term permeability reduction factor of 10.

After choosing the most suitable surface draining material, the design of the layers that make up the permeable road surface can proceed. If parking areas are used frequently and during daylight hours, the lack of light and heat irradiation from the underside of the vehicles may prevent grass cover. In such cases, gravel should be used to fill the pavers, using aggregates with diameters of at least 0.8-1 cm to avoid significant reduction of filtration capacity caused by vehicle pressure, oils, and weathering.

The structural design of permeable pavements must be carried out after a detailed estimation of the expected loads. Permeable pavements can be used in many locations but require appropriate location based on their characteristics. They are typically used as an alternative to impermeable surfaces, so they do not require additional construction space. They only need differentiation from the typical surface that captures rainwater and its drainage system, thus they can also be used on flat terrain. Generally, these types of pavements tend to be used for draining low-traffic pedestrian or vehicular roads, driveways, parking areas, pedestrian and cycle paths, and residential streets.

Advantages and disadvantages

The advantages are:

- Reduction of the impermeable surface of a site
- Reduction of the volume of runoff water
- Maintenance of groundwater, as it is replenished in a more natural, adequate, and constant manner
- Elimination of surface runoff phenomena, benefiting road safety during weather events
- Longer lifespan compared to conventional asphalt pavements

The disadvantages are:

- Difficulty in maintaining grass cover in parking areas with high daytime frequency due to lack of light and heat irradiation from the underside of vehicles.
- Possibility of "cementification" of infiltration areas due to clogging of filling materials by suspended solids conveyed by runoff water or due to vehicular load, resulting in a significant reduction of infiltration capacity.

Maintenance aspects

Monthly:

- Check that the pavement surface is free from sediment.
- Ensure that the system drains between consecutive rainfall events.
- Check that the drained surface and pavement are free from debris.
- Perform adequate maintenance in case of malfunctions.

Annually:

- Inspect for any damages.

Every 3-4 years:

- Clean the pavement by vacuuming to free the surface from sediment.

References

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Green barriers

Figure 10. Green noise barriers (© BAM wegen)

Definition

Green barriers are used to protect residential, protected, or recreational areas from noises produced by roads, highways, railways, and industrial plants. By passing through a vegetation strip (trees, shrubs, tall grass), the sound is forced to undergo a tortuous path that tends to degrade it into heat. The attenuation produced by natural barriers depends on the depth and height of the protective screen, the width and robustness of the foliage, the density of the canopy, and the duration of leaf coverage.

Description

Green barriers contribute to reducing noise pollution through the leaves, which absorb and transform sound energy into heat or deflect it (especially at higher frequencies), and the soil that hosts the barrier, sometimes constituting an integral element (reinforced earth, vegetated walls), which acts by absorbing sound waves or reflecting them, resulting in a loss of energy. In a green structure, the entire barrier, in its composition, plays a role in reducing noise: leaves work better at higher frequencies, while porous soil provides good results for attenuation at lower frequencies.

According to UNI 11160, a green barrier is an artificial noise-reducing system consisting of soil, eventually combined with reinforcement structures or integrated with containment or load-bearing structures. There are different types of green barriers, which can be classified as follows:

- Vegetation Screens:

Vegetation screens are made up of simple plantations or complex associations of high-resistance tree, shrub, and herbaceous species. They are characterized by an arrangement of leaves orthogonal to the direction of noise propagation and rapid growth until reaching an optimal height.

- Covered Embankments:

Covered embankments are linear accumulations of soil, suitably stratified and planted with herbaceous and shrub species. From a landscape and environmental point of view, they represent one of the most suitable and acoustically functional systems, although they have the limitation of requiring large spaces next to the road infrastructure to be shielded.

- Mixed Structure Screens:

Mixed structure screens combine plants with artificial elements (which can also serve as support) designed for the synergistic integration of different components. This category includes reinforced earth and so-called "biowalls" and green walls.

- Reinforced earth, for example, consists of earth and stone embankments with a trapezoidal cross-section, stabilized with appropriate metal grids and covered with vegetation. This solution has a reduced economic-operational impact since it mainly uses material already present on-site and integrates into the environment, resembling a green belt flanking the road infrastructure.
- Biowalls, on the other hand, consist of a combination of artificial load-bearing structures (concrete, steel, plastic, wood) and rapidly growing evergreen plants with a high density of foliage, nourished by sophisticated cultivation substrates.
- Green walls consist of a metal cage structure filled with a mixture of organic or inorganic substrate in which vegetation is sown.

Project and technical guidelines

Vegetation screens are one of the most well-known and used types of green barriers, but they require a large amount of space and entail relatively high installation and maintenance costs, as well as long periods to achieve full effects (at least five years).

Rows of plants (shrubs + trees, evergreen family) must be planted at a distance that allows for regular growth. When choosing plant species, certain characteristics are favored:

- Plants with foliage also on the lower part of the trunk to increase the barrier effect.
- Evergreen species to avoid reductions in effectiveness during winter periods.
- Robust species that require limited maintenance and reduce implementation costs.
- Vegetation resistant to pollutants, considering that many interventions are located near heavily trafficked roads.

These green barriers must also have high resistance to mechanical stresses, especially when used on unstable terrains, and simultaneously have good binding and consolidation capabilities of soils through the root system (measurable by the ratio of shoot volume to root volume), as well as good construction capacity.

Reinforced earth requires a minimum space of at least 2-3 meters and does not require special maintenance. The visible front slope can have a slope greater than 70° relative to the horizontal plane, while reaching heights exceeding 20 meters thanks to the alternation of well-compacted soil layers (with a thickness of 60-70 cm) and specific types of reinforcement structures, such as geogrids, which provide greater stability to the structure.

The main elements characterizing a green wall are the support structure to which the side containment walls of the cultivation substrate are attached. The substrate can be organic or composed of inert material mixed with organic amendments and fertilizers. The substrate can be modified based on local climatic conditions and cultivation species, maintaining a high infiltration and microporosity capacity that favors the retention of water inside it to meet the water requirements of the plants. Irrigation is generally provided by a drip irrigation system directly inserted into the substrate.

In terms of acoustic pollution reduction performance, various experiments in anechoic chambers have identified the long leaves of the plants as the most attenuating part at frequencies with wavelengths between 8-16 cm (2-4 Hz). Regarding soil performance, good results are obtained with vegetated or soft soils, while stony, sandy, or frozen soils, instead of being absorptive, result in reflective.

Advantages and disadvantages

The advantages are:

- Improve the landscape and aesthetic quality of the places; purify the atmosphere through photosynthesis; act as bioindicators of specific pollutants and contribute to soil protection and hydrothermal regulation.
- Reinforced earth and biowalls allow the construction of significant height structures with relatively reduced footprints and lower costs compared to traditional concrete structures. These products are characterized by high durability and very limited installation times, as they are often pre-assembled elements in the factory.

The disadvantages are:

- In general, fully natural barriers like vegetation screens require larger spaces and are on average less effective (5-6 dB A attenuation) compared to artificial ones (10-15 dB A).
- To achieve a significant reduction in perceived sound level (i.e., with sound intensity reductions greater than 10 dB), it is necessary to establish vegetation strips of considerable size, even larger than 20-30 meters.

Maintenance aspects

Maintenance operations can vary depending on the type of green barrier. The following are some common types and related maintenance interventions:

- Vegetation Screens: Thinning pruning of trees and shrubs; sculptural pruning of hedges and wall hedges.
- Vegetated Reinforced Earth (for embankment support): Mowing cleaning in the first 2 meters from the edge of the overlying carriageway; no interventions required for the rest of the slope.
- Vegetated Reinforced Earth (for counter-slopes): Mowing cleaning; shrub pruning considering non-interference with normal traffic flow (height and size of heavy vehicles).
- Vegetated Cellular Walls: Eradication of weeds (first year); strengthening pruning (first year).

During implementation, signboards indicating the presence of particular interventions should be designed and installed, as they may not always be easily recognizable and interpretable by the companies responsible for green maintenance. This is to avoid the accidental approach of machines used for weeding and mowing to the structures themselves with negative effects.

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Green and living walls

Figure 11. Living Wall in a public building (© Paolo Pignataro Studio)

Definition

A green wall refers to all different forms of vertical vegetated enclosures. Greening can be achieved with plant species planted on the ground, with support panels and containment elements anchored to the facade, or through modular structures integrated into the vertical enclosure. Like green roofs, green walls also constitute a naturalization element that serves various functions capable of achieving an environmental mitigation effect resulting from the construction of a building.

Description

Vertical green systems can be classified into green facades and vegetated vertical enclosures, better known as "living walls." These two types of green walls have very different characteristics depending on the type of plant species used, technical solutions and materials employed, irrigation systems, and maintenance practices.

Green facades are based on the use of climbing plants anchored directly to the surface of the wall or with the help of a support system made of nets, cables, or trellises. The vegetative covering is considered as an additional cladding to the wall, not fully integrated with it. The plants used are limited to climbing or sprawling species, which are the only ones capable of covering the wall surface over time without the need for vegetation to be in close proximity to the root systems [1]. Green facades are divided into three main types:

- Green façade direct greening system;
- Green façade direct greening system;
- Indirect greening in combination with containing elements/ planter boxes.

On the other hand, living wall systems are modular systems fully integrated into the wall, containing organic or artificial substrate and relying on a hydroponic cultivation method based on the use of a nutrient solution to meet the plant's needs and ensure proper growth. These systems feature automated irrigation systems, integrated with sensors to measure moisture levels so that they function only when necessary [2]. Depending on the cultivation method used, living wall systems can be classified into three different categories:

- Containing elements/ boxes;
- Expanded resin substrate;

- Felt layers.

Project and technical guidelines

The design of a green wall requires an interdisciplinary approach that integrates various botanical, agricultural, and architectural knowledge and techniques. The characteristics, components, and materials of vertical green systems can have a significant impact on environmental load, microclimatic benefits, and intervention costs. The layers that compose a green wall system, the distance between the green system and the facade, and the thickness of the foliage influence its performance, thermal resistance, and cooling capacity [2].

The support system should be chosen considering the type of vegetation suitable for the specific case, taking into account the climatic conditions as well. Identifying the vegetative cycle, whether evergreen or deciduous, is crucial for achieving the desired microclimatic performance, whether it is contributing to summer cooling or providing protection from wind, rain, and snow in winter. The main selection criteria for plant species can be attributed to the following parameters: biological form, origin, type of foliage, water requirements, plant structure, maintenance needs, microclimatic context of insertion, average lifespan, coexistence among different species, geographical region, climatic characterization (e.g., microthermal, macrothermal, etc.), and light exposure (e.g., heliophilous, shade-tolerant, etc.) [1].

In the case of the redevelopment of a building, another important aspect to consider is the possibility of adapting the different systems to the existing situation, considering the planimetric and volumetric layout of the building, the materials, and the technologies used. In the case of systems integrated into the wall, the building envelope materials and structure must be able to support the additional weight. If they are not, it is possible to provide support for the heavier components on the ground.

Advantages and disadvantages

The advantages are:

Microclimatic and environmental benefits on both a macro-scale and a building level:

- Improvement in air quality, particularly in terms of the ability to capture fine particulate matter.
- Increase in biodiversity.
- Reduction of radiant heat load on people outside near the wall, contributing to the mitigation of urban heat island effects.
- Decrease in thermal load on walls, improved insulation, and consequent energy savings.

The disadvantages are:

- Risks associated with the use of climbing plants mainly concern damage to the building envelope caused by the choice of very vigorous species whose branches can reach diameters of 15 cm or more, deformations of support structures due to not considering the additional loads related to the greenery, and issues caused by possible hindrance to maintenance and wall drying in winter (in the case of evergreen climbers directly attached to the facade).
- Living wall systems require continuous monitoring to ensure the necessary water and nutrient supply for the survival and growth of plants. Regarding the building envelope, the disposal of excess water requires special attention to avoid corrosion damage.

Maintenance aspects

For direct or indirect green facades, maintenance is generally limited to pruning interventions to be carried out once or twice a year, depending on the growth rate of the plant species and the available space.

Living wall systems, on the other hand, require more maintenance (at least 3-4 interventions per year), which may include pruning, possible replacement of individual plants or entire panels, and checking the irrigation system.

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Vegetated pergola and pergola pathways

Figure 13. Vegetated pergola for sitting area (© Iliriana Sejdullahu, 2019)

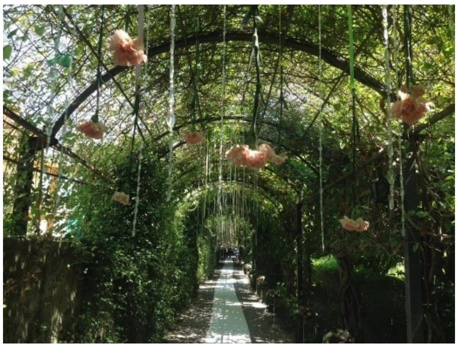

Figure 12. Pergola pathway (©Hotel Legjenda)

Definition

In heavily sunlit streets during the hot season but characterized by heavy pedestrian traffic, where it is not possible to plant trees due to technical or management reasons, the so-called "pergola paths" can be a valid alternative. These are portions of sidewalks equipped with supporting structures for shrubs and climbing plants that can quickly create a shaded path, protected from excessive sun exposure and, to some extent, from automobile emissions and noise.

Description

Many cities have avenues and roads, even of considerable width, without trees. This may be due to inattentive or poorly sensitive planning, cost reasons for tree planting, or fears of significant maintenance costs. Sometimes this may be due to objective difficulties in planting trees and shrubs due to the presence of cables, pipes, and service structures underground. Railway, road, or subway tunnels can make it impossible to provide sufficient space for the development of trees.

"Pergola pathways" can be an interesting alternative, especially for heavily sunlit streets during the hot season but characterized by heavy pedestrian traffic. They are portions of sidewalks equipped with supporting structures for shrubs and climbing plants that can quickly create a shaded path, protected from excessive sun exposure and, to some extent, from automobile emissions and noise. Pergola paths can be free-standing or attached to a building wall and are generally made of wood or simple or wrought iron. Wooden pergola paths have a more linear conformation, while those made of iron can have simple and geometric shapes or, in the case of wrought iron, have shaped and curvilinear structures with possible additions of decorations and friezes.

The placement of the structures requires the preparation of plinths inserted into the road or pedestrian level at predetermined (but not necessarily rigid) distances, masonry containers, or synthetic material from which the plant species identified in the design phase will develop. The structures can be:

- self-supporting: the structure is supported or anchored to the ground or pavement by the uprights that support the beams;
- semi-supporting: the structure is leaning against a wall on one or more sides; at these points, the beams are directly fixed to the wall, while on the other sides, they are supported by uprights.

Project and technical guidelines

For both self-supporting and semi-supporting pergolas, the total height should be between 2.5 and 3 m, and the width should not exceed 5-6 m to achieve a good aesthetic balance, avoiding overly massive structures and ensuring stability. In any case, it is necessary to verify that the pergola is stable and robust enough to withstand wind action, the weight of the covering (climbing plants), or any snow accumulation. These structures must be proportioned to the area in which they are inserted so as not to excessively narrow it.

The elements that compose a wooden pergola are:

- uprights or support poles: in addition to the main ones at the corners, others are needed along the sides every 3 or 4 meters. They usually have a section of 10-15 cm;
- main beams that can be supported by the uprights or partly by these and partly anchored to the wall; they usually have a section of 10 cm x 12-15 cm in height;
- secondary crossbars or beams: perpendicular to the main beams, some crossbars are placed at a smaller section, about 50-80 cm apart from each other, to support the climbing plants.

Iron pergolas can be made in different shapes, including rounded, decorated, or irregular ones. In some special cases, mixed pergolas can be used, which involve the combination of different materials; for example, they can be composed of wooden pillars and arched iron crossbars.

The support structures used should not require maintenance for several years and be made of materials resistant to weathering and UV rays. The installation of the structures is relatively simple, but special attention is required in the design and implementation of the irrigation system, which must provide numerous connection points.

Advantages and disadvantages

The advantages are:

- Pergola paths can be adapted to numerous and different urban environment conditions: they can cover typically sunny urban pedestrian paths or be placed in green areas connecting attractions (refreshment areas, open spaces, water features, etc.).
- The structures for pergola paths can be easily removed, even for limited sections, for road works and maintenance of services located below the pedestrian level.

The disadvantages are:

- Pergola paths require rather attentive and continuous maintenance for the vegetative part.

Maintenance aspects

During the growing season, it is necessary to provide water to the plants through an irrigation system. The flower boxes must be kept clean and well-maintained. Specific measures can prevent the accumulation of cigarette butts and garbage. The support structures do not require particular attention, but stability may need to be monitored at times.

In the cold season (from November to March), the climbing plants must be pruned and fixed so that, in the following growing season, they provide continuous coverage without exceeding the expected limits. During this period, fertilizer is applied to the soil.

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Green roofs

Figure 14. Extensive and intensive green roof (© Tiziana Monterisi)

Definition

Green roofs are a particular finishing solution for the covering of a building, characterized by a vegetative installation on a waterproof structural support layer. Green roofs differ from all other types of roofing because the visible "finishing" material is made up of plant species rather than inert materials. Green roofs constitute an element of renaturalization that serves various functions in achieving an environmental mitigation effect resulting from the construction of a building.

Description

A green roof can host various plant species and is composed of layers specifically designed to guarantee waterproofing and protection of the underlying roof components and drainage of excess water, always in relation to the thickness of the substrate and, consequently, the type of roof. The elements that compose green roofs are similar for all products; however, companies operating in the market have customized the different layers to offer products that adapt to different climates, customer expectations, vegetation, growing substrate, filtering layer, drainage layer, root barrier, waterproof membrane, and covering or load-bearing element.

Green roofs can, therefore, have very different characteristics and performances depending on their usability, maintenance requirements, drainage capacity, and biodiversity attitude. Commonly, two main categories of green roofs are identified: extensive and intensive.

Extensive green roof: a flat roof covered with an 'extensive' green layer, including plant species such as grass, sedum, or low plants with a soil layer <15 cm, which require minimal maintenance interventions. These species are characterized by a high settlement capacity, efficiency in reproduction, frugality, and resistance to water and thermal stresses, both in winter and summer.

Intensive green roof: a flat roof covered with an 'intensive' green layer, including plant species such as herbs, shrubs, and (small) trees with a soil layer >15 cm, which require medium to high-intensity maintenance.

Project and technical guidelines

In the design of a green roof, to assess the most suitable system for the specific case, the architectural and structural characteristics of the building envelope must be considered first. Particular attention must be paid to the design of the load-bearing element, which must support the permanent weights of the growing substrate and vegetation. The thickness of the substrate is the main parameter for defining the different green roof systems, as it determines the type of vegetation that can be integrated.

The main specific requirements of a green roof are as follows:

- Ability to favor and maintain the agronomic conditions necessary for the correct development of vegetation based on the context.
- Control of drainage capacity and management of rainwater.
- Control of aeration, which involves defining the aeration of the growing substrate, which is its ability to maintain sufficient aeration to allow suitable oxygenation conditions.
- Control of water accumulation, to define the green roof system's capacity to support plant hydration and stimulate efficient water use.
- Maintainability control.
- Resistance to biological attacks and microorganisms.
- Biodiversity attitude; the design and implementation must consider a series of essential biological and ecological requirements.

Advantages and disadvantages

The advantages are:

- Over time, it slows down and reduces the thermal load entering indoor environments, both through increased thermal inertia and through the natural functioning mechanisms of vegetation.
- It drains and stores rainwater, significantly reducing the amount that flows into the public sewer system.
- If correctly designed, vegetation intercepts fine dust in the atmosphere and retains harmful substances absorbed through the plants' photosynthesis process.
- It helps reduce noise pollution by reducing sound reflection depending on the different components used.
- Supports photovoltaics, increasing module performance and synergistically combining electricity production to power the irrigation system.
- Reflects solar radiation, allowing a reduction in air temperature. Moreover, through the process of evapotranspiration, the air becomes more humid and, as it cools down, it can reduce the perception of dry and dusty air characteristic of urban heat islands.
- Creates new usable outdoor spaces, increasing opportunities for socializing and, in some cases, commercial opportunities.
- Creating more comfortable and aesthetically pleasing buildings and the possibility of expanding usable surfaces increases the value of the property.

The disadvantages are:

- Depending on the building and the chosen plants, the investment costs are higher compared to a conventional roof.
- In hotter climates, the irrigation needed to avoid plant drying represents an additional water consumption.
- Additional loads of growing substrates and vegetation, especially in intensive roofs, may require structural adjustments to the load-bearing element.

Maintenance aspects

The level of maintenance depends on the type of green roof, extensive or intensive. An extensive green roof requires reduced maintenance with one or two interventions per year. In particular, for the vegetation layer, monitoring should assess the physiological and phytosanitary status of the vegetation, the presence of parasites that may limit its functionalities, and the presence of weeds, whose establishment may affect the system's functionality. Irrigation can be carried out only occasionally, to keep the vegetation alive under extraordinary water stress conditions. The maintenance effort in terms of time ranges from 3-4 hours per year up to 6-7 hours per year for low-maintenance extensive roofs.

On the other hand, an intensive green roof requires constant maintenance for the proper management of plant varieties, like real gardens. Maintenance interventions, in addition to including the checks of the system elements and the vegetation layer, already provided for the extensive system, include all agronomic activities necessary for the correct management of green areas. The use of equipment not suitable for the specific roof situation should be avoided. The maintenance effort in terms of time ranges from 25 hours per year up to 30 hours per year for a high-maintenance intensive roof.

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Balcony gardens

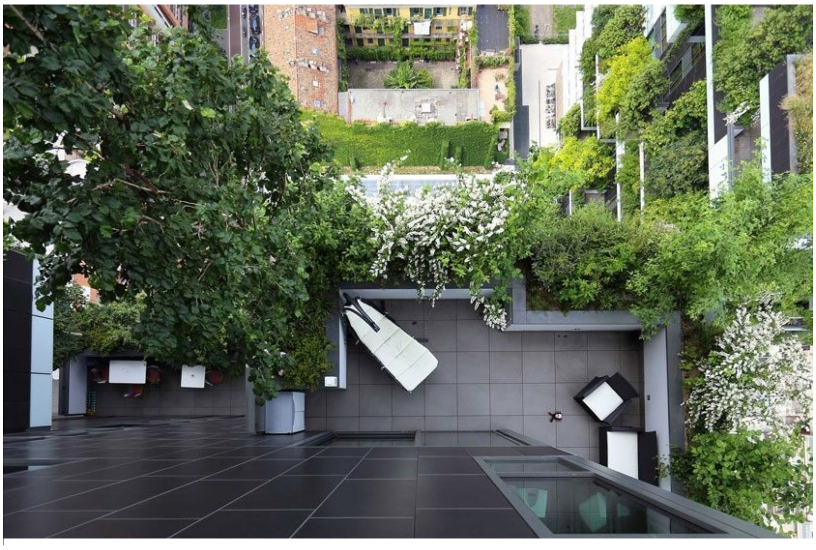

Figure 15. Balcony gardens (© Bosco Verticale, Stefano Boeri Architetti)

Definition

A careful design of greenery on balconies and terraces, even in limited spaces, can actually produce interesting effects in terms of mitigating summer temperatures inside the rooms and act as a filter for atmospheric pollutants. For example, the facade of a six-story building with normal balconies can offer adequate usable surface for the cultivation of shrubs or climbing plant species that can create an effective protective screen from direct sunlight.

Description

The greenery on balconies and terraces is generally considered only for its aesthetic value when, due to the residents' capabilities or a specific botanical project, it manages to offer an aesthetically appealing image of the building in which it is integrated, thanks to a careful choice of species and knowledge of the flowering calendar. However, it is interesting to observe how a meticulous design of greenery, even in limited spaces, can produce interesting effects in terms of mitigating summer temperatures inside the rooms and acting as a filter for atmospheric pollutants. Balconies and terraces can indeed host a significant number of plant species. The facade of a six-story building with normal balconies can offer a usable surface for the cultivation of shrubs or climbing plants that can create an effective protective screen from direct sunlight, especially for the areas exposed to the south. For this protective effect against solar radiation and, at the same time, against air pollution to be effective, it is essential that the selected plants develop a large leaf surface. Evergreen and deciduous species are the ones that provide the most significant results. More generally, caring for and paying attention to all the condominium greenery, including the common areas, can stimulate a more general attention to greenery on balconies and terraces, in addition to improving the performance in terms of summer cooling and interception of some atmospheric pollutants.

Project and technical guidelines

There are several guides to support the creation of balconies rich in greenery that can produce appreciable cooling effects. It is only rarely possible to include tree species, while the use of shrubs or small trained trees is more common. Among climbing plants, species belonging to the Clematis genus (including honeysuckles and clematis) are particularly suitable. The genus Trachelospermum is widespread and resistant, including numerous species and varieties of jasmine, available as both evergreen and deciduous species. The Hedera genus, including common ivy (H. Helix), boasts numerous varieties suitable for various conditions and climates. In case the balcony can accommodate larger tree species, necessary precautions must be taken to ensure their stability. In particular:

- All trees must be equipped with straps that connect the root bulb to a steel net embedded in the ground.
- Medium-large trees must be provided with a safety cable to prevent falling in case of trunk breakage.
- Larger trees, especially those in positions most exposed to wind action, must have a steel maintenance cage around the bulb. It is also essential to carefully evaluate the loads of weights on terraces and balconies, both construction materials and vegetative materials (soil and shrubs themselves), considering the weight of the latter in case of maximum water saturation. The ideal slope of the slab is between 1-3%. Tanks and other containers for plant species must be lined with the following materials:
- Waterproofing membrane combined with an anti-root membrane made of synthetic substances such as PVC and polyethylene.
- Separation, accumulation, and mechanical protection layer. It mainly serves to protect the underlying waterproofing from damage and/or mechanical stresses (also during construction), to form a sliding layer, and to allow the accumulation of reserve water for the roots to use in periods of maximum water stress. The installation must cover the entire surface of the sealing element, with a minimum overlapping of the edges of 10 cm, also at the vertical containment edges. In the case of climbing species, support structures represent the ideal tool to shape the greenery on balconies and keep it in the desired forms. Sometimes, water needs can be significant, and it is useful to have connections provided by the condominium that can, where possible, use greywater and rainwater.

Advantages and disadvantages

The advantages are:

- Microclimate mitigation.
- Filtering action on fine dust in the urban environment.
- Absorption of carbon dioxide and production of oxygen and humidity.
- Contribution to spontaneous vegetal and animal re-densification.
- During summer, reduced cooling energy consumption.
- Protection of residents from radiation and noise pollution.

The disadvantages are:

- In the case of tower buildings, trees on the upper floors are more stressed in terms of exposure to wind.
- Trees on the upper floors may require up to 20% more water.
- The presence of many trees reduces the amount of solar radiation collected during the winter season, resulting in an increase in energy needs for heating the rooms.

Maintenance aspects

The greenery on balconies and terraces requires constant effort from residents for proper maintenance. Regarding water supply, various solutions can be suggested, possibly integrated with each other:

- Adopting drip irrigation systems.
- Using materials and devices to retain water in pots and planters.
- Using species with modest water requirements. At the condominium level, a centralized water distribution system can be implemented in some cases, providing an adequate amount to individual balconies and terraces, avoiding dripping on sidewalks with a suitable choice of distribution times. In addition to ordinary maintenance, the vegetative coating requires periodic pruning by tree specialists. To assess tree health, it is also essential to periodically monitor:
- Verify the success rate of sowing and measure growth activities.
- Nutritional assessment.
- Determine the effects of any environmental stress factors.

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Street trees

Figure 16. Street trees (© www.treepeople.org)

Definition

Street trees generally refer to the arrangement of trees along city streets, including residential neighborhoods, transit roads, traffic arteries, or squares. Street trees represent a relatively small fraction of the urban tree heritage but play a crucial role both in terms of visual impact, air pollution from traffic, and climatic comfort.

Description

Street trees play a prominent role within the built fabric of a city. In addition to the evident importance that tall trees have in determining the aesthetic value of a street or neighborhood, influencing, among other things, the real estate value of buildings, they provide a range of ecosystem services in terms of reducing air pollution, mitigating urban heat islands, and managing first rainwater. The planting of trees along a street or avenue involves, if the design has been adequately cared for, the presence of permeable surfaces around the trunks. These contribute to regulating rainfall runoff and thus help reduce flooding risks due to heavy and intense precipitation. However, in the case of single-row street trees, the effect is noticeably less significant. Thanks to the tree canopies that constitute street trees, it is possible to cool the air, which is also felt on the lower floors of buildings along the street. However, the characteristics of the tree species are essential. This function can be maximized through careful selection of species and varieties. The arrangement of the trees, their maintenance, and, above all, pruning techniques are also crucial.

In recent years, there has been an increase in the use of small-sized species (third or fourth size trees) which, although having showy blooms, require less maintenance and pose a lower risk of falling. Planting such species, outside of selected cases, may lead to a reduction in environmental benefits. Increasing attention should also be given to private condominium green spaces that do not have street trees. In many cases, the tree canopies within condominium spaces can produce the same positive effects as conventional street trees. Therefore, it is useful for local administrations to provide informative support regarding both the design and maintenance to maximize the ecosystem services offered by this type of greenery.

Regarding the reduction of air pollution, it is essential to consider both the placement and the ability of tree species to emit certain pollutants, such as biogenic volatile organic compounds and ozone precursors (e.g., many oaks and conifers). Street trees can indeed have an opposite effect on reducing air pollution at a localized level, depending on the scales considered. Along long and narrow streets, characterized by the so-called canyon effect, the presence of trees can hinder ventilation and the subsequent dispersion of pollutants. At the same time, several studies recommend planting street trees as close as possible to pollution sources since pollutant removal by trees increases with pollutant concentration. Therefore, careful planning of street trees, evaluated case by case, is essential to optimize benefits and minimize negative effects on local air quality.

Project and technical guidelines

In general, the choice of tree species for street trees starts by identifying the aesthetic and formal characteristics of the plants, such as crown shape, texture, color, flowering, etc., and must then be verified in relation to the specific characteristics of the urban environment under consideration. Once the species, or rather groups of species that could best meet the desired aesthetic and formal characteristics, have been identified, their suitability must also be assessed based on the following specific criteria:

- Space requirements for the complete development of the plant.
- Resistance to pollution.
- Resistance to pests.
- Feeding characteristics, exudates, fruiting.
- Emission of surface roots or basal shoots.
- Crown and foliage characteristics.

In Italy, there is a general tendency to use native species as they are considered better acclimated and resistant to natural and anthropic adversities. However, this topic is widely debated, and a large part of Italian historical gardens and valuable street trees, consisting of exotic species, does not absolutely confirm the validity of these assumptions. In the urban environment, the use of exotic species that have already undergone sufficient evaluation over time should be considered without prejudice.

Trees must have a bearing consistent with the typical characteristics of the species, variety, and age at the time of planting. To respect the growth of the plants, street trees must be adequately positioned:

- Large-sized trees (Quercus sp., Tilia sp., Fraxinus excelsior, etc.), from 10 to 15 meters, with a trunk circumference not less than 20 - 24 cm.
- Medium-sized trees (Alnus sp., Acer sp., Carpinus sp., etc.), from 7 to 10 meters, with a trunk circumference not less than 18 - 20 cm.
- Small-sized trees (Prunus sp., Malus sp., etc.), from 5 to 7 meters, with a trunk circumference not less than 16 - 18 cm.
- Columnar trees (Cupressus sempervirens, Populus nigra, etc.), from 4 to 6 meters.

Regarding the area to be allocated to isolated trees, the following classes can be considered:

- Small-crowned isolated trees: 2.5 x 2.5 m.
- Large-crowned isolated trees: 3.5 x 3.5 m.

A significant issue is the distance between trees and buildings, both to allow the canopy to expand without interference and to avoid phenomena of mutual microclimatic influence between trees and buildings. The minimum distance between trees and walls varies between 8 meters for tall trees and shorter distances (up to 4 meters) for medium-small-sized trees. The distance between trees also varies between 5 and 12 meters, depending on the different planimetric solutions that regulate the relationships between sidewalks, roadways, trees, and buildings. It is essential to plant trees at least 1.5 meters away from the roadway to allow the roots to develop in a non-excessively asymmetric manner and avoid damaging the road surface.

Regarding the shading and mitigation of higher temperatures, broadleaf species generally appear more suitable. In many cities in northern regions, plane trees, hackberries, horse chestnuts, and lindens are the most used species. Maples and ash trees are less common. Among conifers, only cedars and yews appear suitable for the urban environment, but they are hardly considered for street tree implementations. However, there is an extensive technical and scientific literature that analyzes the potential and limitations of different species in the various climatic and seasonal conditions presented by Italian cities.

The choice of species to be used is generally subject to considerations of different nature, technical and operational, economic but also aesthetic. One of the aspects to be examined is the sensitivity to pathogens and pests, which are sometimes imported and particularly challenging to control. The resistance to air pollution is another aspect to take into account.

The planting of trees intended for street trees involves a complex preparation of the soil and spaces destined to adequately accommodate the root and aerial systems of the trees for a long period (several decades). The first element also influences the soil's water infiltration capacity: careful planning and appropriate implementation favor runoff disposal in the event of significant weather events. The second aspect affects the vitality of the canopies, their development, and consequently, their performance.

Irrigation and drainage systems are essential in all types of green spaces, and in the case of street trees, they are often indispensable for the survival of the plants. In street tree plantings, deep drainage systems are used, consisting of flexible, corrugated, and slotted plastic drains (PVC) to ensure the rapid removal of excess water and prevent the clogging of the drains. These drains must be placed close to the root system of each tree at a depth that varies according to the different species and soil types, as well as connected to the drainage network. This technology can also be used for any emergency irrigation and fertigation.

Advantages and disadvantages

The advantages are:

- One of the most relevant functions concerns the regulation of the microclimate in the immediate vicinity of the trees: the mechanism is linked, on one hand, to the level of solar radiation interception (shading), and on the other hand, to the process of evapotranspiration, which is the transformation of water into vapor. This mechanism lowers the temperature of the surrounding air by removing the thermal energy required to form water vapor.
- The cooling effect can be significant where trees are more extensive: in hot and dry climate cities, the temperature reduction can reach 2-3°C in streets with a rich tree canopy.
- Trees can positively impact air quality by intercepting gases and particulate matter, especially when located near high concentrations, particularly concerning particulate matter. In some cases, the cooling capacity of trees can also contribute to reducing ozone, a gas whose concentrations are significantly influenced by solar radiation and, therefore, expected to increase in the presence of high temperatures.

The disadvantages are:

- In recently urbanized areas, street greenery has often been limited to the wealthier and more desirable residential areas. The suburbs that developed in the 1950s and 1960s were slow to have street trees, and often, due to inadequate planning, the trees are poorly positioned concerning nearby buildings or the roadbed.

- Depending on the selected species and their placement, street trees can have negative effects on the concentrations of certain pollutants in the atmosphere. Many plants, in fact, emit biogenic volatile organic compounds and ozone precursors (such as many oaks and conifers, for example). Furthermore, along long and narrow roads with the so-called canyon effect, the presence of trees can hinder ventilation and the consequent dispersion of pollutants.
- Threats to the survival of street trees primarily result from incorrect placement. If, in fact, plants, particularly those with broad canopies, are placed too close to each other or to buildings, they tend to grow excessively in height with an unbalanced canopy to occupy the limited available space.
- Periodic pruning interventions are necessary to reduce and rebalance the volume of the canopy; these interventions, besides being costly and challenging to execute due to numerous urban constraints (safety perimeters for pedestrians, interferences with power lines and buildings, the need for temporary traffic diversion), can weaken the trees and make them susceptible to pests and diseases.

Maintenance aspects

The management of street trees is a complex activity that requires specific expertise. The maintenance methods applied to different tree species affect all the functions that the tree must fulfill. Maintenance significantly affects the overall stability of the tree and the robustness of the main branches, and therefore, more generally, the safety conditions for pedestrians and objects near the trees. Tree maintenance is entrusted to specialized companies equipped with specialized means (mobile platforms) and specially trained personnel.

The stability analysis is conducted based on the V.T.A. technique (Visual Tree Assessment), an approach that involves the visual analysis of the tree and subsequent instrumental checks where necessary. Both for public and private green spaces, particular attention must be given, both in the design and maintenance phases, to the potential underground and above-ground development of the species used.

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Urban forestation

Figure 17. Urban forest (© Distrito Castellana Norte)

Definition

The FAO guidelines define urban forests as a network or system that includes forests, groups of trees, and individual trees found in urban and peri-urban areas. This includes forests, street trees, plants in parks and gardens, but also those present in abandoned areas. Urban forests are the "backbone" of green infrastructure, connecting rural and urban areas and improving a city's environmental footprint.

Description

Urban forest is a category that includes all different types of urban greenery. This is also the case in the FAO guidelines, where five types of urban forests are mentioned, with varying levels of tree elements: peri-urban forests and wooded areas; urban parks and woodlands; small neighborhood parks, private gardens, and green spaces; street trees, squares, and avenues; other green spaces with tree presence (embankments, riverbanks, cemeteries, botanical gardens, agricultural lands, etc.).

Natural ecosystems (tree formations, shrubs, bushes, and wetlands) also contribute to the formation of urban forests. These ecosystems generally include native species, often with high conservation value. Such formations can be included not only in the network of protected areas but also in the urban and peri-urban fabric without any additional protection regime.

Along with urban forests, the National Urban Green Strategy complements the role of the peri-urban forest strip, which occupies a physical position intermediate between the urban system and the natural forests present in the agricultural and natural territorial mosaic, representing one of the main nodes of green infrastructure that functionally connects the natural and urban systems.

These mainly wooded structures have the task of improving the environmental quality of cities. While they can host moments of direct use by citizens, they must also efficiently serve as ecological connections between different green infrastructures. It is in the suburban and peripheral space that suitable areas can be found to significantly increase the surface dedicated to urban greenery.

The objectives of urban and peri-urban afforestation are diverse and numerous, responding to the need to protect non-urbanized spaces by preserving natural and landscape values, limiting urban sprawl, and soil consumption.

Project and technical guidelines

In general, the choice of tree species for street trees starts by identifying the aesthetic and formal characteristics of the plants, such as crown shape, texture, color, flowering, etc., and must then be verified in relation to the specific characteristics of the urban environment under consideration. Once the species, or rather groups of species that could best meet the desired aesthetic and formal characteristics, have been identified, their suitability must also be assessed based on the following specific criteria:

- Space requirements for the complete development of the plant.
- Resistance to pollution.
- Resistance to pests.
- Feeding characteristics, exudates, fruiting.
- Emission of surface roots or basal shoots.
- Crown and foliage characteristics.

In Italy, there is a general tendency to use native species as they are considered better acclimated and resistant to natural and anthropic adversities. However, this topic is widely debated, and a large part of Italian historical gardens and valuable street trees, consisting of exotic species, does not absolutely confirm the validity of these assumptions. In the urban environment, the use of exotic species that have already undergone sufficient evaluation over time should be considered without prejudice.

Trees must have a bearing consistent with the typical characteristics of the species, variety, and age at the time of planting. To respect the growth of the plants, street trees must be adequately positioned:

- Large-sized trees (Quercus sp., Tilia sp., Fraxinus excelsior, etc.), from 10 to 15 meters, with a trunk circumference not less than 20 - 24 cm.
- Medium-sized trees (Alnus sp., Acer sp., Carpinus sp., etc.), from 7 to 10 meters, with a trunk circumference not less than 18 - 20 cm.
- Small-sized trees (Prunus sp., Malus sp., etc.), from 5 to 7 meters, with a trunk circumference not less than 16 - 18 cm.
- Columnar trees (Cupressus sempervirens, Populus nigra, etc.), from 4 to 6 meters.

Regarding the area to be allocated to isolated trees, the following classes can be considered:

- Small-crowned isolated trees: 2.5 x 2.5 m.
- Large-crowned isolated trees: 3.5 x 3.5 m.

A significant issue is the distance between trees and buildings, both to allow the canopy to expand without interference and to avoid phenomena of mutual microclimatic influence between trees and buildings. The minimum distance between trees and walls varies between 8 meters for tall trees and shorter distances (up to 4 meters) for medium-small-sized trees. The distance between trees also varies between 5 and 12 meters, depending on the different planimetric solutions that regulate the relationships between sidewalks, roadways, trees, and buildings. It is essential to plant trees at least 1.5 meters away from the roadway to allow the roots to develop in a non-excessively asymmetric manner and avoid damaging the road surface.

Regarding the shading and mitigation of higher temperatures, broadleaf species generally appear more suitable. In many cities in northern regions, plane trees, hackberries, horse chestnuts, and lindens are the most used species. Maples and ash trees are less common. Among conifers, only cedars and yews appear suitable for the urban environment, but they are hardly considered for street tree implementations. However, there is an extensive technical and scientific literature that analyzes the potential and limitations of different species in the various climatic and seasonal conditions presented by Italian cities.

The choice of species to be used is generally subject to considerations of different nature, technical and operational, economic but also aesthetic. One of the aspects to be examined is the sensitivity to pathogens and pests, which are sometimes imported and particularly challenging to control. The resistance to air pollution is another aspect to take into account.

The planting of trees intended for street trees involves a complex preparation of the soil and spaces destined to adequately accommodate the root and aerial systems of the trees for a long period (several decades). The first element also influences the soil's water infiltration capacity: careful planning and appropriate implementation favor runoff disposal in the event of significant weather events. The second aspect affects the vitality of the canopies, their development, and consequently, their performance.

Irrigation and drainage systems are essential in all types of green spaces, and in the case of street trees, they are often indispensable for the survival of the plants. In street tree plantings, deep drainage systems are used, consisting of flexible, corrugated, and slotted plastic drains (PVC) to ensure the rapid removal of excess water and prevent the clogging of the drains. These drains must be placed close to the root system of each tree at a depth that varies according to the different species and soil types, as well as connected to the drainage network. This technology can also be used for any emergency irrigation and fertigation.

Advantages and disadvantages

The advantages are:

- Helps reduce climate-altering emissions, acting as a reservoir for carbon capture and contributing to the improvement of the local microclimate.
- Contributes to the mitigation of air pollution (especially suspended particles) and noise.
- Improves environmental functionality and connectivity, contributing to the establishment of an ecological network through forest interventions in selected areas prioritized for increasing local biodiversity.
- Enhances the urban and peri-urban landscape.

The disadvantages are:

- Urban afforestation strategies, if not carefully planned and coordinated, may encounter problems in operational implementation as they require the involvement of various stakeholders, both public and private, operating in the area.

Maintenance aspects

Maintenance operations are not only essential for the success and sustainability of the intervention over time but also important from the perspective of public opinion, which perceives the new forested area as subject to attention and care, especially in an urban context.

Irrigation: In the early years, it is crucial to regularly water the newly planted trees. In the absence of substantial rainfall, it is generally recommended to water the plants every 10 to 15 days, using at least 50 to 100 liters per plant.

Weeding: To counter water shortages (especially in hot periods and/or in the presence of compact and clayey soils), it may be useful, in some cases, to disturb/crumble the soil in its upper layers.

Staking system: After placing the stake, it is necessary to periodically check the connecting ring, preferably made of plant fibers, to prevent strangulation as the species grows.

Surface soil cultivation: For less competitive and slow-growing species, it is good practice to reduce competition from other species by periodically clearing the surrounding soil. If the soils are clayey, periodic hoeing of the upper layers (above the primary roots) is also appropriate.

Fertilization: If the afforestation intervention has been carried out in a degraded area with particularly altered soils, additional fertilization may be necessary, in addition to the one applied before planting.

Limiting weed growth: In addition to the aforementioned mulching, it may be necessary to carry out weed control interventions (manual or mechanical), taking utmost care not to damage the new plantings (especially around the collar area).

Formation pruning: In the early years of growth, especially for fast-growing tree species, careful stability control is necessary, intervening with appropriate pruning if needed.

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Community Gardens

Figure 18. Community garden (© FAI Fondo per l'Ambiente Italiano)

Definition

The community garden is a public space with sociocultural and environmental purposes. Unlike traditional public gardens, shared gardens involve active citizen participation in the creation and/or management of a revitalization project for abandoned or unused spaces, with the aim of making areas more livable and enhancing opportunities for social interaction.

Description

Community gardens, also known as shared gardens, are a socio-cultural phenomenon that addresses issues related to garden design, management, and botanical aspects. They represent a network of spontaneous public spaces created to address environmental and/or social challenges and to build or strengthen local communities. Organized on a voluntary basis within non-profit associations, citizens exchange knowledge and experiences while engaging in gardening activities to rehabilitate degraded or abandoned areas, benefiting the entire community [1].

There are different types of shared gardens, depending on the involved parties, management methods, and primary objectives [2]:

- Neighborhood gardens are the most common type, typically defined as gardens where a group of people gathers to cultivate fruits, vegetables, and ornamental plants. These are identifiable as plots of private or public land where individual gardens are rented at a nominal annual fee.
- Residential gardens are generally shared among residents living around them and can include both private complexes and public residential buildings.
- Institutional gardens are connected to public or private organizations and provide specific services that might involve rehabilitation and mental or physical therapy (e.g., therapeutic gardens) or the teaching of various skills for workforce integration.
- Demonstrative gardens are used for educational and recreational purposes. They often offer short seminars or presentations on gardening and provide the knowledge and tools necessary for managing a shared garden.

Project and technical guidelines

Community gardens are spaces conceived and created directly by citizens with the aim of establishing lived-in spaces and genuine gathering spots that adhere to shared rules. For instance, the Municipality of Milan has developed a specific manual outlining the fundamental steps for creating a shared garden:

1. Identify a space: Any degraded area or space of any size with potential for better use can be turned into a shared garden.
2. Establish an association: To propose a project and subsequently enter into an agreement for a Community/Shared Garden, it is necessary to be part of or establish a non-profit association. The association ensures the collective use of the garden, its openness to the neighborhood, and the continuity of activities.
3. Develop a project: Once it's confirmed that the proposed area is owned by the Municipality and usable, the association submits a project proposal containing:

- A brief overview describing the association, its activities, and objectives.
- Copy of the association's constitution and bylaws.
- Initial plan for the Community/Shared Garden, including a descriptive report of interventions, social events, or activities to be carried out, indication of the sign to be placed outside the area, commitment to provide required insurance coverage, and acceptance of contractual clauses.

4. Follow the rules of the shared garden: A Community/Shared Garden is not a personal but a communal space and must adhere to some simple rules:

- Organize at least one public event per year to be held in the garden.
- Establish areas for collective cultivation to promote social interaction and cohesion.
- Practice organic cultivation methods, water conservation, composting, and, in the case of vegetable cultivation, use raised beds.
- Place a sign outside the area in a visible location, indicating the garden's name, association's name, and participation details.
- Private plots are not allowed.
- Vehicle transit and parking within the garden are prohibited, as are commercial or advertising activities.
- No construction of any kind is permitted.

The city of Paris, through the "Charte main verte" (Green Thumb Charter), has promoted a support program for shared gardens that offers technical consultations, method advice, and official recognition. The association creating the shared garden, by signing the Charter, commits to basic rules: responsible and conscientious site management, scheduled public openings, and organization of events open to the entire neighborhood. The Green Thumb Charter also includes a map of shared gardens and allotments in the city. The association "Graine des jardins" works alongside the municipality, offering the "Jardinons ensemble" (Let's Garden Together) portal, a website where all information regarding community gardening can be found and announcements can be published.

Advantages and disadvantages

The advantages are:

- They represent an innovative method for reclaiming and/or managing degraded and abandoned public areas, where participatory management is the preferred tool to enhance the perception of these places, increase their usage and social cohesion, counteract degradation, and promote eco-sustainable management of public spaces.

- They can serve as an opportunity to raise awareness about social issues related to multicultural societies and create opportunities for intercultural dialogue.
- They can provide a chance to improve understanding of the relationship between green spaces and health.

The disadvantages are:

- Hygiene, health, and environmental issues can arise due to the lack of proper management of the gardens. For example, the cultivation of allergenic species near recreational areas or walkways, or the use of pesticides and herbicides that can further compromise the physical and chemical conditions of the groundwater.
- Shared/community gardens with a mobile and temporary nature can become agents of socio-cultural change, such as in cases of gentrification caused by the settlement or property acquisition by a wealthier population segment in a less affluent community. While revitalization itself is not a risk, it can attract investors interested in constructing profitable new properties and raising rents in the area, potentially displacing previous residents with financially stronger individuals [3].

Maintenance aspects

The maintenance of the trees within the shared garden area can be the responsibility of the administration (remaining part of the city's tree assets) or be managed directly by the citizens.

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Pocket Parks and Parklets

Figure 19. Parket in the middle of buildings (© Skyliner)

Definition

Pocket parks and parklets are small-scale urban design tools, intermediate spaces between the public and private dimensions, with the aim of revitalizing and stitching together fragments of the city by creating a network of green spaces experienced by citizens. They are typically the size of a building lot, generally bordered on two or three sides by adjacent buildings or facing the sidewalk.

Pocket parks and parklets can represent a strategy for upgrading residual spaces, transforming them into small green laboratories of creativity and social inclusion, a resource to improve the environmental impact of the urban environment, and simultaneously, the physical, mental, and social well-being of inhabitants.

Description

The concept of Pocket Parks emerged in the 1960s in Harlem, New York, amidst a climate of strong social tension and consequent degradation of public space. The idea was then adopted in the 1990s in Lyon and much more recently in Copenhagen.

Unlike other components of the urban landscape (squares, streets, avenues, etc.), residual urban spaces are difficult to precisely define and identify. They are enclosed or marginal areas, often small and lacking in relational functions, but endowed with social, identity, and environmental potential capable of triggering urban regeneration processes. Their richness and potential lie in their small extent, ease of management and maintenance, and low commercial or residential attractiveness.

The dimensions are typically those of a building lot, generally bordered on two or three sides by adjacent buildings or facing the sidewalk.

The foundation of creating a pocket parks and parklets is to utilize greenery in vaguely defined patches of land. This potential space, through the use of naturalistic solutions and special attention to social aspects, can become a new neighborhood focal point. Regenerating a marginal or underdeveloped area becomes an opportunity for redefining an urban space aimed at the well-being, social, and environmental aspects of a community. Working in these new spaces means starting from their specificities and potentialities.

Project and technical guidelines

The spaces in which to create a pocket park, precisely because they are small and located in strategic yet critical areas (strong relationship with the street space, conflicts with built structures in terms of shading and ventilation), require extremely careful design that considers the contextual forms and the needs of the population to be effectively revitalized. The areas to be selected can include internal courtyards of building complexes, remaining buffer strips, or abandoned enclosed areas; the pocket park system can be adapted to both compact and structured contexts as well as less dense fabrics. The goal is to equip these city fragments with green areas, possibly featuring functions for first rainwater drainage, equipped with facilities for sports, leisure, and relaxation. Corners that, thanks to the adoption of naturalistic solutions, become small, colorful, and vibrant gardens, where one can take time for oneself while enjoying the climatic and environmental benefits that vegetation brings.

To maximize the environmental and landscape benefits of a temporarily unused space, it's necessary to employ design methods that align well with the unique characteristics of pocket-parks: cost-effectiveness and flexibility. [2]

Given the limited complexity of design and execution and the contained costs, these interventions are suitable for bottom-up initiatives that start from the grassroots, creating participatory pathways. However, it's important to ensure that these spaces are not repurposed for other functions for a temporary period of at least five years.

When the area takes on a new function, if the design of the temporary greenery has been well-considered, equipment and structures can be removed and placed elsewhere, while the planted vegetation, if compatible with the new project, can be left in place. [2]

A proper strategic planning of these interventions can lead to the creation of a true network—informal green infrastructure of scattered pocket-parks—becoming an economical yet effective tool for urban revitalization.

The incorporation of guidelines for rethinking these spaces within a green system management tool would contribute to enhancing these spaces of great strategic importance.

The city of Copenhagen, in defining its pocket park development strategy, has identified 5 key elements that characterize them:

- Size (maximum of 5,000 m^2);
- A visible green element;
- Openness and a positive image;
- Demarcation and protection;
- Identity and local community.

Advantages and disadvantages

The advantages are:

- • Small urban green interventions capable of triggering social and relational mechanisms, bringing environmental benefits, and contributing to the urban revitalization of surrounding areas.
- • The vegetation component, properly designed, can help reduce the urban heat island effect by lowering temperatures, improving air quality, and creating micro-ecosystems within the city.

The disadvantages are:

- Operating in areas that are not always easy to precisely identify, sometimes with only temporary use guarantees, can represent an element of uncertainty that is not always easy to design and manage, especially if the area is designated for a new purpose.

Maintenance aspects

The limited size and the design tailored in collaboration with potential area users are elements that facilitate the maintenance of pocket parks and parklets. Maintenance can be carried out directly or partially by groups of citizens, private entities, or foundations, in collaboration with the public administration.

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Urban Farming and Urban Orchard

Figure 20. Urban farming garden (© www.ucanr.edu)

Definition

Urban farming holds a high potential for innovation and knowledge closely tied to specific contexts (local markets, social relationships, urban space utilization, traditions, cultural heritage, etc.), playing sociocultural, environmental, recreational, educational, and therapeutic roles. Simultaneously, urban orchards represent agricultural activities with potentially significant environmental impacts, considering the substantial inputs required to support production. Therefore, particular attention must be paid to soil fertility conservation, rational water resource management, protection of crops from weather conditions and pathogens, and minimizing the use of chemical substances.

Description

When considering the kind of "available" spaces within the urban fabric that are most suitable for urban horticulture activities, abandoned or unused green areas in public or private spaces (accessible and with services such as water and electricity) appear to be the most suitable for highlighting the multifunctional role of urban farming gardens. Various modes of "space access" exist: entering into a temporary contract, finding a sponsor or initiative that purchases the space, incorporating the garden into a public park project, renting or leasing space in collaboration with the owner (e.g., a parish community). Depending on the type of agreement, the garden will inherently possess distinct characteristics, influencing its accessibility, such as entry possibilities and opening hours, as well as insurance and liability matters.

Urban farming can be practiced in-ground or above-ground, including flat roofs, one of the most abundant spaces available within cities.

Gardens characterized by above-ground systems are increasingly spreading in urban areas. These systems can be divided into two main categories based on how excess water from irrigation is managed: a closed-loop system where drained water is reused for subsequent irrigation, and an open-loop system where drained water is discarded. While the former exhibit a higher water usage efficiency (saving up to 80% of the water typically used in a similar cultivation area), the latter are generally more economical and require less advanced technologies and expertise for plant management. Another classification of systems can consider how water (or nutrient solution) is managed within the system. Some systems maintain a water reserve in constant contact with the plant roots, while in others, water is supplied at regular intervals and then allowed to drain. Once again, the former require less technology and labor, while the latter are more complex but present fewer issues due to better water reservoir oxygenation and generally provide better production results.

The most widely adopted above-ground cultivation systems fall into the following categories:

- Modified Nutrient Film Technique (NFT) system;
- Tray systems;
- Floating panel systems;
- Vertical bottle systems;
- Cultivation pots and containers;
- Cultivation in bags system.

Project and technical guidelines

The design and management of an urban farm and garden certainly requires specific attention and considerations related to the unique context in which it operates. The orientation and volumes of the garden should be conceived in a way that ensures adequate natural lighting and ventilation of the spaces, contributing to improved photosynthetic efficiency and greater hygienic-sanitary control of the plant crops present in the garden. As a general rule, the most suitable areas for creating a garden should receive at least six hours of direct sunlight a day and not be exposed to strong winds. The orientation of the longest side of the production system should be towards the North. The same enclosure that defines the garden area, if well-designed, can serve multiple purposes: productive (e.g., timber, small fruits, and flowers), ecological (e.g., wind protection and animal shelter), defensive (e.g., soil erosion, property and crop defense), hygienic-sanitary (e.g., acting as a buffer barrier for noise, protection from pollution), and aesthetic-landscape functions.

For waste management, it's advisable to establish a composting facility where organic residues from leaves, herbaceous plants, and prunings can be brought together. After shredding and maceration, these materials can also be useful for fertilization.

Maintaining biodiversity in an urban farm and garden can be promoted through biological control of harmful insects using predatory entomophagous insects (which feed on other insects), such as aphid-predatory ladybugs and parasitoids. Encouraging the presence of these insects or actively introducing them might be the most effective approach to biological control of harmful insects. There are also natural insecticides like Neem (an extract from Azadirachta indica), Natural Pyrethrum, and some products that utilize fungi or entomopathogenic bacteria (harmless to humans). In small plots like family gardens, mechanical traps like chromotropic traps (colored plastic panels coated with glue and hung just above the vegetation level) can be effective aids.

The biological approach to disease control primarily considers the compatibility of cultivated species with different environments and employs natural products such as copper, sulfur, potassium bicarbonate, etc., and/or certain microorganisms that have a direct effect on pathogens.

- In-Ground Farming Systems

To ensure the homogeneity and structural harmony of the cultivated area, one must take into account the vegetative habit of the cultivated species. A proper balance needs to be studied between the presence of tree crops (fruit-bearing and ornamental), shrub species, and herbaceous plants (vegetables, herbs, and medicinal). The accumulation of crop residues in the soil and the presence of specific pests can be avoided through rotation and intercropping. Rotation involves not planting crops from the same family on the same soil surface for at least 3 years, or if two different crops are cultivated in the same year, for at least 4 cropping cycles. Similarly, intercropping allows for the improvement of growth conditions for individual crops by utilizing the characteristics and functions of other crops. For example, carrots can be intercropped with leeks or onions, which have insect-repelling abilities, or corn can be intercropped with beans, where the former provides support, and the latter can fix nitrogen.

- Above-Ground Farming Systems

Temperatures during the hotter periods can be excessive for plant growth, especially in gardens located on roofs or in windy environments. It is therefore extremely important to properly install windbreak and shading structures.

The use of pots and containers (preferably recycled) or filling sacks with substrate is one of the simplest ways to cultivate plants above ground. In these systems, closed-loop irrigation cannot be employed (excess water is lost), but a reduction in water consumption can be achieved by adopting a drip irrigation system. Through the use of organic nutrient-rich soil (such as compost), it may be possible to avoid the use of mineral fertilizers.

Advantages and disadvantages

The advantages are:

- Urban farms and gardens provide an opportunity for reclaiming and greening residual areas within the urban fabric, offering multiple benefits from an environmental, social, recreational, educational, and therapeutic standpoint.
- Above-ground farming systems allow cultivation even in tight and residual spaces.
- In closed-loop above-ground farming systems like hydroponics, it's possible to maximize water and nutrient efficiency, with complete reuse of excess nutrient solution. Other above-ground systems like container-based ones show lower water use efficiency due to the larger substrate surface exposed to air. However, water savings compared to traditional agriculture are still significant.

The disadvantages are:

- Access to urban farms and gardens is not always easy to manage and requires specific agreements and regulations between owners and users, including insurance and liability matters.
- In above-ground systems, autonomous cycles of resource regeneration and revitalization are not possible, making it essential to replenish resources consumed by cultivation.
- In conditions of strong wind and sun exposure, which quickly dry the substrate in raised cultivation containers, water and nutrient losses are high. Additionally, if the substrate volume is limited (such as in systems created from food containers or bottles), water reserves are extremely limited, necessitating frequent irrigation and reducing water use efficiency. In this specific situation, above-ground systems require special care and solutions, such as mulching (using straw coverings, for example, to reduce water losses) and composting.

Maintenance aspects

In managing the urban farm and garden, particular care should be taken in preserving soil fertility, rational water resource management, protecting crops from weather conditions and pathogens, while minimizing the use of chemical substances.

Ideal conditions for plant growth are achieved by retaining organic matter on the surface, which, as it decomposes, provides nourishment to the plants. Consequently, the soil should be turned only when absolutely necessary (for example, breaking up a lawn or burying manure), and efforts should be made to limit the depth of cultivation as much as possible (maximum 20-30 cm).

Irrigation should be carried out in the morning or evening, avoiding the hottest parts of the day (midday hours). Watering in the morning during winter months reduces the risk of cold damage, while watering in the evening during summer months helps refresh the plants for the night. Additionally, the type of soil must be considered. Sandy soils require frequent and smaller doses of irrigation, while clayey soils can tolerate larger, less frequent waterings. Under normal conditions, with strong plants and well-developed roots, the garden should be irrigated once every 5-7 days. A good rule to understand when to irrigate again is to observe the soil and see when the top two centimeters are completely dry.

The use of organic fertilizers compared to mineral ones improves the chemical and physical characteristics of the soil. Organic matter lightens and aerates the soil, enhances water retention capacity, and nourishes all the microorganisms essential for plant fertility. The most useful application is done in October-November when, after a season of intensive production, it's necessary to replenish the depleted reserves from the just-ended year. Therefore, after working the soil, a layer of 2/5 cm of organic matter is spread over the entire surface, which should be mixed with the soil to a depth of about 15 cm.

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4. Criteria for Planning NbS and GI in Urban Areas:

In the context of pilot cities, the integration of nature-based solutions (NBS) and green infrastructure (GI) has garnered substantial attention as a multifaceted approach to address pressing urban challenges. As these cities strive to enhance their resilience, mitigate environmental degradation, and improve the quality of life for their inhabitants, the deliberate and strategic planning of NBS and GI emerges as a pivotal undertaking.

This section delves into a comprehensive exploration of the fundamental criteria that underpin the effective planning of NBS and GI within these urban areas. By elucidating the critical dimensions that encompass ecological, socio-economic, and spatial considerations, this section seeks to provide urban planners, policy makers, and researchers with a structured framework for devising and implementing contextually relevant interventions.

The criteria and principles for planning NbS/GI in GreenScape CE are based on the Guide developed by the EU FP7 project GREEN SURGE "Urban Green Infrastructure Planning: A guide for practitioners"[5] and on the scientific publication by Christian Albert et.al. "Planning nature-based solutions: Principles, steps and insights"[6].

An essential criterion for the successful implementation of NbS and GI lies in their **multifunctionality**, designed to yield a diverse array of benefits that extend beyond their primary purpose. Therefore, while delivering environmental benefits, it is crucial to ensure that improvements to the urban area do not inadvertently lead to negative social effects, such as gentrification. Instead, a focus should be placed on fostering social inclusion and equitable community engagement.

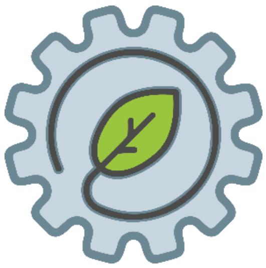
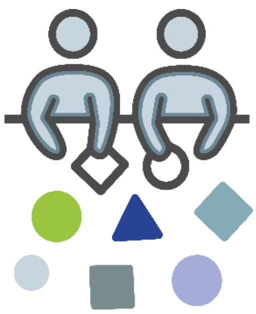
Moreover, recognizing the intricate interplay between communities and the environment, the approach of **co-creation**, co-design, co-implementation, and co-management (additionally co-monitoring) emerges as a guiding principle. NbS and GI interventions should ideally be forged through collaborative efforts, engaging local stakeholders, residents, technical experts, and policymakers to collectively shape and execute these solutions. By involving diverse perspectives, these initiatives gain a higher likelihood of effectively addressing the needs and aspirations of the community they serve.

In tandem with this collaborative approach, a fundamental consideration is the **site-specificity** of NbS and GI interventions. These solutions ought to be meticulously tailored to the unique characteristics, challenges, and opportunities presented by each specific location. A one-size-fits-all approach is inadequate in the face of the dynamic urban landscape; hence, a keen understanding of the local context and its intricacies is indispensable in crafting interventions that resonate with the immediate environment and its inhabitants.

Following these main principles of **multifunctionality and integration, the co-creation method, site-specificity, and social inclusion and equity**, public officers and local decision-makers are empowered to strategically plan and implement comprehensive Nature-Based Solutions (NbS) and Green Infrastructure (GI) and Climate Change Initiatives (CCI). In the table below, the criteria for planning NbS/GI are structured based on the three aspects that the GreenScape CE project works on (technical, engagement and financial) and can support city partners and support partners in developing actions plans.

[5] Hansen, R., Rall, E., Chapman, E., Rolf, W., Pauleit, S. (eds., 2017). Urban Green Infrastructure Planning: A Guide for Practitioners. GREEN SURGE. Retrieved from http://greensurge.eu/ working-packages/wp5/

[6] Albert, Christian, Mario Brillinger, Paulina Guerrero, Sarah Gottwald, Jennifer Henze, Stefan Schmidt, Edward Ott, and Barbara Schröter, "Planning Nature-Based Solutions: Principles, Steps, and Insights", Ambio, Vol. 50, No. 8, August 14, 2021, pp. 1446–1461. https://link.springer.com/10.1007/s13280-020-01365-1

 TECHNICAL	▪ To gain better understanding of **urban challenges** (see fig.1) related to combating climate change requires a comprehensive approach by local municipalities, such as: conduct climate vulnerability and risk assessment to identify the areas most at risk and the sectors that need immediate attention, gather **environmental data** to understand the municipality's potential to deploy NbS/GI. ▪ It is crucial for local authorities to **align NbS/GI with strategic priorities** within a place-based setting. ▪ **Integrate** urban green spaces with existing 'grey' infrastructure (e.g. roads, canals, drainage systems) and to promote combined green-grey infrastructure in ways that provide more benefits than traditional engineering approaches. ▪ **Connect** different green spaces in order to enhance recreation, mobility by bike and on foot, biodiversity and natural ventilation, ideally by combining different goals for humans, other species and abiotic flows. ▪ **Spatial considerations:** assess the site suitability, connectivity, and scale for implementing NBS and GI interventions. ▪ The **long-term management** and **monitoring** requirements are crucial for ensuring the effectiveness and sustainability of NBS and GI interventions
 ENGAGEMENT	▪ The **inclusive engagement** goes beyond traditional top-down decision-making processes and fosters a collaborative atmosphere that is essential for the successful planning and implementation of NbS/GI. ▪ This implies to build a **co-governance**/collaborative governance as a continuous process among all stakeholders and actors in a shared responsibility to deal with the decisions. ▪ Strategize with stakeholders in a **constant dialogue** as co-producers.For steps on how to identify and engage all types of target groups/stakeholders refer to deliverable D1.4.1. Multi-stakeholders' engagement roadmap.
 FINANCIAL	▪ Conducting a comprehensive **cost-benefit analysis** helps quantify both tangible and intangible benefits, allowing for an informed comparison between different NbS options and traditional infrastructure alternatives. ▪ NbS/GI should be evaluated for their **cost-effectiveness** compared to conventional, gray infrastructure solutions. The initial investment, maintenance, and operational costs should be balanced against the projected benefits, both in terms of direct outcomes (e.g., flood mitigation, air quality improvement) and indirect benefits (e.g., increased property values, reduced health care costs). ▪ Consideration of **financial incentives, subsidies, tax breaks**, or other mechanisms that encourage private investment and participation in NBS implementation can help overcome financial barriers. ▪ Identifying and securing appropriate **funding sources** is essential. ▪ Identify and assess potential **financial risks** associated with NbS implementation.

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