13

PERGOLAS
create fresh and shaded paths and urban spaces

Pergolas are shaded passageways comprising a system of horizontal and vertical elements where climbing plants are installed.
Its function is to make walkways or resting areas shaded and cool, thanks to the use of plants on the overhead cover and possibly on side walls. The environment underneath a green pergola is shaded, with lower temperatures than under mineral covers, thanks to the plants' lower temperature. A "cool roof" is created, toward which people release heat.
Pergolas are shaded and comfortable spaces to socialize, rest or pass through in an urban context.
Seating elements can be added to promote permanence and gatherings.

Pergolas are installed to:
- create relaxation and socialization areas;
- promote the reduction of the "heat island" effect and improve microclimate.

Top right.
Pergola with iron load-bearing elements and wisteria vines at the Catella Foundation in Milan. The structures are located within a recently built garden of 4 thousand square meters.
(photo by Luisa Ravanello)

Bottom right. Pergola with iron structure and climbing greenery in Mint Plaza, San Francisco city centre.
The square was created within an urban redevelopment project of an ill-famed street used solely as access way to the buildings. Apart from the shaded pergola, parallel to the new commercial units and the furnishing elements that promote permanence, the project entails local management of rainwater. The square pavement has a dual gradient toward the central drain; from here, the water flows into the two rain gardens on the sides, and then naturally infiltrates into the sandy subsoil.
(Project and photo by CMG Landscape Architecture)

CONSTRUCTION ASPECTS

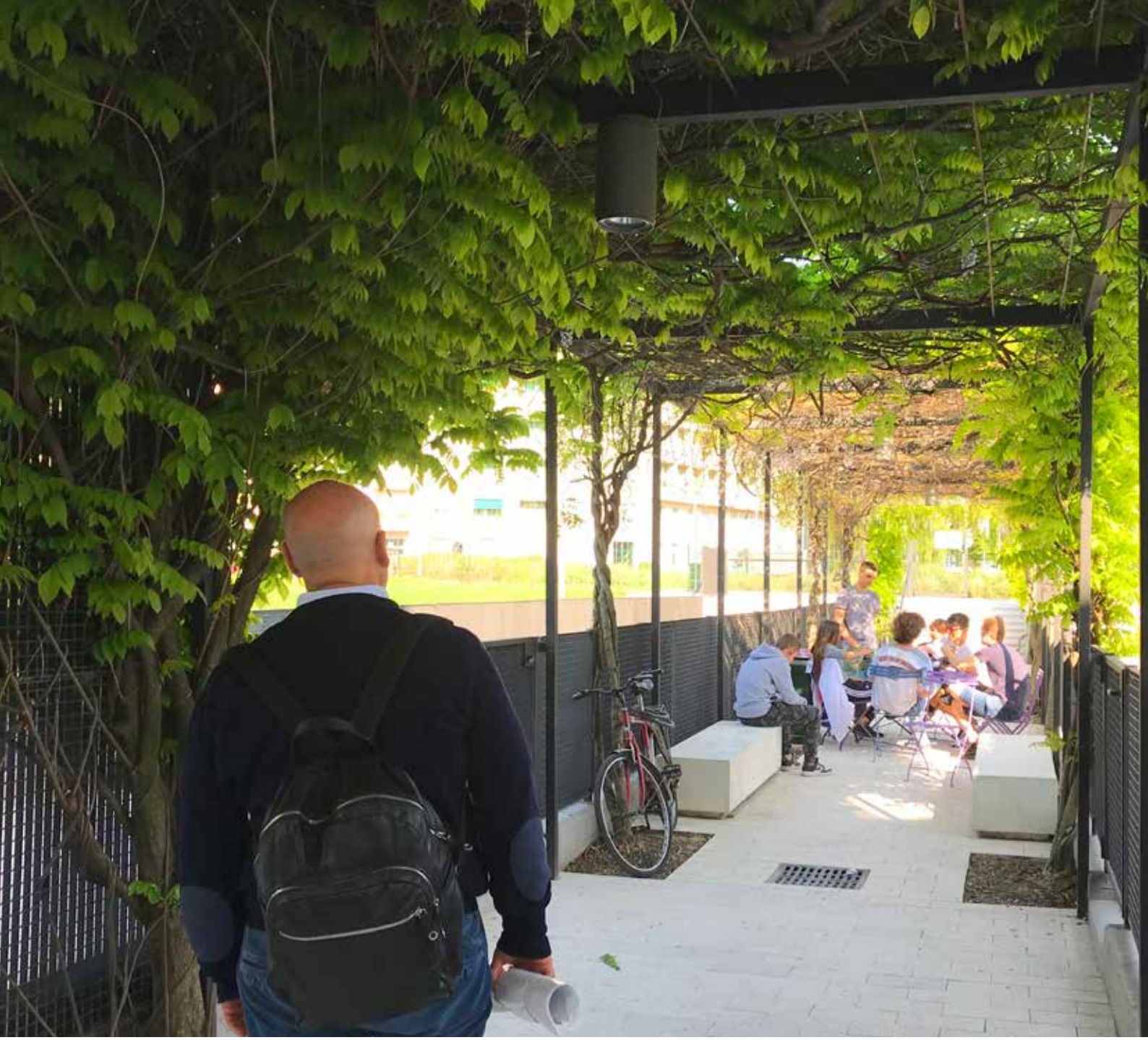
In order to create a pergola, the best materials and climbing species should be identified.
The materials employed are wood, iron, steel and aluminium. Considering the different characteristics of each material, the right choice should take both aesthetic and context-related aspects, and technical assessments on the expected load and material durability aspects, into account.

- WOOD gives a rustic and natural effect, and allows the creation of customized shapes. However, it requires more frequent and greater maintenance, depending on the environmental context.
- IRON allows the creation of sturdier structures and maximize space, thanks to the reduced dimension of load-bearing elements. Limited maintenance costs. If duly protected, the surface lasts long, without requiring any significant intervention.
- STAINLESS STEEL a more expensive material that fits well both into historical centres and in modern contexts.
- ALUMINIUM the most highly performing material, allows the creation of light and sturdy structures. It requires less maintenance than iron and wood, but the structure loading capacity needs to be assessed, especially in relation to the type of climbing plants planned.

The use of wall climbing plants increases the green surfaces, solving any space-related issue to plant the green elements.

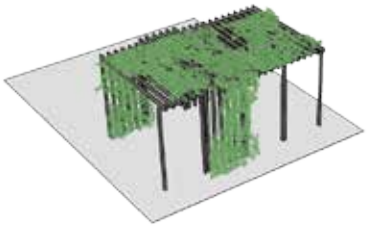
APPLICATION CONTEXTS AND LIMITS

Pergolas can be implemented in a wide variety of public spaces, such as parking lots, squares, resting and relaxation areas, and parks, by adopting different layouts, materials and plant species based on the architectural, landscaping and climatic context.

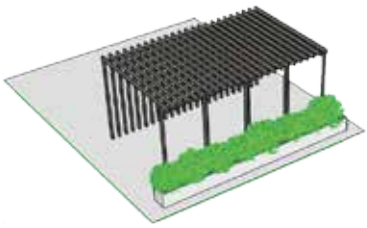


Regardless of the building material, pergolas can be:
⇢ FREE-STANDING and therefore positioned in the center of the public space to be shaded;
⇢ CANTILEVERED and hinged to the front of a building overlooking the public space to be shaded.

Vegetation can consist of:
⇢ CLIMBING PLANTS planted in correspondence with punctual vertical elements or green surfaces;
⇢ SHRUBS planted directly on the ground or in special containers;
⇢ a COMBINATION OF CLIMBING PLANTS AND SHRUBS.

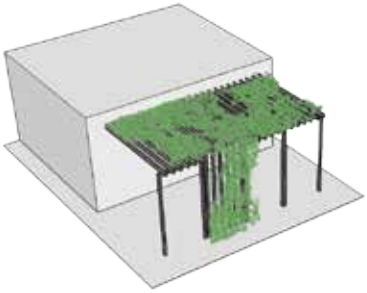


self-supporting pergola with climbing plants

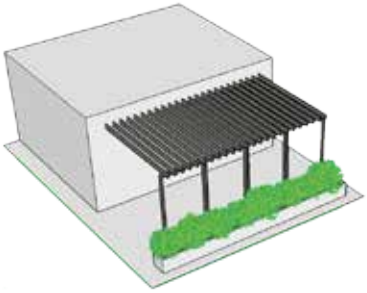


self-supporting pergola with shrubs

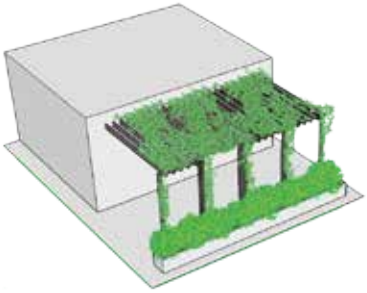
self-supporting pergola with climbing plants and shurbs



cantiliver pergola with climbing plants

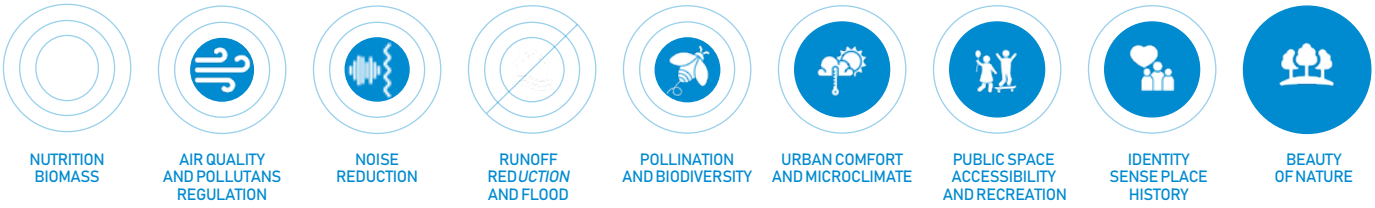


cantiliver pergola with shrubs



cantiliver pergola with climbing plants and shurbs

ECOSYSTEM SERVICES PROVIDED



PLANT SPECIES

Climbing species should be selected based on the venue's climatic and environmental parameters and its solar exposure. Climbing plants can develop both on the roof, ensuring a shady place in the hottest hours of the day, and on the side walls, ensuring a shaded pathway throughout the day (both walls covered with plants) or in the morning/afternoon (only one wall covered with plants).
The recommended species are:

- CLIMBING PLANTS FOR BRIGHT SUNLIGHT CONDITIONS almost all species, except for climbing hortensia and Ficus repens;
- CLIMBING PLANTS THAT TOLERATE SHADE and grow with just a few hours of sunlight, such as akebia, Ampelopsis, Celastrus, ivy, confederate jasmine, Ficus repens, lonicera, hop, climbing hortensia, Schizophragma integrifolium, Virginia creeper.

PUBLIC USAGE

Pergolas encourage people to pass by and stop, since they improve the microclimatic conditions of the public space where they are installed, ensuring a shaded and cool spot.
The integration of seating elements promotes a use of the space for social and gathering purposes, thus enhancing the venue's image and perception.

MAINTENANCE

The type of materials and plant species chosen determine the maintenance frequency and costs. Long-lasting and weather-resistant materials, such as aluminium or iron, require fewer maintenance interventions, contrary to wood.
Concerning plant care, the pergola should include species that do not require any containment pruning (such as some varieties of wisteria and wide ivy), which could damage the materials and compromise the structures over time.

INDICATIVE COSTS

Construction costs depend on the material chosen for the structure. Indicatively:

- 400-1,000 euro/linear meter as average cost considering the material variability, type of structure and variety of plant species used.

Pergola with wooden structure and climbing plants in the Jardín de las Hespérides in Valencia, a small contemplative garden that showcases traditional botanical species, that have been replaced by citrus groves in recent years. (Project by VAM10 architecture and landscape, photo by Luisa Ravanello)

Pergola with iron structure and climbing greenery at Yorkville Park, Toronto. Despite the limited green cover, the pergola is surrounded by green spaces and tree rows that create shadow and mitigate summer temperatures. (Project and photo by Martha Schwartz)

Pergolas in Lyon, along the path that from the top of the Basilica of Notre-Dame de Fourvière goes into the urban parks of the hill and descends into the city. The pergolas are made of wood or iron and covered with vines. Project Christine Dalnoky, photo Luisa Ravanello and Elena Farnè)

Pergola with iron and wisteria load-bearing elements at the Catella Foundation in Milan. The structures are located within a newly built garden of 4 thousand square meters, with young plants and adjacent to the new Milanese urban park. The library of trees (Photo by Luisa Ravanello)

14

GREEN ROOFS
manage urban rainwater through roof gardens

Green roofs are implemented on existing and newly-built flat or sloping building roofs.
This integrated and complex system of functional layers recreates the ideal habitat for the growth and development of tree species in non-natural contexts.
Apart from improving the building comfort and energy performance, they also create welcoming spaces to relax and socialize.

Green roofs are built to:
- remove pollutants through filtering and biological absorption mechanisms by plant species *(medium-high effectiveness)*;
- reduce flood peaks in receiving bodies *(medium effectiveness)*;
- promote biodiversity, improve the building visual perception and increase the context landscaping value *(medium effectiveness)*;
- increase the building energy efficiency and acoustic climate *(high effectiveness)*;
- reduce the urban heat island effect *(high effectiveness)*.

The Sensory Garden on the roof of the Magneten parking lot, Copenhagen, a healthcare facility for adults with physical and mental disabilities. The garden is employed for outdoor therapies, and it features small and intimate spaces for one-on-one sessions, larger areas for group activities, and workout and balance equipment. (Project by MASU Planning and photo by Kirstine Autzen)

The roof of the Gary Comer Youth Center, Chicago, has been designed as an after-school space to learn urban farming practices, in a district that lacks green and social spaces. (Project and photo by Hoerr Schaudt Landscape Architecture)

CONSTRUCTION ASPECTS

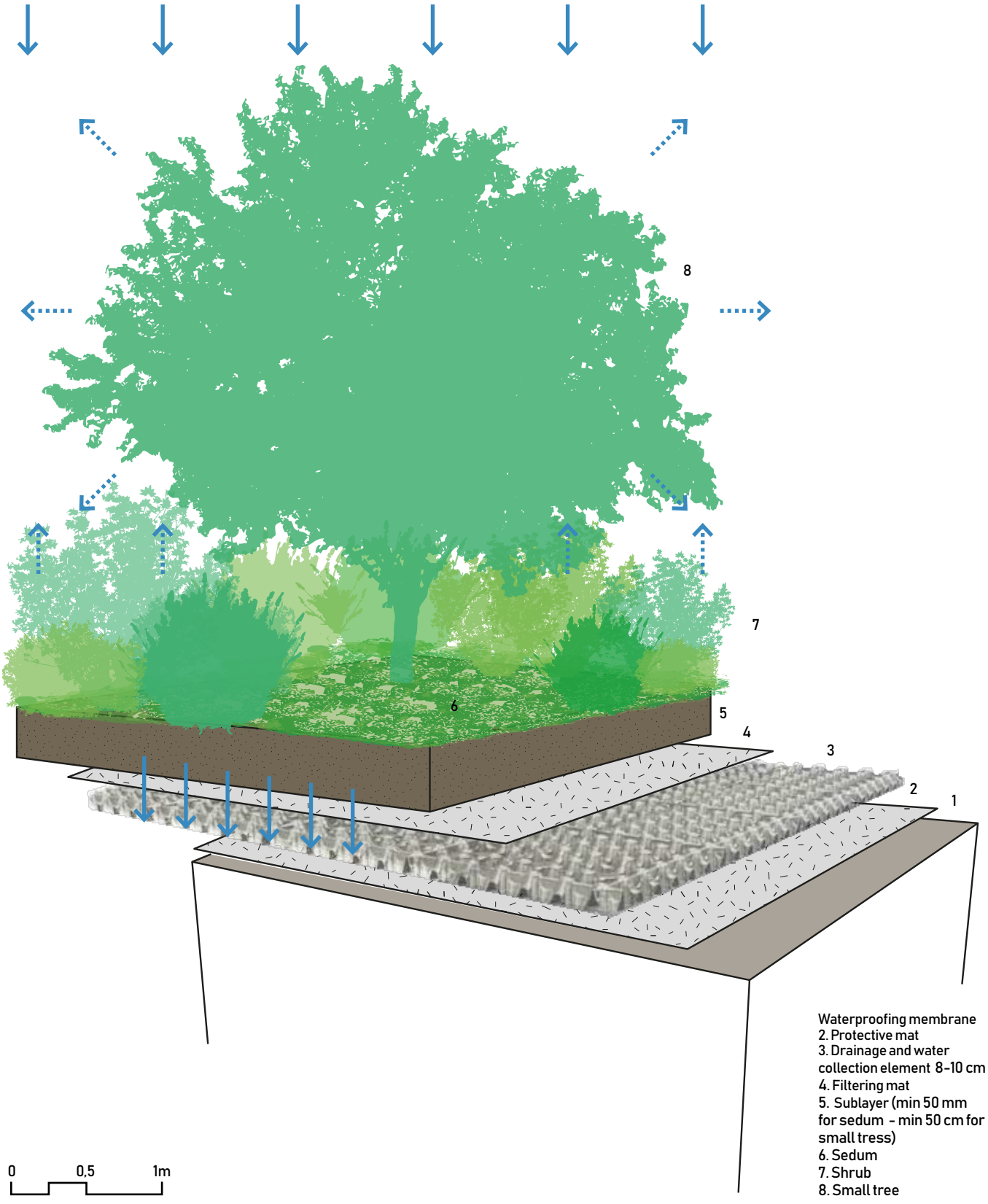
In order to be correctly designed, a green roof requires the analysis of several factors, including:
- ASSESSMENT OF OVERLOAD on the building and of the cover (and building) structural capacity;
- ASSESSMENT OF ACCESSIBILITY REQUIREMENTS;
- ASSESSMENT OF THE SITE'S ENVIRONMENTAL PARAMETERS, such as cover height, wind and solar exposure, and level of shade to determine the right plant species;
- IDENTIFICATION OF BIODIVERSITY OBJECTIVES, based on the project's aesthetic value, and its integration in the context;
- INTEGRATION WITH THE MACHINERY AND TECHNOLOGICAL SYSTEMS on the roof.

The creation of a green roof increases the load on the building, determined by the soil layer, the temporarily stored water volume, the accidental maintenance-related loads, and snow build-up. In addition, suitable waterproofing of the roof must be ensured, by installing an impermeable membrane. For these reasons, it is not always possible to apply these elements on existing roofs.

They are divided into two macro-categories:
- EXTENSIVE ROOFS, when very resistant plant species that can tolerate hard climate conditions are employed (such as Sedum, herbal and grassy plants); the layer thickness is limited to 10-20 cm and requires low maintenance; irrigation is not required, except at the initial stage; normally, they are not accessible;
- INTENSIVE ROOFS with thicker layers (25-100 cm) that can house a wide range of plant species, including small trees and shrubs; they require a greater level of maintenance and are usually accessible; in order to ensure their appearance and efficiency, a regular water and nutrients supply must be provided.

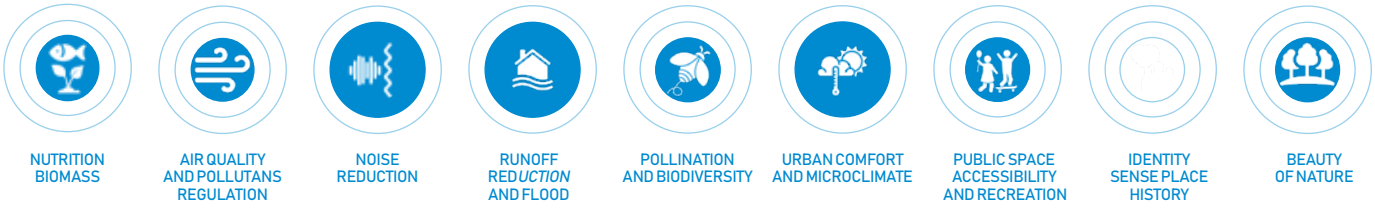
From a water-management standpoint, green roofs ensure different performances, depending on the season:
- IN THE SUMMER, they ensure the retention of at least the first 5 mm of rain, thanks to the peculiar evapotranspiration process;
- IN THE WINTER, the sublayer is saturated for most of the period.

Typical section of intensive green roof.



1. Waterproofing membrane
2. Protective mat
3. Drainage and water collection element 8-10 cm
4. Filtering mat
5. Sublayer (min 50 mm for sedum - min 50 cm for small tress)
6. Sedum
7. Shrub
8. Small tree

ECOSYSTEM SERVICES PROVIDED



For this reason, as observed in many empirical studies, during the majority of rainfall events (approx. 70-80%), the green roof does not generate any runoff, while in other conditions it tends to behave as an impermeable surface (due to the sublayer saturation).
No pre-treatment is required, unless the rainwater needs to be reused to irrigate the green roof system.
The water overflow discharge points must be designed so as to minimize the risk of clogging, and they must be accessible for seasonal cleaning and extraordinary maintenance purposes. Discharge points should be separated from the plant growth sublayer, to prevent access of fine particles and roots.
A green roof should not surrender its water content into the soil too quickly, in order to ensure a correct plant growth. This is ensured by the sublayer itself, or, if required, additional water collection elements can be added to the sublayer base, or even an irrigation system.
Irrigation is not usually recommended for extensive roofs, due to the related costs, construction and management, while it is often required in intensive roofs. In general, additional irrigation may be necessary in the first 2 growth seasons, to ensure plant survival.
The typical section of a green roof generally comprises the following layers and materials:

- WATERPROOF MEMBRANE to prevent the water from flowing to the underlying structure;
- ANTI-ROOT MEMBRANE a permeable membrane subject to a peculiar treatment to prevent damages to the underlying waterproof membrane caused by the roots;
- DRAINAGE AND STORAGE LAYER 8-10 cm thick, this layer temporarily stores the water, draining the excess quantity not absorbed by the soil and the root system; in general, this layer is created with geocomposite/geocellular prefab elements;
- FILTERING LAYER comprising a geotextile that prevents clogging of the filtering layer, separating it from the plant growth layer above it;
- SUBLAYER OR GROWTH MEDIUM, whose thickness depends on the type of plants chosen; thickness may vary between a recommended minimum of 50 cm (for Sedum and musk) to over 50 cm (for small trees); it must comprises low-density soil with good water retention capacity and fertility; it can also include an organic and mineral material mix (such as crushed inert materials and pumice);
- PLANT SPECIES this selection affects the growth medium layer, and it must be done by taking into account the site's climatic and environmental conditions.

APPLICATION CONTEXTS AND LIMITS

Green roofs can be applied on a wide variety of covers, both for size and geometry, in residential, commercial or industrial areas, and on public buildings, such as schools and hospitals.

- SPACE REQUIRED

There are no minimum or maximum space requirements; however, since it is implemented on the roof surface, the green roof project must be integrated with the system and technological equipment present.

- LIMITATIONS

Assessing the building's structural capacity to bear the permanent and accidental loads caused by a green roof is essential.

Green roof of a community space in the Area 143 Bicocca, Milan. The extensive green roof features skylights protruding from the walk-over flooring. The hanging garden comprises a series of tree and lawn stripes arranged in sequence. The plant species chosen aim to give a unitary character to the green space fragmented by the skylights.
(Project and photo by LAND)

Bottom right. The green roof complex of the Mærsk tower of the University of Copenhagen has an extension of 5,000 m2. It is part of the SUND Nature Park, the urban park for students on campus that provides a wide range of natural and social services to the city. The large roof is public and offers a variety of outdoor study places and new social gathering opportunities for researchers, students and ordinary citizens. The green roof - conceived as a climate adaptation measure - is also designed with high biodiversity differentiated mowing lawns, favorable for the life of bees.
(Project and photo in upper SLA, photo details Elena Farnè)

PLANT SPECIES

It can house a great variety of plant species, taking into account the growth medium thickness, the microclimatic conditions, etc. In extensive systems, the plants must be selected between perennial species - usually herbaceous, such as Sedum - with the following characteristics:

- REGENERATION AND SELF-PROPAGATION;
- FRUGALITY;
- TOLERANCE TO ADVERSE CLIMATE CONDITIONS (wind, drought);
- WATER AND THERMAL STRESS RESISTANCE;
- LOW MAINTENANCE REQUIREMENTS, with no or limited need to mow or prune.

In intensive systems, virtually all plant species can be planted, apart from lawn, provided that they are cared for in the right way; although tall trees that require powerful anti-wind systems, suitable sublayer depth and supporting elements proportionate to the growth rate (1 cubic meter of dry wood weights over 1 t) should be avoided.
In general, planting different species with a high water absorption level improves the performance of a green roof, in varying terrain humidity conditions.

PUBLIC USAGE

In case of intensive green roofs, they make a technical or inaccessible and unused area accessible and attractive, improving it with excellent environmental comfort characteristics.

MAINTENANCE

The maintenance level required varies, depending on the intensive or extensive green type.
In case of intensive green roofs with grass species, the green area requires a regular maintenance and inspections, usually comprising:

- grass mowing (once a week/every two weeks);
- green bed weeding before/after sowing;
- annual weeding of lawns with wild species;
- regular inspection, once a year and after intense events, of all the green roof elements, such as the sublayer, irrigation system (if present), membranes, and rainwater discharge points.

In case of extensive green roofs, inspection and maintenance are less frequent, and comprise:

- inspection and waste removal;
- inspection and cleaning of the green roof elements and the rainwater discharge points;
- invasive plant removal (once a year/every six months).

For this type of roof, maintenance is more important in the plant establishment and initial development phase (12-15 months).

INDICATIVE COSTS

Implementation costs are mid-high, but they are compensated, over the long period, by the reduction of the costs to improve the building heating performances.
Indicatively:

- 70–150 euro/sqm for extensive green roofs (with reduced maintenance costs);
- 100–200 euro/sqm for intensive green roofs (with high maintenance costs).

15

PERVIOUS PAVEMENTS
infiltrate urban rainwater

Drainage surfaces are made with porous permeable materials (porous surfaces) or with impermeable materials equipped with suitable gaps or grout lines for water drainage (permeable surfaces).
They ensure a surface that can be adapted to many different uses (e.g. pedestrian, bicycle or vehicle traffic), while reducing surface runoff, thanks to the infiltration of rainwater into the underlaying structural layers and into the subsoil. In addition, they improve the climatic context, by contrasting the "heat island effect" - thanks to low solar reflectance levels (that can absorb and release a low heat quantity) - and promoting green and circular economy, since they are usually made with eco-friendly materials.
They can adapted to virtually any urban context: from highly populated ares to parking lots, to high-traffic public spaces, such as squares and pedestrian avenues.

Drainage surfaces are installed to:
- improve infiltration into groundwater (effectiveness based on the terrain characteristics);
- remove pollutants through filtering and biological absorption mechanisms by plant species (low effectiveness);
- reduce flood peaks in receiving bodies (medium effectiveness).

Drainage surface on a portion of the Passeig De St Joan pedestrian area, in Barcelona. (Landscaping project by Lola Domènech)

Stabilized soil pedestrian walkway in Place Bellecour, Lyon, France. (Landscaping project by Atelier Jacqueline Osty, photo by Elena Farnè)

CONSTRUCTION ASPECTS

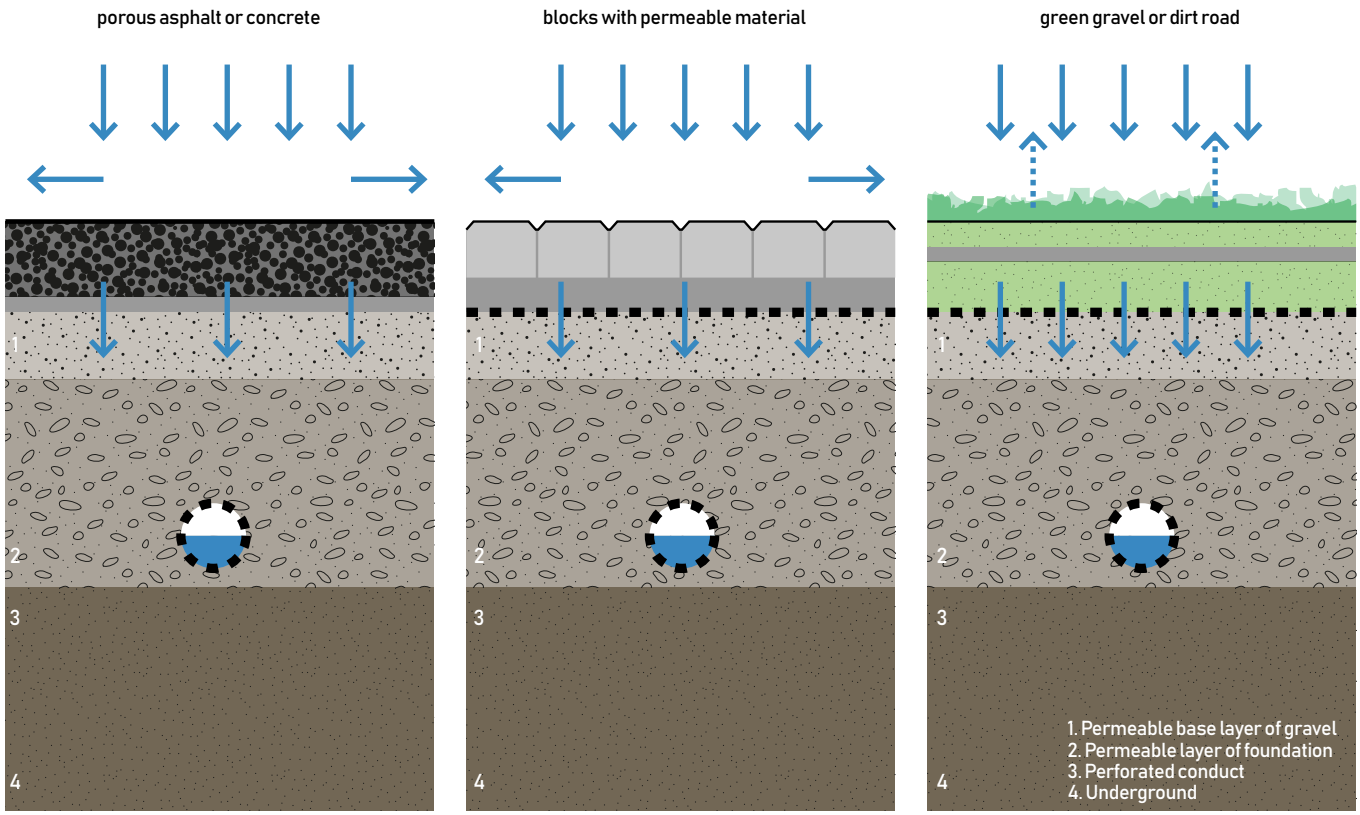
Permeable surfaces are used to drain and infiltrate rainwater from the surface where they are installed.
The possibility of infiltrating rainwater into the subsoil depends on the type and entity of vehicle traffic (i.e. on the expected pollution load), and on the groundwater characteristics. Therefore, these solutions cannot be implemented, in the case of particularly intense vehicle traffic, contexts with risk of pollutant spillage, and in aquifer vulnerability conditions.

The market offers a wide range of solutions that can be adopted, based on the area's intended use, and on the landscape and urban context.
The main types of drainage surfaces are:
- POROUS SURFACES, such as lawn, green gravel, plastic grids with grass, dirt roads/ compacted soil;
- PERMEABLE SURFACES, such as concrete grids with grass, cubes or blocks with green grout lines or filled with draining materials, porous blocks, drainage asphalt and concrete.

Choosing the best surface is essential for its capacity of tackling the rainfall flow; a correct design should consider:
- HYDRAULIC ASPECTS the surface should be capable of collecting and draining the rainfall flow for a certain project event, and then gradually discharge the water into the underlying layers or into the sewage system;
- STRUCTURAL ASPECTS the surface's structural resistance should be defined based on the level and type of expected vehicle traffic.

Therefore, the surrounding conditions and limitations - such as the existing soil infiltration capacity and the water volume that needs to be collected and infiltrated - should be determined in advance.
Based on the type of traffic, the structural project defines the type of surface and its thickness. The size of the base layers and road foundation is based on the need to ensure suitable bearing capacity

Comparison of different types of drainage surfaces, ensuring partial infiltration: porous asphalt or concrete, blocks with permeable material, green gravel or dirt road.



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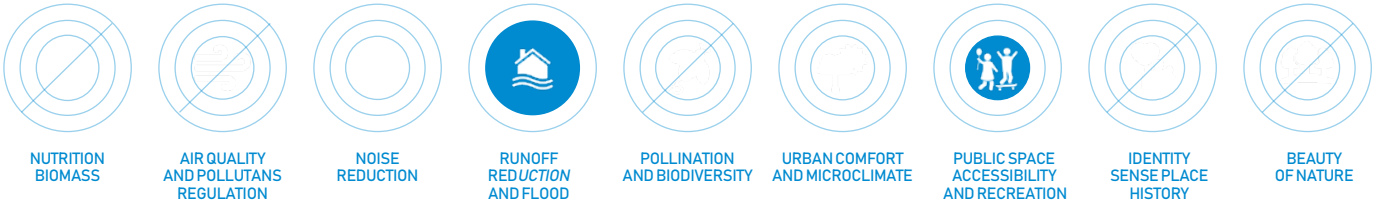


(structural project) and a suitable water flow into the subsoil (hydraulic project).

The surface permeability level depends on the specific project, and is generally indicated by the manufacturers. The infiltration capacity can be reached in optimal operating capacity, that is, assuming that the underlaying layers can suitably infiltrate the flow incoming from the surface, and that the surface grout lines or gaps are not clogged.
For sizing purposes, an infiltration rate reduction factor of 10 should be considered, in order to simulate the reduction of the filtering capacity over time (gap clogging, compacting of the drainage layers, etc.).
An overflow sewage system should always be implemented, to receive and discharge the quantities exceeding the reference project event into the sewage system.
In case of block surfaces with large grout lines, lawns are not recommended if the parking lot is intensely trafficked during the day, with the vehicles blocking sunlight. In this case, inert materials are recommended.

APPLICATION CONTEXTS AND LIMITS

Lawn, porous cubes and blocks or stabilized soil can be used on pedestrian/bicycle paths.
Lawns, porous cubes and blocks, and plastic or concrete grids can be used on access roads and parking lots.
Drainage cubes, asphalt or concrete surfaces can be used on minor squares or roads, while drainage asphalt or concrete surfaces are better for high-traffic roads.
Permeable surfaces cannot be used if there is a risk of groundwater contamination (industry outdoor areas with risk of spills), or on unstable areas (steep slopes).

SPACE REQUIRED

Permeable surfaces are generally used to drain water from the surface area. In some cases, they can also drain impermeable surrounding areas (e.g. roofs); in that event, the maximum ratio between surrounding surface and flooring surface is 2.

TYPE OF SOIL AND PRESENCE OF GROUND WATER

If the project foresees groundwater infiltration, permeable soil should be present underneath the surface. Alternatively, a suitable collection system to channel the water drained from the permeable surface to the sewage system or another receiving body should be installed. Usually, this solution cannot be adopted in groundwater protection areas.

Draining flooring built at the entrance of a house in the car-free district of Vauban. The blocks laid with large and coarse joints facilitate the infiltration of water into the entrance garden.
(Photo Luisa Ravanello)

Draining flooring made at Zollhallen platz in Freiburg. The blocks laid with large and coarse joints facilitate the infiltration of the water into the subsoil, where there are rainwater storage tanks.
(Photo Luisa Ravanello)

Draining flooring made at Zollhallen platz in Freiburg. The blocks laid with wide and coarse joints towards the grassed meadows favor the infiltration of the water in the subsoil, where there are rainwater storage tanks.(photo Luisa Ravanello)

Draining flooring made in Copenhagen in self-locking blocks in parking areas on the roadside. Among the blocks laid with wide joints is the soil that favors the infiltration of rainwater.
(Photo Luisa Ravanello)

PLANT SPECIES

In general, no plants are present on drainage surfaces, except for lawns and grids with grass, where the green elements prevail over the mineral ones.
In case of surfaces covered with grass, the species chosen should be highly resistant to wear and droughts.
Trees can be well-integrated into drainage surfaces, since they allow air and water (beneficial elements for the tree's growth) to penetrate into the subsoil; in such conditions, it is unlikely for the roots system to damage the surface. By contrast, traffic and vehicle parking can compact the soil, choking the roots. Therefore, if the drainage surface is applied on a tree-lined parking lot, the measures set forth in Chapter 4 should be implemented.

PUBLIC USAGE

Drainage surfaces can be adapted to different urban landscape contexts, and the variety of products available allows choosing the best finishes, colour and shape for each context.
By effectively planning these and the functional aspects, the surfaces will become aesthetically pleasing with an improved climatic comfort, by reducing the "heat island effect" typical of mineral materials.

Draining flooring in Lyon, in the Confluence district. The pedestrian path between the two rain gardens is made of stabilized earth. Thanks to the slopes, the water infiltrates and dilates towards the side gardens.
(Photo Elena Farnè)

Draining flooring in Lyon, inside a garden. The flooring infiltrates the subsoil.
(Photo Elena Farnè)

Parking place with draining asphalt. We are near the Tiberius Bridge in Rimini.
(Project by the Municipality of Rimini, photo by Elena Farnè)

Pedestrian path in stabilized earth in Lyon, built near the entrance garden of the shopping center.
Carré de Soie
(Photo by Elena Farnè)

MAINTENANCE

Routine maintenance includes:
- monthly inspection of the surface, to check it is free from debris and sediments;
- checking for stagnation areas and flow difficulties, following a weather event;
- waste removal and clearing of permeable surfaces in autumn, to prevent leaf occlusion, and when required, based on the quantity of debris and sediments.

Occasional maintenance comprises:
- cleaning and/or replacing the gap infill;
- replacing damaged elements/blocks;
- restoring depressed stagnation areas, etc.

INDICATIVE COSTS

The average construction costs depend on the project thickness and subsoil type.
Indicatively:
- 10 euro/sqm for lawns;
- 40-50 euro/sqm for green gravel;
- 70-80 euro/sqm for plastic grids with grass;
- 30-50 euro/sqm for dirt roads/compacted soil;
- 70-80 euro/sqm for concrete grids with grass;
- 80-100 euro/sqm for cubes or blocks with green grouts or filled with draining material;
- 80-100 euro/sqm for porous blocks;
- 70-80 euro/sqm for drainage asphalt and concrete.

16

DAYLIGHTING RIVERS
unearth urban features of rivers and waterways

In recent centuries, and in the last few decades in particular, the urban sections of rivers and watercourses have been often entombed and transformed into underground channel. This practice originated in the Napoleonic period for sanitary reasons, when watercourses were open sewers. Subsequently, this custom consolidated for a different reason: increasing buildable surface.
Today, entombed rivers increase the risk of flooding in urban centres, due to a limited "plugged" shape that limits the flood flow.
Current climate changes and environmental conditions require us to give the right space back to water and natural components in our cities, even by digging up or day-lighting the channels entombed in their city portions, e.g. by demolishing their covers and restoring their open section.

Digging or day-lighting interventions are performed to:
- reduce the risk of flooding in the urban portions of watercourses, by mitigating water flow in the event of flood;
- restoring the watercourses' natural habitat, to promote biodiversity and river flora/fauna growth;
- improve the landscaping value of the context;
- create new paths for slow mobility with leisure and rest areas;
- improve microclimatic comfort.

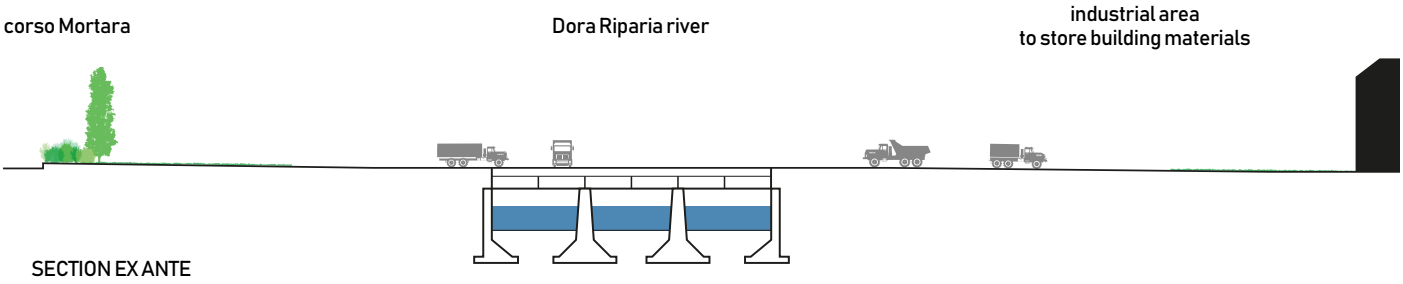
CONSTRUCTION ASPECTS

Digging up watercourses requires special executive measures and planning, since it usually involves the demolition of reinforced concrete works, and is carried out in an urban context where residents are significantly affected by construction site activities. For this reason, when planning and executing the works, the following aspects should be taken into account:

- DRAFTING A DETAILED DEMOLITION PLAN, taking into account the quantity of demolition materials to be temporarily stored and moved away from the construction site;
- SAMPLING AND ANALYZING THE SOIL AND MATERIALS BEFOREHAND, considering that the areas often contain landfill material, pollutants (e.g. in case of industrial areas), and rubble/poor quality materials;
- IMPLEMENT SUITABLE ENVIRONMENTAL MITIGATION MEASURES, since such works can have a significant impact on the population;
- ASSESSING THE QUALITY OF WATERCOURSE WATER BEFOREHAND, since they are often used as sewage collection systems, and, if required, include their environmental remediation.

La Dora is one of the two rivers that cross Turin. Along the banks of the river were the historic Fiat factories. Between 1950 and 1970 the Dora was buried to allow the expansion of the Fiat Ferriere, to expand the area of the Valdocco plant. With the closure of the factories in this area of the city, a long debate started which led in 2017 to the first works of filling the river and the arrangement of the banks, transforming the former industrial area into a large urban park. In the pictures, the construction sites.
(Project and photo Municipality of Turin)

Day-lighting of the Dora river, Turin, which was covered in 1950-1970 by Fiat Ferrier, to extend the Valdocco plant area.
The project, started in 2017, will dig up the portion of underground river, fix the banks and equip the area next to the Dora Park.
(Project and photo by Municipality of Turin)



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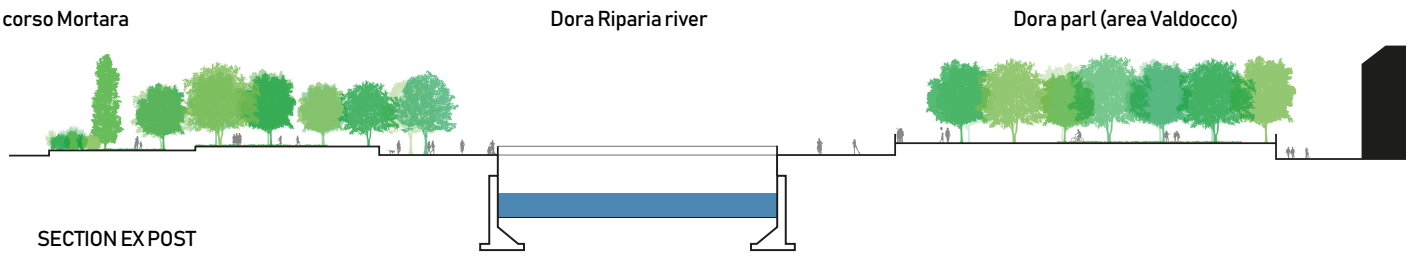

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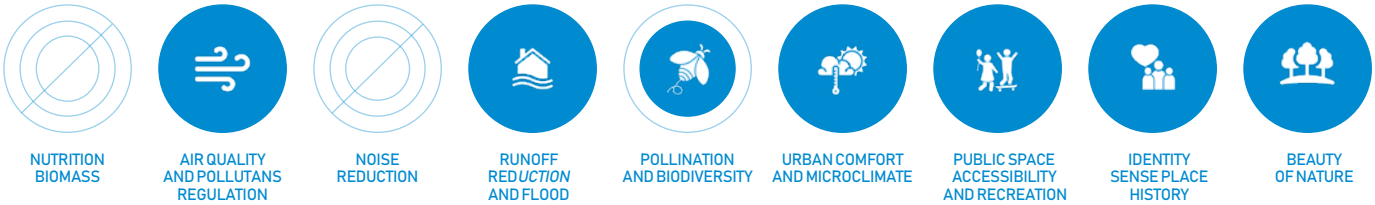


PLANT SPECIES

Watercourse day-lighting promotes greater level of naturalness; green edges will improve the watercourse's natural appearance.

The banks should be free from trees and tall shrubs that could bend and fall into the watercourse, obstructing the water flow. Banks should be mowed once a year with suitable mowers. Taller species should be planted at least 10 meters from the river edges, with enough space for machine access.

PUBLIC USAGE

Day-lighted channel portions can be made accessible via pedestrian/bicycle paths and roads along the banks, creating comfortable (thanks to the cooling effect from the running water) and aesthetically pleasing spaces. They can also include footbridges and raised crossways.

17

URBAN PARKS
insert green areas for urban biodiversity, comfort and sociality

Tree-filled gardens are an essential elements to design and strengthen the urban green infrastructures, with different functions within the urban context. In particular:
- ecological function, by connecting the city natural and semi-natural elements and improving biodiversity;
- environmental mitigation function, since they are urban fabric resilience elements that mitigate extreme phenomena related to water, air, temperature and pollution cycles;
- landscaping function, by improving the landscape perception;
- public access function, by connecting and promoting recreational, debating and social inclusion activities, thanks to pedestrial/bicycle paths and resting areas that encourage people to stop in greater environmentally comforting areas, shielded from noise and traffic.

The purpose of tree-filled gardens is to:
- promote rainwater infiltration into the groundwater and reduce flood peaks with green surfaces and trees, that can also exercise a phyto-purifying function;
- mitigate pollutants in the atmosphere, by capturing fine particles in the air, thanks to the green species infiltration and absorption mechanisms;
- reduce noise by adding tree rows and "green" barriers;
- reduce the heat island effect thanks to green surfaces and trees that generate a cooling effect thanks to the combined action of shading and evapotranspiration;
- increase biodiversity creating new habitats that allow different species to reproduce in an urban environment.

The garden of Potters Fields Park in the Southwark district of London is located near Tower Bridge and City Hall. it is frequented daily by neighborhood workers. In the garden there are over 50 species of plants, which make it particularly attractive in every season. The garden is in fact known for its perennial herbaceous plants, where a wide variety of wild animals, bees, birds and insects live. Although of modest size, the garden is an ideal place for quiet, to rest and relax among the shady foliage of the trees and the colorful flowers. (Project by Piet Oudolf, photo by www.pottersfields.co.uk)

The garden of SKY UK headquarters in London. (Landscape project by URBAN, photo by Edward Denison).

CONSTRUCTION ASPECTS

Designing green spaces such as tree-filled gardens must be based on different aspects, such as:
- CONTEXT ANALYSIS to identify the main issues that need to be mitigated;
- SURVEYING THE PRE-EXISTING URBAN GREEN INFRASTRUCTURE to identify how the garden can be interconnected to the existing green areas;
- SELECTING THE PLANT SPECIES, favouring those that can best survive in that context, and that can ensure the desired benefits; in particular, local environmental conditions must be considered, such as water supply, temperature, subsoil pH, light exposure, level of exposure to pollutants and salt (e.g. for surfaces in contact with groundwater salinated by salt water);
- AESTHETIC AND LANDSCAPING CONSIDERATIONS, subjected to the analysis of the environmental limitations and issues in the specific context;
- GREEN ELEMENTS PLANTING METHODS and subsequent maintenance stages.

APPLICATION CONTEXTS AND LIMITS

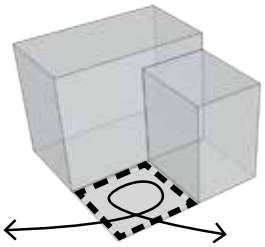
In residential areas, both private, semi-private or public gardens can be implemented, as well as larger green areas, scaled with the district.
On road networks and avenues, they can be implemented in the areas around the existing roads.
In commercial and/or production areas, they can be implemented in marginal and leftover spaces to be used by industrial sector workers.

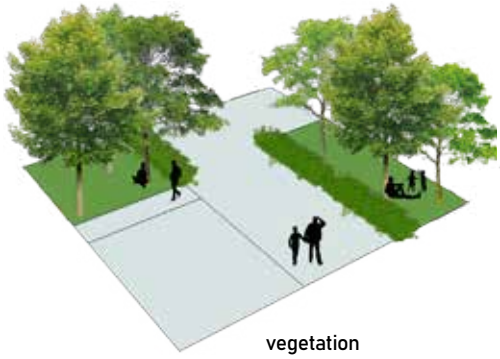
Abacus of the elements that characterize the courts:
⇢ LOCATION the area is usually surrounded by buildings but can be crossed;
⇢ GREEN FACILITIES with numerous shrubs, meadows and trees of different sizes, planted in groups or in rows,

⇢ presence of WATER such as fountains or misting systems to improve comfort;
⇢ use of different MATERIALS, permeable or semi-permeable, to differentiate main, secondary and rest areas;

⇢ presence of primary and secondary SEATS to encourage parking and socialization;
⇢ URBAN FURNITURE such as playgrounds;
⇢ LIGHTING to allow the space to be used even in the evening, with lights on the ground or on time to indicate the routes;

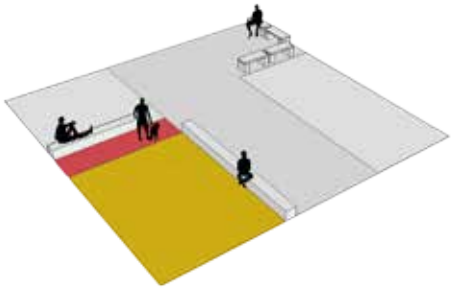
⇢ presence of SHADING systems such as pergolas, canopies or roofs to protect against atmospheric events.



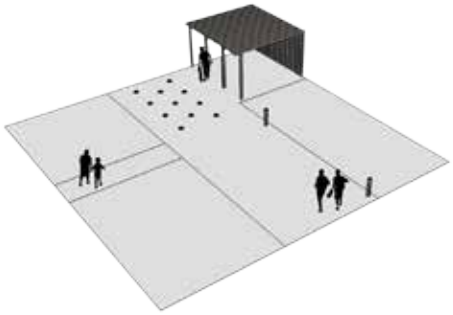


vegetation

urban furniture e acqua

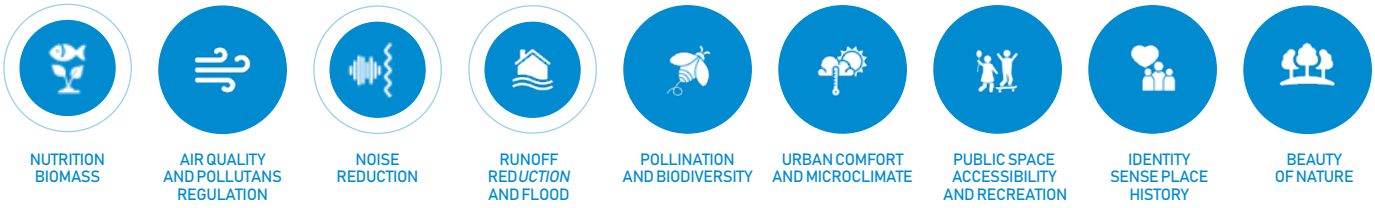


pathways and sittings



lighting and shading systems

ECOSYSTEM SERVICES PROVIDED



SPACE REQUIRED

Both large, marginal or leftover spaces can be transformed into an equipped green spaces, in highly populated urban contexts; the choice of tree species to be planted depends on local conditions: space available for plant growth, in relation to existing or project infrastructures, and environmental and local conditions.

TYPE OF SOIL AND PRESENCE OF GROUNDWATER

The soil chemical-physical characteristics must be compatible with the plant and tree species selected; in case of salt-affected shallow groundwater (possible contact with the roots), check that the trees are compatible.

PLANT SPECIES

When choosing the tree species, the following aspects should be considered:

- MAXIMUM DEVELOPMENT SIZE OF THE TREE CANOPY, which must be compatible with the available space;
- PLANTING LAYOUT it depends on the specific site and on the goals to be achieved;
- DISTANCE BETWEEN THE TREES, which should be generally defined based on the long-term layout (with the canopies fully developed), and should take into account the light needs of the spaces and surrounding areas;
- SHAPE, COLOUR, STRUCTURE AND SEASONAL VARIATIONS of the trees can significantly affect the garden's appearance.

The garden of Potters Fields Park in the Southwark district of London. (Project and photo by Piet Oudolf)

PUBLIC USAGE

Tree-filled gardens are green urban spaces that promote social aggregation, offer rest and relaxation areas, are shielded against noise and traffic, and promote an increased environmental comfort.

MAINTENANCE

Maintenance on the lawn and planted areas consists in periodical mowing and pruning activities, replacement of dead plants, and removal of debris, sediments and weeds.
The maintenance interventions' frequency also depends on the type of area where the garden is located (residential, suburban, backland, etc.) and on its use.
Maintenance costs are low, since the frequency of the interventions is limited, and they can often by carried out while maintaining adjoining public and road spaces, with very little increases

INDICATIVE COSTS

Indicative costs comprise:

- 10-20 euro/sqm for paving the surface (for mineral systems);
- 120-150 €/sqm for green areas and irrigation system.

18

PERMEABLE MINERAL PARKING LOTS
filter and drain urban rainwater

Parking lots are generally asphalted and impermeable, and often uncomfortable, due to the heat island effect and the concentration of high pollution levels. These public or private spaces can be redesigned with alternative solutions, which are often less costly and have less impact on the water cycle and on the environment. The adoption of draining and permeable/semi-permeable materials, and the introduction - where pertinent - of permeable and filtering green areas, promotes the reduction of their environmental impact and improves the climatic comfort.
There is a wide range of materials available to ensure both high performance levels (based on the expected loads) and an increased infiltration.

The purpose of permeable mineral parking lots is to:
- promote infiltration into groundwater and reduce flood peaks;
- remove pollutants through filtering and biological absorption mechanisms performed by plant species used in rain gardens or swales;
- reduce noise with sound-absorbing paving and green components;
- reduce the heat island effect with the use of light-reflecting paving, green elements and shading trees;
- increase biodiversity through green elements.

The NSE Kitakyushu Technology Center parking lot in Fukuoka, Japan. (Landscaping project and photo by PLATdesign)

Private company parking lot in Sint-Pieters-Woluwe, Brussel. (Project by Pauwels)

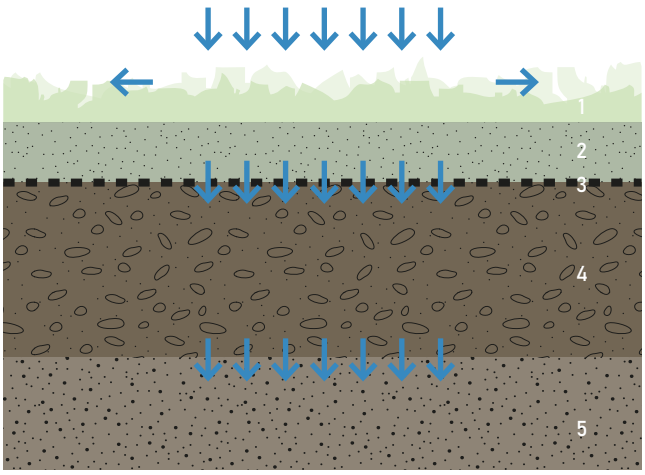
CONSTRUCTION ASPECTS

Permeable mineral parking lots can be created by transforming existing parking areas, depaving (impermeable) surfaces) and identifying one or more permeable materials for roads, parking spaces and connecting paths.
The possibility of infiltrating rainwater into the subsoil depends on the type and entity of vehicle traffic (i.e. on the expected pollution load), and on the (vulnerable) groundwater characteristics. Permeable mineral parking lots should not be implemented, in the case of particularly intense vehicle traffic, in context with risk of pollutant spillage, and in aquifer vulnerability conditions.
The material and subfloor should be selected on a case-to-case basis, considering the traffic category (in order to ensure a suitable pavement-bearing capacity) and the level of desired groundwater infiltration. In order to meet both the structural and hydraulic requirements, the surface paving and road foundation need to be suitably designed.
In addition, sound-absorbing (to improve the acoustic climate) and light-reflecting (to reduce the heat island effect) materials should be employed. For the latter category, preference should be given to so-called “cool materials”, characterized by a high level of solar reflection, obtained through the use of light hues or darker colours, treated with special reflective pigments that help reduce the thermal load.

- TRAFFIC drainage asphalt and/or concrete can be used; a suitable sublayer should be implemented, to promote groundwater infiltration (filtering layers) and the road structure stability, based on the expected loads.
- PARKING SPACES apart from drainage asphalt or concrete, more permeable finishes - such as green gravel, cement blocks or plastic grids - can be used in the parking spaces.
- PEDESTRIAN/BICYCLE PATHS permeable paving can be used, such as dirt roads, filtering blocks, stabilized soil, etc.

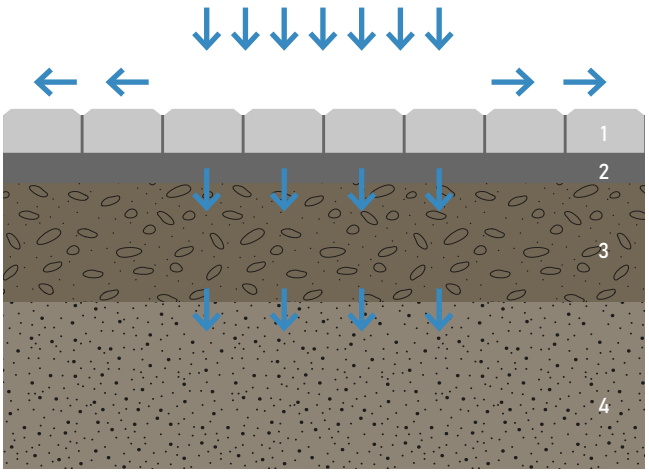
Where possible, paving covered with grass should be preferred, for an improved water purification effect. Apart from the paving filtering effects, groundwater infiltration can be improved by adding trench drains and/or wells.

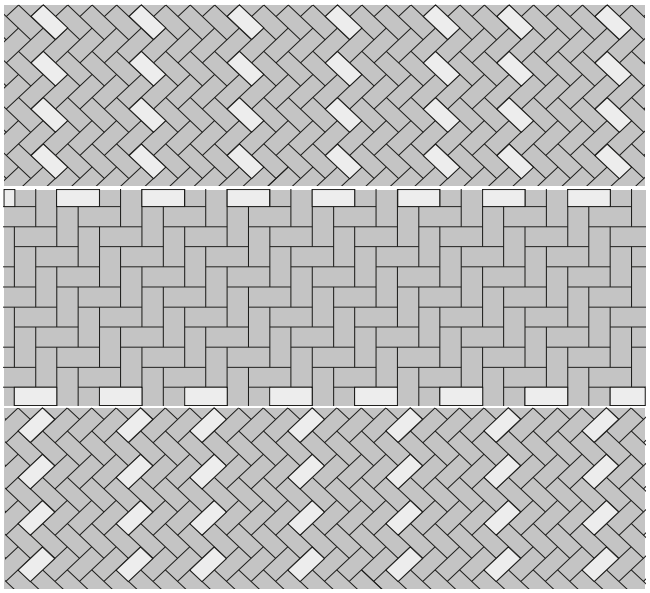
Different uses of permeable materials for the realization of a draining mineral parking: on the left, the option foresees revered gravel parking spots and draining asphalt or concrete for the driveway; the right option has parking spots and driveway in draining and filtering betonelles.



PARKING SPOTS IN GREEN GRAVEL FLOORING
AND DRIVEWAY IN DRAINING ASPHALT OR CONCRETE

1. Meadow
2. Greennatural sunflower - 8 cm
3. Geotextile in non-woven fabric
4. Stabilized granular mixture - 30 cm
5. Sand - 20 cm

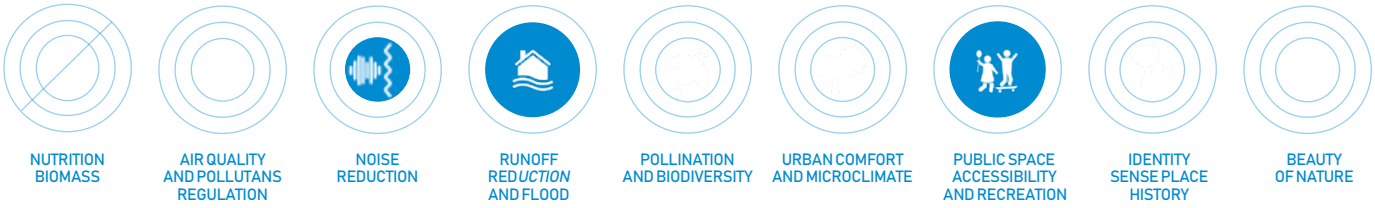




PARKING SPOTS AND DRIVEWAY REALIZED WITH DRAINING PAVEMENT
AND FILTERING BETONELLES

1. Betonelle - 6/8 cm
2. Breastfeeding - 5 cm
3. Stabilized - 20cm
4. Sand - 30cm

ECOSYSTEM SERVICES PROVIDED



In case of high traffic and polluted runoff water (e.g. the parking lot of a mall), or where regional or local regulations require it, a pre-treatment system with first rainfall and oil separator system (or an equivalent phyto-purification system) should be implemented. To this end, the groundwater vulnerability level should also be taken into account.

APPLICATION CONTEXTS AND LIMITS

In residential areas, the first rainfall treatment system is generally not required, and materials that infiltrate water directly into the subsoil can be implemented.
In commercial/production areas, depending on the level of pollution and traffic, a first rainfall treatment system may be necessary.

SPACE REQUIRED

Choosing suitable drainage or semi-permeable materials ensures the same parking lot performance as with traditional materials (asphalt), albeit with a significantly reduced impact on the water cycle and improved environmental comfort

TYPE OF SOIL AND PRESENCE OF GROUND WATER

Permeable soil is recommended (if a set rainfall infiltration quantity performance level is required), as well as groundwater distance of at least 1 meter from the drainage layers, to promote a good level of pollution reduction.

PLANT SPECIES

Where the available space allows it, traffic and parking spaces should be integrated with accessible green areas between the lots or on the perimeter, to reduce atmospheric and rainfall pollution, increase biodiversity and limit the heat island effect.
If the space is limited, tree boxes can still be implemented, e.g. every 4-5 parking spaces, between two adjoining lines, without stealing any space from parking areas, albeit improving shade.

PUBLIC USAGE

Mineral parking lots ensure a significantly higher environmental comfort than traditional parking lots made with impermeable materials.

MAINTENANCE

The use of drainage or semi-permeable surfaces requires a periodical assessment of the surface conditions (to ensure it is free from debris and sediments) and of its infiltration capacity. Periodical leaf sweeping and aspiration is required, to prevent gap occlusion with consequent hindrance to subsoil infiltration.
Maintenance costs are low, since interventions are infrequent and can be carried out at the same time as those in adjoining public and road spaces.
The use of trench drains, wells or other infiltration solutions may increase the infiltration system maintenance costs (filtering layer effectiveness assessment, perforated pipe inspection and cleaning, etc.).

INDICATIVE COSTS

Indicatively, construction costs are:
- 80-100 euro/linear meter for filtering drains (for a 1 sqm portion trench);
- 1,500-2,000 euro/each dry well (well diameter: 2.0 m, and depth: 2.5 m);
- 70-80 euro/sqm for drainage asphalt and concrete used on roadways;
- 40-50 euro/sqm for green gravel for parking spaces;
- 80-100 euro/sqm for porous cubes and blocks for parking spaces and/or pedestrian/bicycle paths;
- 30 euro/sqm for dirt roads or compacted soil for pedestrian/bicycle paths.

19

GREEN PARKING LOTS
store, purify and infiltrate urban rainwater

Parking lots are generally asphalted and impermeable, and often uncomfortable, due to the heat island effect and the concentration of high pollution levels. These spaces can be redesigned and redeveloped to increase their climatic comfort, and make them suitable for tackling climate change. For this reason, reintroducing a suitable green portion to promote soil desealing by replacing widespread impermeable surfaces (generally asphalt and concrete) with permeable or semi-permeable layers is essential.

The purpose of green parking lots is to:
- promote groundwater infiltration and reduce peak floods, with trench drains, dry wells, rain gardens, swales or drainage surfaces;
- remove pollutants through filtering and biological absorption mechanisms performed by plant species by adding rain gardens or swales;
- reduce pollution thanks to plant species that help decrease the level of fine particles;
- reduce noise with sound-absorbing paving and green elements;
- reduce the heat island effect with the use of light-reflecting paving, green elements and shading trees;
- increase biodiversity through green elements.

Honfleur Normandy Outlet parking lot, France. (Project by Edouard François).

Zenith Music Hall parking lot in Eckbolshein, Strasburg, France.(Architectural project by Studio Fuksas, landscaping project by Emmanuel MORO landscape designer)

CONSTRUCTION ASPECTS

Green parking lots (in whole or in part) can be created also on existing parking grounds, by implementing a great variety of solutions. In general, the essential components of a green parking lot are:

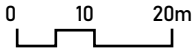
- GREEN AREAS, all the leftover, marginal or perimeter spaces that can be made permeable with green flowerbeds used as rain gardens, swales, trench drains or drainage tree boxes; in the design stage, promoting the parking lot direct runoff flow toward these infiltration areas is essential, as well as ensuring suitable shade by planting trees;
- DEPAVING AND RE-PAVING IMPERMEABLE SURFACES, by removing impermeable materials, such as asphalt and concrete, and replacing them with permeable and (possibly) sound-absorbing (to improve the acoustic climate) and light-reflecting (to reduce thermal heat and the heat island effect) materials.

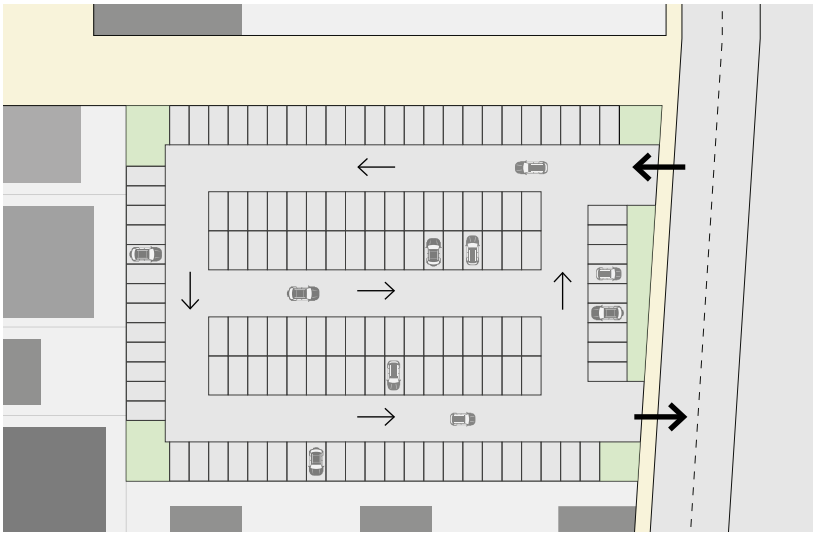
Road traffic and pedestrian/bicicle areas can be treated with different materials and design solutions.

- TRAFFIC drainage asphalt and/or concrete can be used; a suitable sublayer should be implemented, to promote groundwater infiltration (filtering layers) and the road structure stability, based on the expected loads.
- PARKING SPACES apart from drainage asphalt or concrete, more permeable finishes - such as green gravel, cement blocks or plastic grids - can be used in the parking spaces.
- PEDESTRIAL/BICYCLE PATHS permeable paving can be used, such as dirt roads, filtering blocks, stabilized soil, etc.

In case of high traffic and polluted runoff water (e.g. the parking lot of a mall), or where regional or local regulations require it, a pre-treatment system with first rainfall and oil separator system (or an equivalent phyto-purification system) should be implemented. To this end, the groundwater vulnerability level should also be taken into account.

Planimetric plans for transforming mineral car parks into areas equipped for parking with green areas and use of semi-permeable materials.

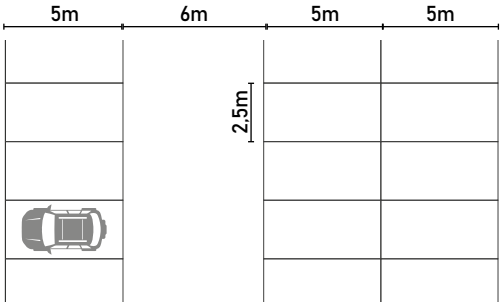


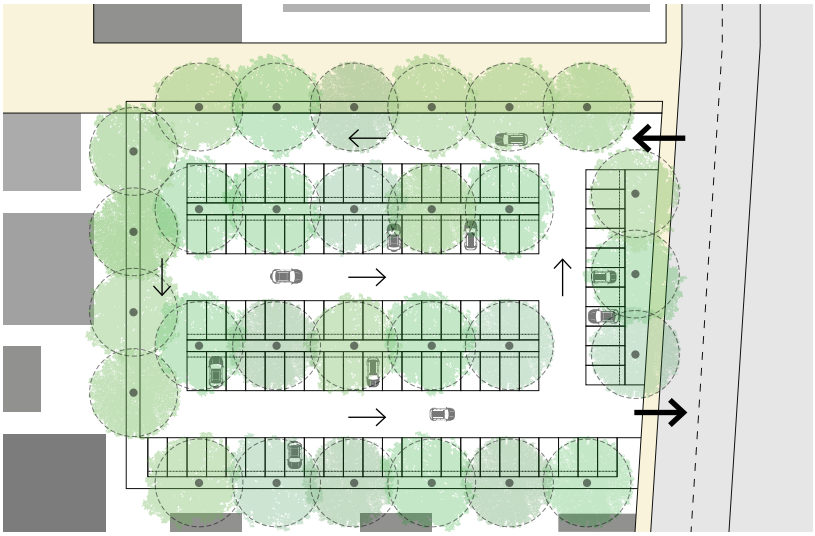


mineral: 95% - green: 5% - shade: 0%

ASPHALT MINERAL PARKING

Traditional parking on asphalt without trees with 135 spots.

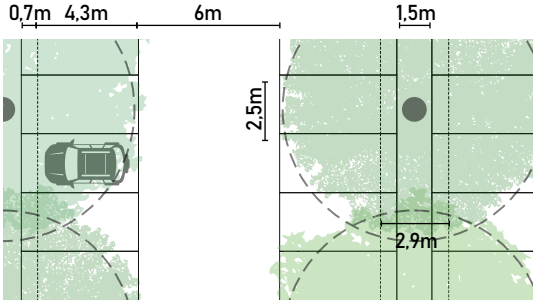




mineral: 80-85% - green: 15-20% - shade: 80-85%

PARKING AREA WITH RAINGARDENS

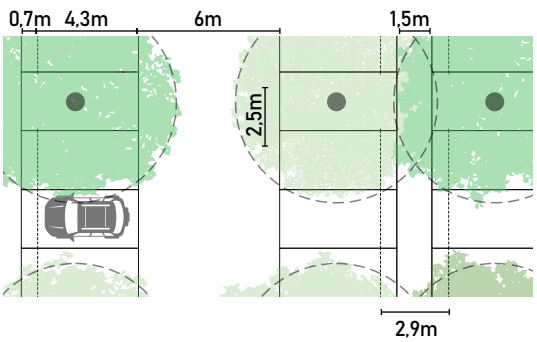
Following a desealing operation, tree-lined rain gardens are inserted and parking spaces are optimised and reduced to 107 spots. The driveways are made with draining asphalt while the parking sposts with green gravel or betonelles.



mineral: 70-75% - green: 25-30% - shade: 70-75%

PARKING AREA WITH INFILTRATION TRENCHES AND BIOSWALES

Following a de-sealing operation, vegetated bioswales and infiltration trenches with trees are inserted between the parking spots, that are optimized and reduced to 74 spots. The driveways are made with draining asphalt while the parking spots with green gravel or betonelles.



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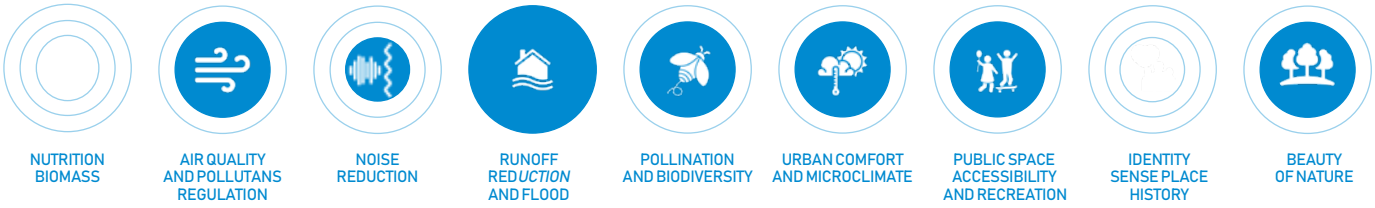


APPLICATION CONTEXTS AND LIMITS

In residential areas, no first rain water treatment is required; while in commercial/production areas, based on the level of pollution and traffic, a first rainfall treatment system may be necessary.

SPACE REQUIRED

For the same parking spaces, a tree-lined parking lot requires a greater surface (approx. +15%) than a parking area without trees.

TYPE OF SOIL AND PRESENCE OF GROUND WATER

Permeable soil is recommended (if a set rainfall infiltration quantity performance level is required), as well as groundwater distance of at least 1 meter from the drainage layers, to promote a good level of pollution reduction.

PLANT SPECIES

The green project depends on the selected solutions (green and tree flowerbeds, swales or rain gardens). Recommended plants: size two or three class trees with rapid growth, capable of surviving in a polluted environment and ensuring suitable shading.

In order to ensure a suitable level of water pollutant reduction, the filtering layer between the drainage medium and groundwater should be at least 1 meter deep.

A careful selection of plants promotes the depolluting effect (reduction of fine particles, water phytopurification), increases the landscape value and biodiversity, and reduces the heat island effect.

PUBLIC USAGE

Mineral parking lots ensure a significantly higher environmental comfort than traditional parking lots made with impermeable materials.

MAINTENANCE

Maintenance is performed on:

- green areas; based on the project, a traditional ordinary maintenance level may be required (with mowing to prevent the proliferation of invasive species and inspections to check the plants conditions), or a more specific maintenance level (to assess the infiltration systems effectiveness - filtering layers and drainage channels - and the phyto-purifying species conditions);
- areas paved with draining surfaces, to assess (and restore by sweeping and vacuuming) the pavement conditions (which must be free from debris and sediments) and infiltration capacity.

Maintenance costs for paved areas are low, since interventions are not very frequent and can be carried out at the same time as those in adjoining public and road spaces. The implementation of infiltration/phyto-purification green areas (such as rain gardens or trench drains) may require higher maintenance costs, related to the infiltration systems and plant species.

INDICATIVE COSTS

- 30-40 euro/sqm for swales without filtering layer;
- 50-100 euro/sqm for rain gardens;
- 80-100 euro/linear meter for filtering drains (for a 1 sqm portion trench);
- 1,500-2,000 euro/each dry well (well diameter: 2.0 m, and depth: 2.5 m);
- 70-80 euro/sqm for drainage asphalt and concrete used on roadways;
- 10 euro/sqm lawn.

20

TREE-LINED MINERAL SQUARES
create comfort, shade and well-being for socialization

Often, urban squares have impermeable mineral pavings, lack any green or natural elements and are not comfortable, both due to the heat island effect, and to the concentration of high pollution levels.
(Re) designing these public spaces with solutions focused on natural elements - with colourful trees and plants, different level of noise and shade - is possible, to encourage people to cross them and spend time there.
Choosing the right materials is also important: draining, permeable/semi-permeable (to reduce weather flows), sound-proofing (to improve acoustic climate), and light-reflecting (to reduce the heat island effect) materials should be preferred.
The combined effect of green and suitable materials helps create welcoming public spaces with an improved microclimate that can be accessed by citizens.

Tree-lined squares help:
- promote groundwater infiltration and reduce peak floods, with trench drains, dry wells, or drainage surfaces;
- remove pollutants through filtering and biological absorption mechanisms by plant species;
- reduce noise with sound-absorbing paving and green components;
- reduce the heat island effect with light-reflecting paving and shading trees;
- increase biodiversity with trees and green elements.

Place de la République, Paris. (Landscaping project by TVK / Trévelo & Viger-Kohler with Martha Schwartz Partners, photo by Clement Guillaume).

Place des Célestins in Lyon. The square was redeveloped was carried out between 1993 and 1996 following the construction of a parking lot below. On that occasion magnolias, bushes and dense hedges were planted to protect the square from the starda and cars. It is one of the liveliest squares in Lyon, where locals and tourists love to rest in company. During the spring the square turns pink thanks to magnolias and the blooming of the magnolias. (Project by Christine Dalnoky and Michel Desvigne, photo by Elena Farnè)

CONSTRUCTION ASPECTS

Tree-lined mineral squares can be implemented also on existing public spaces, by desealing (impermeable) surfaces and identifying one or more permeable materials to cover them.
The material and subfloor should be selected on a case-to-case basis, considering the traffic category on vehicle-accessible areas (in order to ensure a suitable pavement bearing capacity and assess the need to introduce a first-rain treatment system) and the level of desired groundwater infiltration. In order to meet both the structural and hydraulic requirements, the surface paving and road foundation need to be suitably designed.
In addition, sound-absorbing (to improve the acoustic climate) and light-reflecting (to reduce the heat island effect) materials should be employed. Among these, the so-called cool materials should be preferred, thanks to their high solar reflectance level.

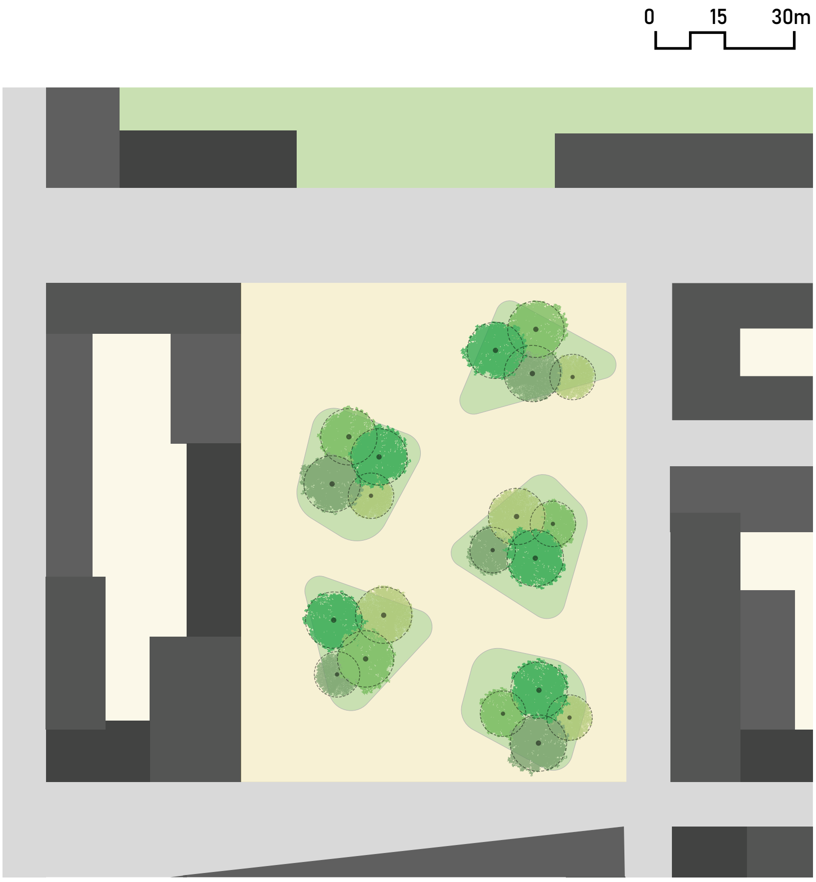
Concerning the trees, the species selected should be pollutant resistant and should be arranged at such a distance as to ensure a suitable shade and the space required for roots growth.

In depaving and repaving impermeable surfaces, permeable and, if possible, sound-absorbing and light-reflecting materials should be employed (widely available on the market), in place of impermeable materials such as asphalt and concrete. To this end, see the drainage surfaces datasheet.

APPLICATION CONTEXTS AND LIMITS

In residential areas, the first rainfall treatment system is generally not required, and materials that infiltrate water directly into the subsoil can be implemented.
In commercial and production areas, depending on the level of pollution and traffic, a first rainfall treatment system may be necessary.

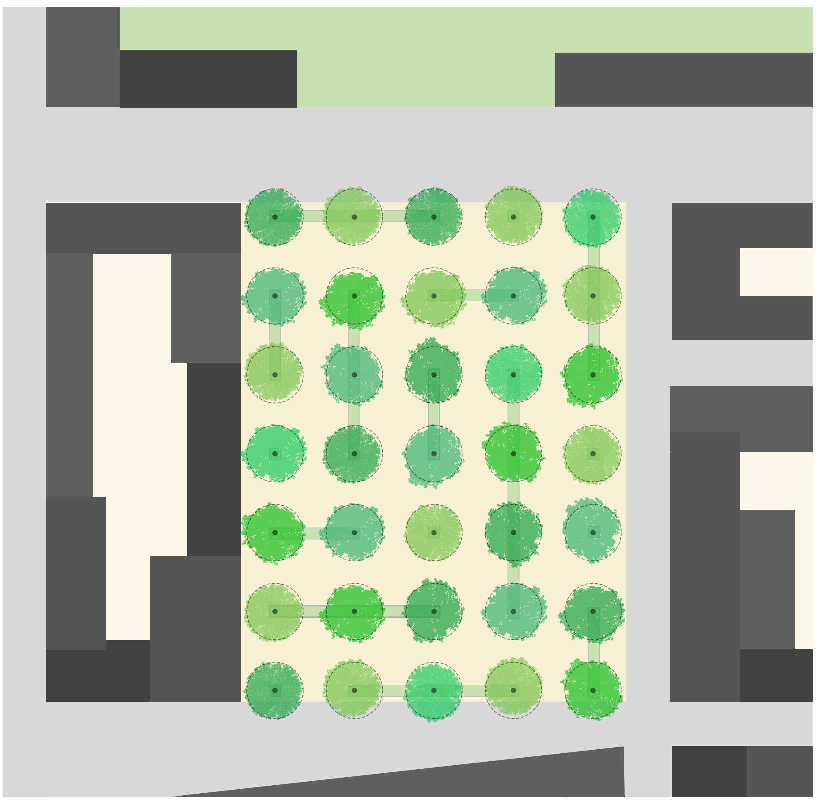
Schematic plan diagrams of tree-planted squares.



mineral surfaces: 60-65%
green surfaces: 35-40%
shaded surfaces: 25-30%

SQUARE WITH GROUPS OF TREES

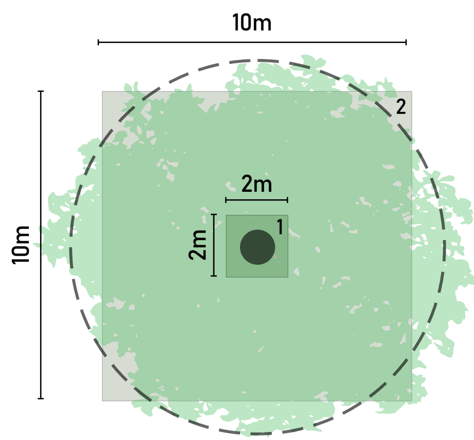
Trees of I and II magnitude are planted in scattered groups distributed on the site of the square. This creates shaded spaces depending on the time of day and areas with different functional connotations.



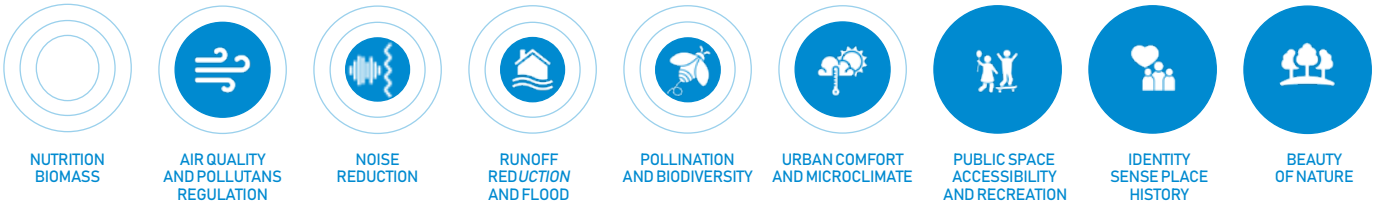
mineral surfaces: 85-90%
green surfaces: 10-15%
shaded surfaces: 45-50%

SQUARE WITH TREES SPREAD OVER THE ENTIRE SURFACE

Trees of I and II magnitude are planted all over the square, thus allowing to completely shade the spaces.



ECOSYSTEM SERVICES PROVIDED



SPACE REQUIRED

Choosing suitable drainage or semi-permeable materials ensures complete access to the spaces, albeit with a significantly reduced impact on the water cycle and improved environmental comfort

TYPE OF SOIL AND PRESENCE OF GROUNDWATER

Permeable soil is recommended (if a set rainfall infiltration level is required), as well as groundwater distance of at least 1 meter from the drainage layers, to promote a good level of pollution reduction.

PLANT SPECIES

The project must integrate functional areas for public events, resting and strolling, with green areas and trees providing suitable shade.
If space is limited, tree boxes can be implemented, instead of green flowerbeds, so as to preserve strictly functional areas.
The implementation of green spaces helps reduce atmospheric pollution and rainwater, increase biodiversity and lessen the heat island effect.

PUBLIC USAGE

Tree-lined mineral squares ensure a higher level of environmental comfort, compared to impermeable squares (asphalt, concrete, cement blocks or blocks with closed grouts), especially due to the beneficial effect promoted by trees, which create pleasant shaded resting areas. In addition, the wide range of draining or semi-permeable materials for the different areas improves the environmental benefits (reduction of the heat island effect and runoff), by combining aesthetic/architectural and functional needs.

MAINTENANCE

The use of draining or semi-permeable surfaces requires regular inspections of the paving conditions (it must be free from debris and sediments) and of its infiltration capacity, and regular sweeping and vacuuming of leaves and debris, to prevent occlusions that could hinder infiltration into the subsoil.
In addition, trees must be regularly pruned and their growth kept in check.
Maintenance costs are low, since intervention frequency is limited, and they can often be carried out while maintaining adjoining public and road spaces, with very little increase in costs.
The use of trench drains, dry wells or other infiltration solutions may require high infiltration system maintenance costs (filtering layer effectiveness assessment, perforated pipe inspection and cleaning, etc.).

INDICATIVE COSTS

Indicatively, construction costs include:
- 50-100 euro/sqm for rain gardens;
- 80-100 euro/linear meter for filtering drains (for a 1 sqm portion trench);
- 1,500-2,000 euro/each dry well (well diameter: 2.0 m, and depth: 2.5 m);
- 30 euro/sqm for dirt roads/compacted soil;
- 70-80 euro/sqm for drainage asphalt and concrete;
- 80-100 euro/sqm for porous cubes and blocks.

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TREE-LINED MINERAL SQUARES
accommodate temporary uses and weekly markets

Mineral squares that house temporary events or weekly markets can be designed with green elements and paving so as to reduce the environmental discomfort caused by the heat island effect and by high levels of pollution.
Trees and plants have an essential role in creating comfortable and attractive spaces that make people want to pass by and stop.
The use of draining and permeable/semi-permeable materials helps reduce rainfall flows, while sound-absorbing materials improve the acoustic climate and light-reflecting materials help reduce the heat island effect.
The combined effect of green and suitable materials helps create welcoming public spaces with an improved microclimate that can be accessed by citizens.

Tree-lined/semi-lined squares for temporary uses help:
- promote groundwater infiltration and reduce peak floods, with trench drains, dry wells, or drainage surfaces;
- remove pollutants through filtering and absorption mechanisms by plant species;
- reduce noise with sound-absorbing paving and green components;
- reduce the heat island effect with light-reflecting paving and shading trees;
- increase biodiversity with trees and green elements.

Pittsburgh public market, re-opened in 2010, after repaving the square and reorganizing vehicle traffic. (Photo by Market Square PGH Blog).

Lubiana central market in Vodnik square, the largest public market in the city. Apart from the square, the stalls occupy a Renaissance-style building designed for this purpose by architect Jože Plečnik in 1931-1939.
(Photo by Charlie/Flickr)

CONSTRUCTION ASPECTS

Tree-lined squares for temporary uses can be implemented also on existing public spaces, by switching to draining or semi-permeable materials and adding green areas and trees. In the case of squares used for markets, further measures should be adopted in the planning phase, to take into account the specific needs of street vendors and temporary exhibitors. In particular:

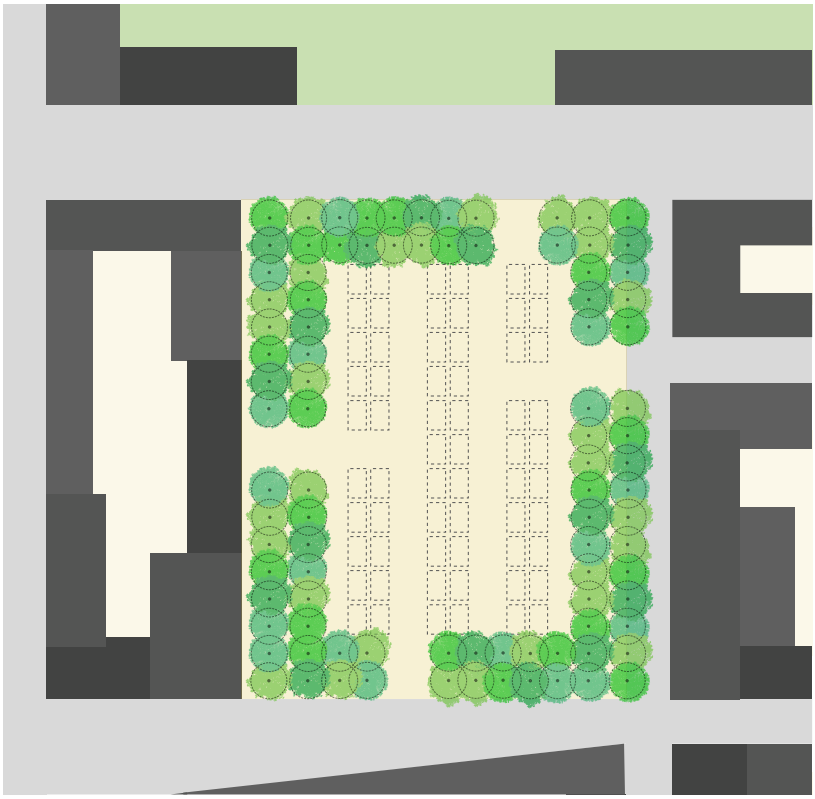
- TREES planted with a suitable distance to allow stand positioning; choosing species with a tall structure and umbrella-shaped canopies, to exploit the lower area surrounding the trunk; and taking into account possible damage caused by vehicles, by protecting the trunk with barriers made of different materials;
- SOILING ACTIVITIES, albeit temporary, can affect the quality of rainwater and washing activities flowing into the sewage system; in case of surfaces being washed and/or subject to the risk of vehicle liquid leakage, a separated first rainwater collection and management system should be implemented, avoiding the use of semi-permeable and drainage materials.

For those surfaces not subjected to pollution risks (e.g. pedestrian walkways, relaxing areas, etc.), drainage or semi-permeable materials with light-reflecting characteristics (cool materials) should be preferred.

Concerning trees and plant species, the species selected should be pollutant resistant and they should ensure suitable shading without interfering with the intended temporary uses.

Floorplan diagrams of tree-lined squares used for temporary events or weekly markets.

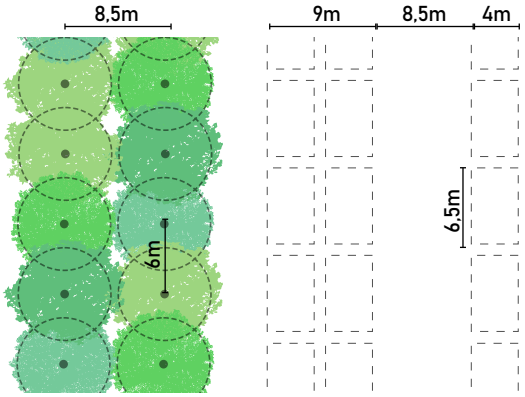
0 15 30m

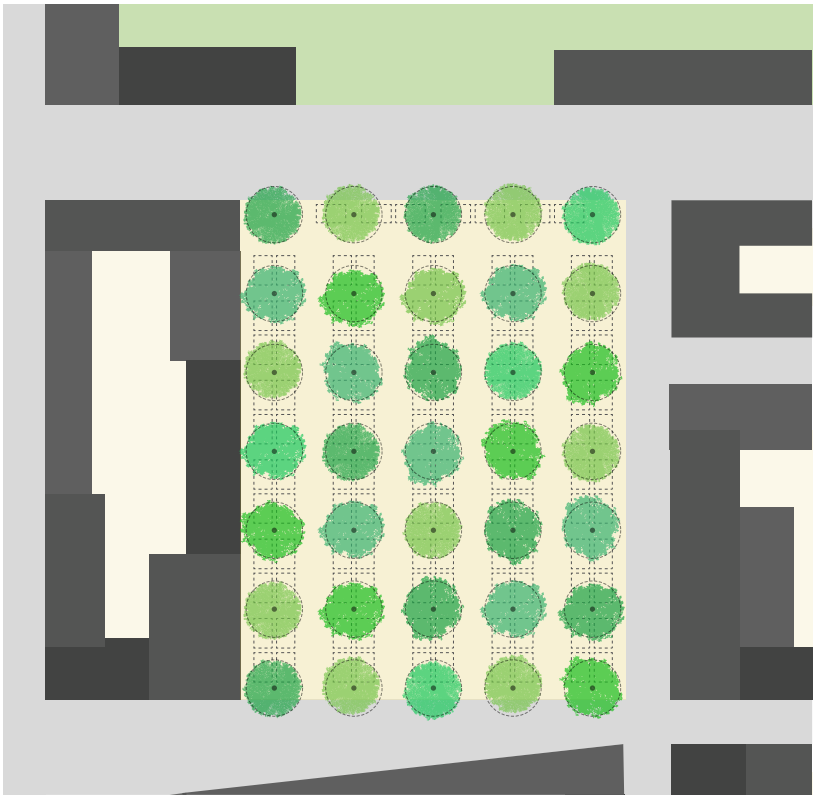


mineral surfaces: 80-85%
green surfaces: 15-20%
shaded surfaces: 45-50%

DOUBLE ROW OF TREES ALONG THE PERIMETER

The rows along the perimeter are made of trees II dimension trees that allow to shade the edges of the square at different times of the day, while the central portion remains free to set up markets or to organize temporary events that need large free areas.
The double rows are discontinuous at the main driveways, so as to allow temporary access to the square to vans or vehicles.
The mineral surfaces can be realized with draining materials.

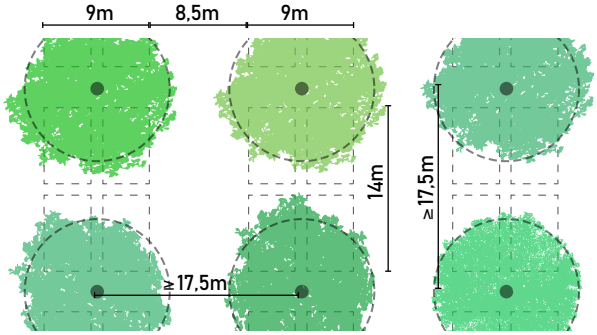




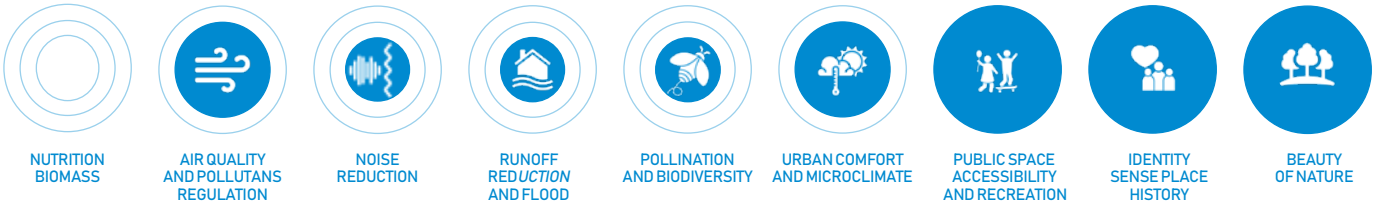
mineral surfaces: 90-95%
green surfaces: 5- 10%
shaded surfaces: 45-50%

SQUARE WITH TREES SPREAD OVER THE ENTIRE SURFACE

Trees of I dimension are planted all over the square at a distance that allows temporary access to vans or vehicles.
The mineral surfaces can be realized with draining materials.



ECOSYSTEM SERVICES PROVIDED



APPLICATION CONTEXTS AND LIMITS

Based on the presence of "soiling activities" (even temporary), a first rainfall treatment system may be required;

SPACE REQUIRED

Planting trees in a mineral square helps improve environmental comfort and ensures the use of the areas for temporary markets and other activities

TYPE OF SOIL AND PRESENCE OF GROUND WATER

Check the presence of permeable soil (if a set rainfall infiltration level is required), and groundwater distance of at least 1 meter from the drainage layers, to promote a good level of pollution reduction. For those areas that will house "soiling activities" (such as food markets), impermeable materials should be used, to prevent infiltration into the subsoil and create a first rainfall collection and processing network.

PLANT SPECIES

In the areas used for market activities or other temporary uses, flowerbeds or tree boxes can be implemented at such distances to ensure the right level of shade and leave enough space for stands and practicability in-between.

Trees should have a tall structure and umbrella-shaped canopies, to exploit the lower area surrounding the trunk.

The implementation of green spaces helps reduce atmospheric pollution, increases biodiversity and lessens the heat island effect.

PUBLIC USAGE

Tree-lined market squares ensure better environmental comfort than impermeable squares (asphalt, concrete, cement blocks or blocks with closed grouts), by creating shaded and welcoming areas that can be accessed by the citizens.

MAINTENANCE

The use of draining or semi-permeable surfaces for "non-soiling" areas requires regular inspections of the paving conditions (which must be free from debris and sediments) and of its infiltration capacity, and regular sweeping and vacuuming of leaves and debris, to prevent occlusions that could hinder infiltration into the subsoil.
In addition, trees must be regularly pruned and their growth kept in check, to ensure the necessary space for the market or other stalls and stands.
Maintenance costs are low, since the frequency of the interventions is limited, and they can often by carried out while maintaining adjoining public and road spaces, with very little increase in costs.
The use of trench drains, dry wells or other infiltration solutions may require high infiltration system maintenance costs (to check the filtering layer effectiveness or inspect and clean perforated pipes).

INDICATIVE COSTS

Indicatively, construction costs include:
- 50-100 euro/sqm for rain gardens;
- 80-100 euro/linear meter for filtering drains (for a 1 sqm portion trench);
- 1,500-2,000 euro/each dry well (well diameter: 2.0 m, and depth: 2.5 m);
- 30 euro/sqm for dirt roads/compacted soil;
- 60-70 euro/sqm for traditional asphalt for "soiling areas";
- 70-80 euro/sqm for drainage asphalt and concrete;
- 80-100 euro/sqm for porous cubes and blocks.

22

TREE-LINED STREETS
shade pathways and parking spaces

Avenues and road networks in general are usually almost completely impermeable, and they lack green areas, except in marginal or leftover spaces.
The road - beyond its mere function as a vehicle traffic infrastructure, including also pedestrian/bicycle paths - can be designed as a "green network" resilient to climate change, with shaded avenues that can help contrast the heat island effect and reduce pollution.

Trees planted along the road networks bring with them many benefits:
- ⇢ they create shaded and attractive paths for pedestrians and cyclists, improving sustainable mobility;
- ⇢ they improve air quality by reducing the concentration of fine particles and producing new oxygen;
- ⇢ they help promote rainwater infiltration;
- ⇢ they improve path safety, by acting also as "slow-down islands" and physical barriers between road and pedestrian viability;
- ⇢ they reduce vehicle traffic noise.
- ⇢ they are connection elements for the city habitat and increase urban biodiversity.

Grand Boulevard on Constitution Avenue, Canberra, Australia (Landscaping project by Jane Irwin Landscape Architecture, photo by John Gollings)

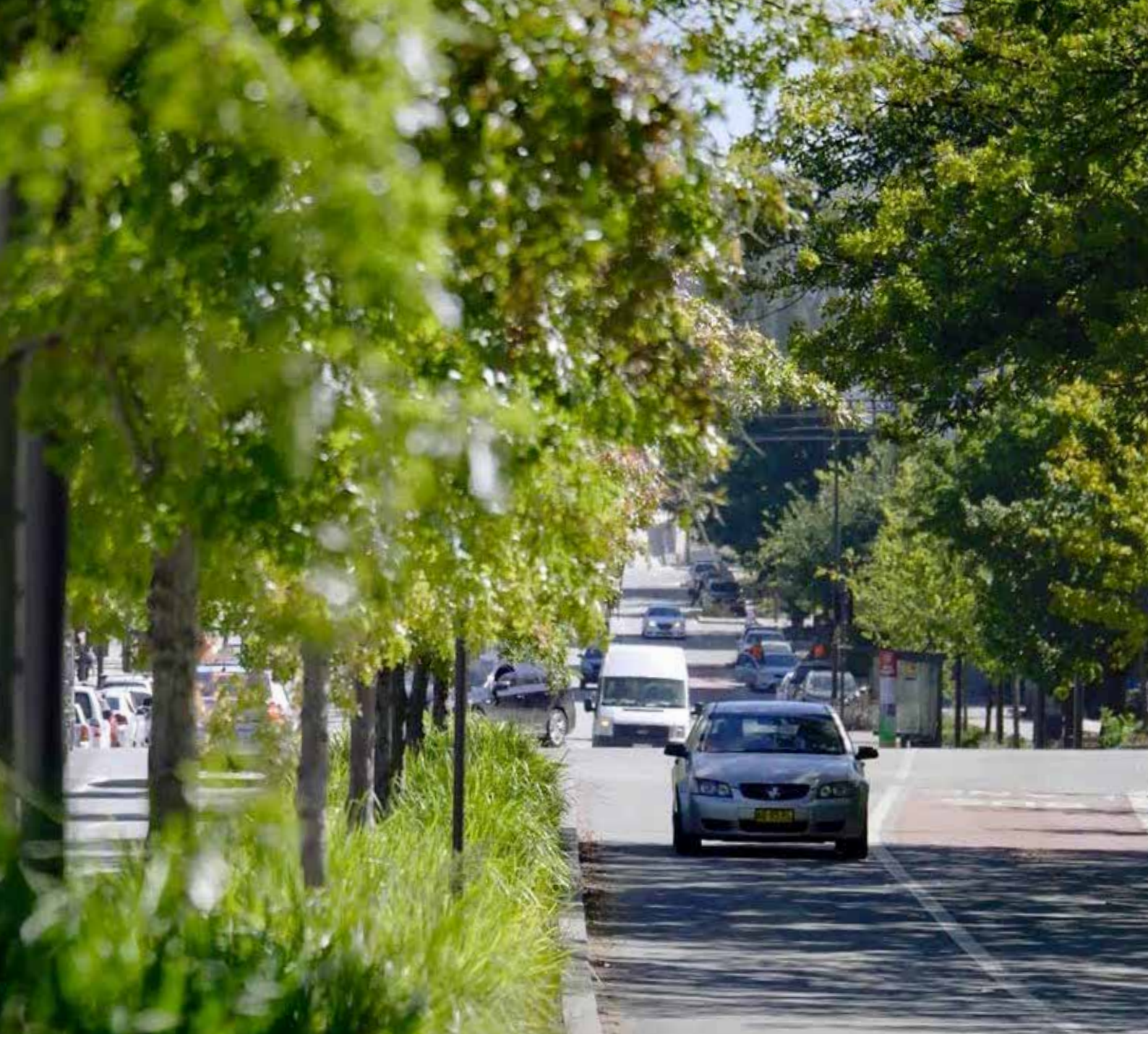
Redevelopment of the streets of the district of the satzione in the city of Le-Mée-sur-Seine, France. The intervention involved extensive reshaping of the road and careful work on the treatment of the border, guaranteeing pedestrians a large, mainly pedestrianized, vegetated and shaded area. (project and photo Agence Laure Planchaise)

CONSTRUCTION ASPECTS

Designing flowerbeds on the roadside requires a multi-disciplinary approach and the integration of different specific skills in mobility, road safety, green design and maintenance, to avoid interferences between mobility and the green infrastructure.
Integrating vehicle space and parking lots with the trees' needs in mind is essential, and trees can be planted, based on the space available and on the goals to achieve:
- ⇢ IN SINGLE ROWS ALONG THE ROAD, interspersed with parking areas, by removing some parking spaces to house tree-filled flowerbeds; for instance, in case of in-line parking lots, a tree should be placed every 2/3 spaces to ensure a good level of shading;
- ⇢ IN SINGLE ROWS ALONG PEDESTRIAN/BICYCLE PATHS, creating linear green flowerbeds to house plant species or inserting point elements;
- ⇢ IN DOUBLE ROWS OR IN CLUSTERS IN THE MIDDLE OF THE CARRIAGEWAY to separate the two directions of travel, or near pedestrian crossings, as traffic separation elements;
- ⇢ IN CLUSTERS to reduce the carriageway width and vehicle speed, e.g. before residential areas/limited speed/traffic areas.

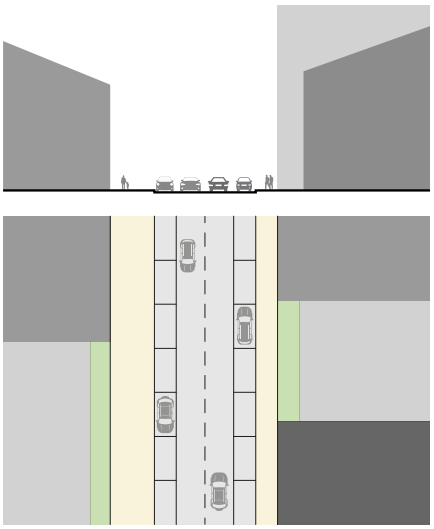
Safe mobility requirements must taken into account when choosing the trees and their layout: species with a shape and growth that ensure suitable visibility, whose canopy does ont hinder the road surface and that can resist different weather conditions (and wind in particular) should be preferred. These measures can help improve a safe, fast (cars, buses, streetcars) and slow (pedestrians and cyclists) mobility, limiting hazardous situations.

Concerning the flood prevention effects, the installation of flowerbeds with trees - following desealing interventions - promotes water infiltration into groundwater, based on the soil infiltration capacity. Water runoff from pedestrian and bicycle paths, and from the roofs can be channelled toward the permeable flowerbeds and green areas, while, in case of high-traffic networks, a first rainfall management system may be required. An overflow system connected to the public sewage system should be implemented, to prevent an excess water flow on the plants.



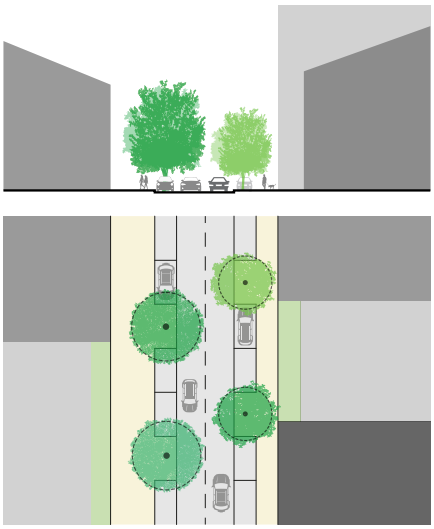
0 5 10m

mineral surfaces: 100%
green surfaces: 0%
shaded surfaces: 0%



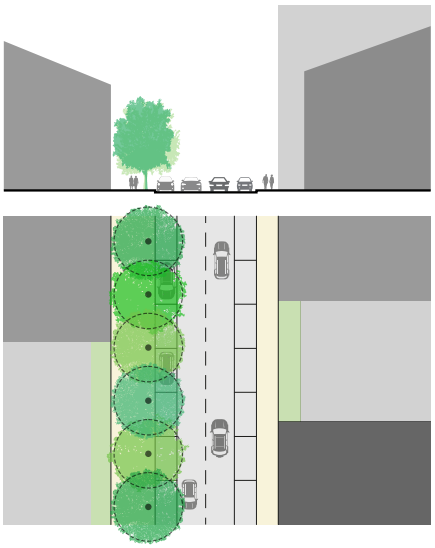
TWO-WAYS ROAD
WITH A SINGLE LANE
AND PARALLEL PARKING
Road section 20m

mineral surfaces: 85-90%
green surfaces: 10-15%
shaded surfaces: 25-30%



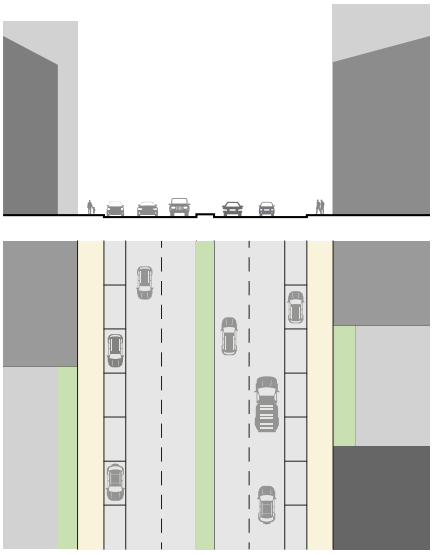
TWO-WAYS ROAD
WITH A SINGLE LANE
AND PARALLEL PARKING
Two rows of 2nd-sized trees are planted along the road interspersed with parkings, eliminating some spots to make space for tree-beds.

mineral surfaces: 80-85%
green surfaces: 15-20%
shaded surfaces: 35-40%



TWO-WAYS ROAD
WITH A SINGLE LANE
AND PARALLEL PARKING
A row of 2st-sized trees is planted on the sidewalk along the driveway creating a continous green area.

mineral surfaces: 90%
green surfaces: 10%
shaded surfaces: 0%



TWO-WAYS ROAD WITH DOUBLE LANES,
CENTRAL SAFETY ISLAND
AND PARALLEL PARKING
Road section 30m

mineral surfaces: 60-65%
green surfaces: 35-40%
shaded surfaces: 50-55%

TWO-WAYS ROAD WITH DOUBLE LANES,
CENTRAL SAFETY ISLAND
AND PARALLEL PARKING
After the reduction of one lane per direction of travel, it is possible to plant a double row of trees in a large central green area that separates the carriageways.

mineral surfaces: 75-80%
green surfaces: 20-25%
shaded surfaces: 50-55%

TWO-WAYS ROAD WITH DOUBLE LANES,
CENTRAL SAFETY ISLAND
AND PARALLEL PARKING
Narrowing the sidewalks on the sides, it is possible to plant a single row of trees in the central green area and two linear rows along the road interspersed with parking spots.

ECOSYSTEM SERVICES PROVIDED

NUTRITION BIOMASS | AIR QUALITY AND POLLUTANS REGULATION | NOISE REDUCTION | RUNOFF REDUCTION AND FLOOD | POLLINATION AND BIODIVERSITY | URBAN COMFORT AND MICROCLIMATE | PUBLIC SPACE ACCESSIBILITY AND RECREATION | IDENTITY SENSE PLACE HISTORY | BEAUTY OF NATURE

The flowerbeds' surface layer can be obtained with different materials, depending on their accessibility and uses: natural (organic soil or loose aggregates) or artificial surfaces (porous and permeable paving). In addition, crossing paths (made of wood or cls blocks) and protection grids or fences can be added, to prevent damage to the tree trunks.

APPLICATION CONTEXTS

In residential areas, a first rainfall management system is usually not required, while it should be implemented in high-traffic and high-speed road networks (limited to the roadside).

SPACE REQUIRED

The volume of soil made available for the tree affects the plant growth.

TYPE OF SOIL AND PRESENCE OF GROUND WATER

Permeable soil and ground water located at least 1 meter away from the bottom of the filtering bed promotes a good level of pollutant reduction.

PLANT SPECIES

In urban contexts, the species selected should be resistant to the relevant environment, while not necessarily native, and characterized by a pediment-, column- or pyramid-like structure, to avoid canopy diametral pruning. In addition, monocultures should be avoided, e.g. using the same species/variety, and multicultural rows should be implemented, to increase biodiversity and limit pest damage and allergies.
In general, those species that survive in polluted contexts and best adapt to flooding conditions or more or less extended periods of drought should be preferred.

PUBLIC USAGE

A tree-lined and shaded avenue improves the microclimatic conditions of the context (de-polluting effect, heat island effect reduction), and encourages pedestrians and cyclists to walk on it and rest, in welcoming and safe spaces (trees can also act as separating elements from the road or as slowing elements in traffic separation flowerbeds).

MAINTENANCE

Regularly pruning the trees and keeping their growth in check is essential to ensure suitable visibility along the road network and preventing the lower canopy section from interfering with the road surface. In addition, the trees' stability must be assessed, especially in windy conditions.
The type of maintenance interventions depend on the surface finishes chosen for tree boxes (natural materials, semi-permeable surfaces, urban furniture finishes, etc.), and on the presence of an irrigation system.
Maintenance costs are low, since they are infrequent and can be carried out at the same time as those in adjoining public and road spaces.
The use of trench drains, dry wells or other infiltration solutions may require high infiltration system maintenance costs (to check the filtering layer effectiveness or inspect and clean perforated pipes).

INDICATIVE COSTS

Indicatively, construction costs include:
- 20-30 euro/sqm for a 1 m deep trench and related disposal;
- 30-40 euro/linear meter for a filtering layer on the bed (approx. 100xH50cm);
- 300-800 euro/sqm for planting size two or three class trees, depending on the species and on the presence of an irrigation system.

23

STREETS WITH RAIN GARDENS
accumulate, infiltrate and purify urban rainwater

Rain gardens are linear or round elements that collect rainwater from roofs, streets, parking lots or squares by using sloping ground.
They can be easily implemented along road networks, in slow-down islands, in the empty areas between parking lot spaces, and along the road.
Rain gardens ensure a high added value in terms of biodiversity, urban aesthetic appearance and improvement of microclimatic conditions; in addition, the presence of trees improves path shading.

Rain gardens along the road help:
- reduce surface runoff and promote infiltration into groundwater;
- remove pollutants through filtering and absorption mechanisms by plant species;
- reduce flood peaks in receptor bodies;
- promote biodiversity and increase the local landscape value;
- reduce the urban heat island effect.

Linear rain gardens separating the carriageway from the bicycle path and sidewalk in Avenue Mermoz, Lyon, France. (Landscaping project by Gautier+Conquet Architects, photo by Fabian Da Costa).

Rain gardens on the roadside in Portland
The road section includes, beyond the roadway, a cycle path, a continuous linear garden - vegetated and tree-lined - and a pedestrian path shaded by trees.
(Project and photo by Metro Transportation Planning and Development)

CONSTRUCTION ASPECTS

Rain gardens are particularly versatile nature-based solutions that can be adapted to different spaces. Their width ranges from 50-60 cm to several metres; for this reason, they can be adapted to any context, to redevelop existing urban areas.
Their purpose is to drain and infiltrate water runoff from the road and pedestrian/bicycle path surface, with suitable measures to allow a uniform distribution of water along its length (e.g. with flush curbs or with raised curbs with frequent openings). The quantity of excess water not infiltrated into the subsoil must be discharged into the public sewage system, through an overflow connection.
Plants that can suitably reduce the pollution load usually present on the road network and survive in a frequent succession of dry and flooded conditions and high soil humidity should be preferred. If the pollution load is significant, a first rainwater management system may be required on the road surface.
If suitably designed, rain gardens along the road help pursue many different goals, such as reducing the risk of floods, improving infiltrated water quality, creating a high added value from a biodiversity and aesthetic standpoint, and encouraging the use of slow mobility paths.

APPLICATION CONTEXTS AND LIMITS

In residential areas, where a first rainwater management system is usually not required, they can also be implemented inside roundabouts, in the green sections along parking lots, along the carriageways to separate vehicle traffic from pedestrian/bicycle paths.
In the case of high-traffic and high-speed networks, a first rainwater treatment system may be required (limited to the road side).

SPACE REQUIRED

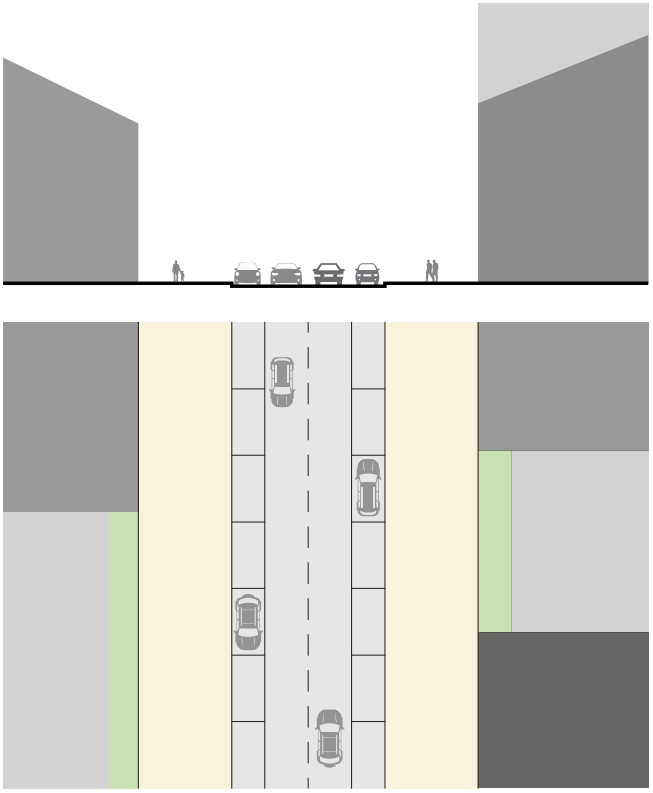
Since they are compact linear elements, they can be well adapted to any space available. They are generally associated with small impermeable surfaces.

TYPE OF SOIL AND PRESENCE OF GROUND WATER

Permeable soil and ground water located at least 1 meter away from the bottom of the filtering bed promotes a good level of pollutant reduction.

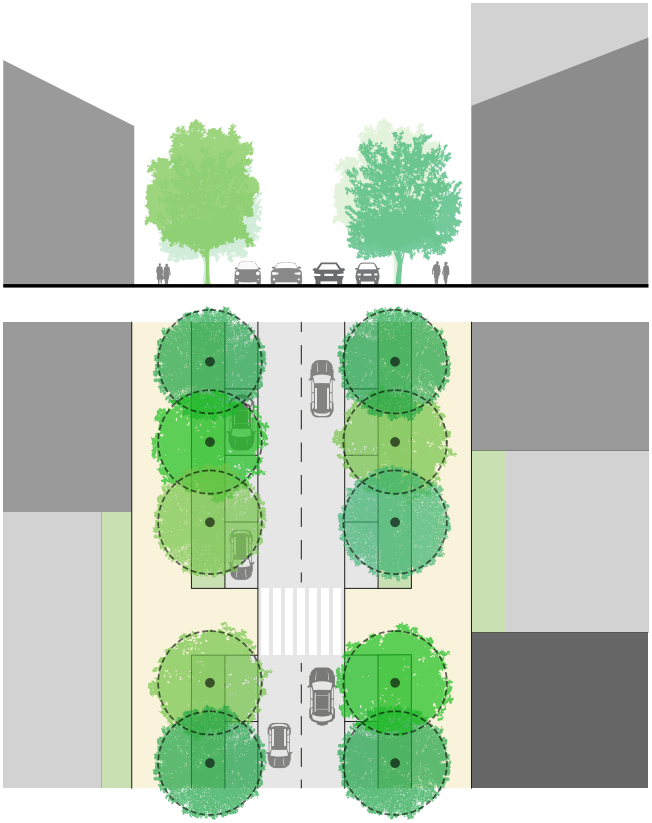
0 5 10m

mineral surfaces: 100%
green surfaces: 0%
shaded surfaces: 0%

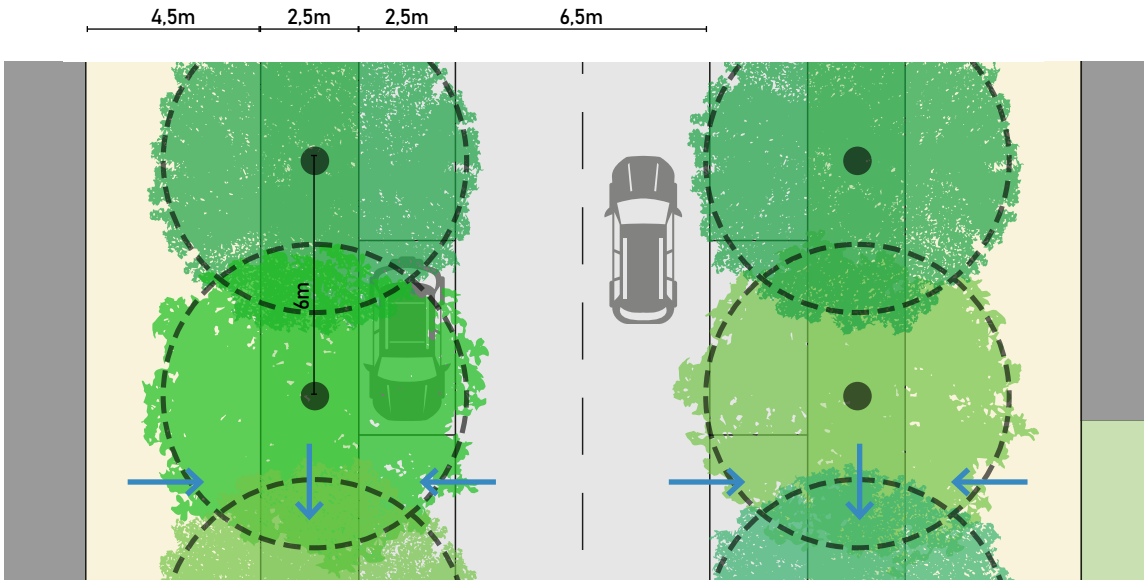


TWO WAYS ROAD WITH SINGLE LANE
AND PARALLEL PARKING
Road section 25,5m

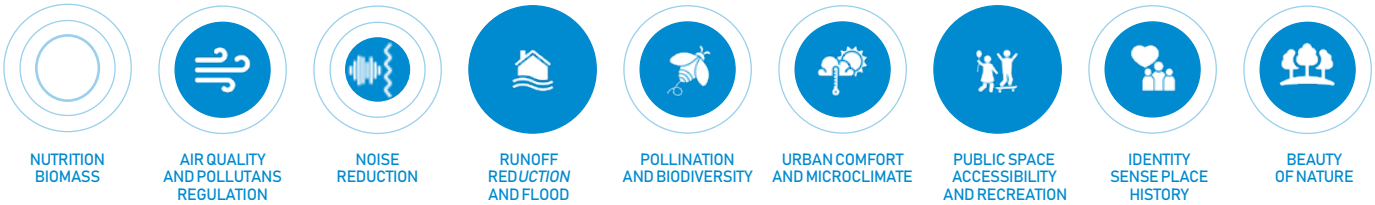
mineral surfaces: 80%
green surfaces: 20%
shaded surfaces: 55-60%



TWO WAYS ROAD WITH SINGLE LANE
AND PARALLEL PARKING
A portion of the sidewalk is desealed to create space for linear rain gardens parallel to the roadway.
Roads and pedestrian paths are designed to facilitate the outflow of rainwater.
The rain gardens are interrupted at the pedestrian crossings.



ECOSYSTEM SERVICES PROVIDED



PLANT SPECIES

The plant species that can be included in a rain garden must be capable of adapting to flooding conditions and droughts, and of surviving in polluted atmospheres. A thick plant system (about 6-10 plants/sqm, based on the species) is needed to improve the density of the root system and promote soil permeability.

In those systems with significant development areas, the different species must be distributed based on their resilience in extreme conditions.

Shrub species are effective thanks to their capillary root system, and because they can be used as green barriers to prevent access, if required.

Choosing the right type of plant depends on the site and on the relevant climatic context.

There are many riparian species to choose from:

- HERBACEOUS PLANTS Impatients noli-tangere, filipendula, marsh fern, iris;
- SHRUBS cornus, frangula, shrub willow, viburnum;
- TREES bald cypress, alder, poplar, willow trees.

PUBLIC USAGE

Rain gardens along the road help improve microclimatic comfort and the wellbeing of the people crossing them, thanks to shaded and attractive paths, that encourage resting and crossing.

MAINTENANCE

The phytopurification system performance and the filtering capacity depend on the maintenance level, with particular attention to plant species.

Maintenance should be thorough in the first few months after creation: the system must be inspected after storms, assessing the quantity of sediments deposited to check the drainage and filtering layers infiltration capacity.

After this initial period, routine maintenance should be performed on a quarterly basis to:

- collect waste (harmful from a visual and landscape standpoint);
- clean the road runoff collection area, to reduce the sediment volume;
- check the plant conditions and prevent the proliferation of invasive species;
- check and clean trench drains (if present) - once a year.

Extraordinary maintenance is performed to replace the mulching and/or the other filtering and drainage layers, in case of clogging.

INDICATIVE COSTS

Indicatively, construction costs include:

- 20-30 euro/sqm to dig a 1 meter deep trench, including disposal and lawn surface finish;
- 30-40 euro/linear meter for a filtering layer on the bed (approx. L100xH50cm);
- 5-30 euro/sqm to plant the species

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PEDESTRIAN AND CYCLE PATHS
protect and shade cyclists and pedestrians

Pedestrian and bicycle paths developed in urban areas can be made with draining or semi-permeable materials, to promote rainwater infiltration into groundwater. The water runoff on these surfaces is 'clean' and does not require special processing, before being directly infiltrated into the subsoil.
Draining or semi-permeable materials can also have light-reflecting (cool materials that help reduce heat retention) and sound-absorbing (to improve the acoustic climate) characteristics. There are several products available on the market to meet the most diverse project needs, such as high performance, cost/effectiveness and aesthetic appeal.
Pedestrian and bicycle paths that adopt these solutions are more comfortable from a climatic standpoint, and more attractive.

The purpose of draining pedestrian/bicycle paths is to:
- promote infiltration into groundwater;
- reduce the urban heat island effect;
- partially reduce flood peaks in receiving bodies;
- promote biodiversity and increase the local landscape value.

On the green Grand Boulevard of Constitution Avenue in Canberra in Australia.
The cycle paths are always protected by a vegetation belt and by a row of trees and shade.
The pedestrian paths are equipped with seats and shaded with flowering trees, fragrant and colorful.
(Landscape project by Jane Irwin Landscape Architecture, photo by John Gollings)

CONSTRUCTION ASPECTS

Permeable surfaces are generally used to drain and infiltrate rainwater from the surface where they are installed.
Therefore, the surrounding conditions and limitations - such as the existing soil infiltration capacity and the water volume that needs to be collected and infiltrated - should be determined in advance.
An overflow sewage system should always be implemented, to receive and discharge the quantities exceeding the reference project event into the sewage system.

APPLICATION CONTEXTS AND LIMITS

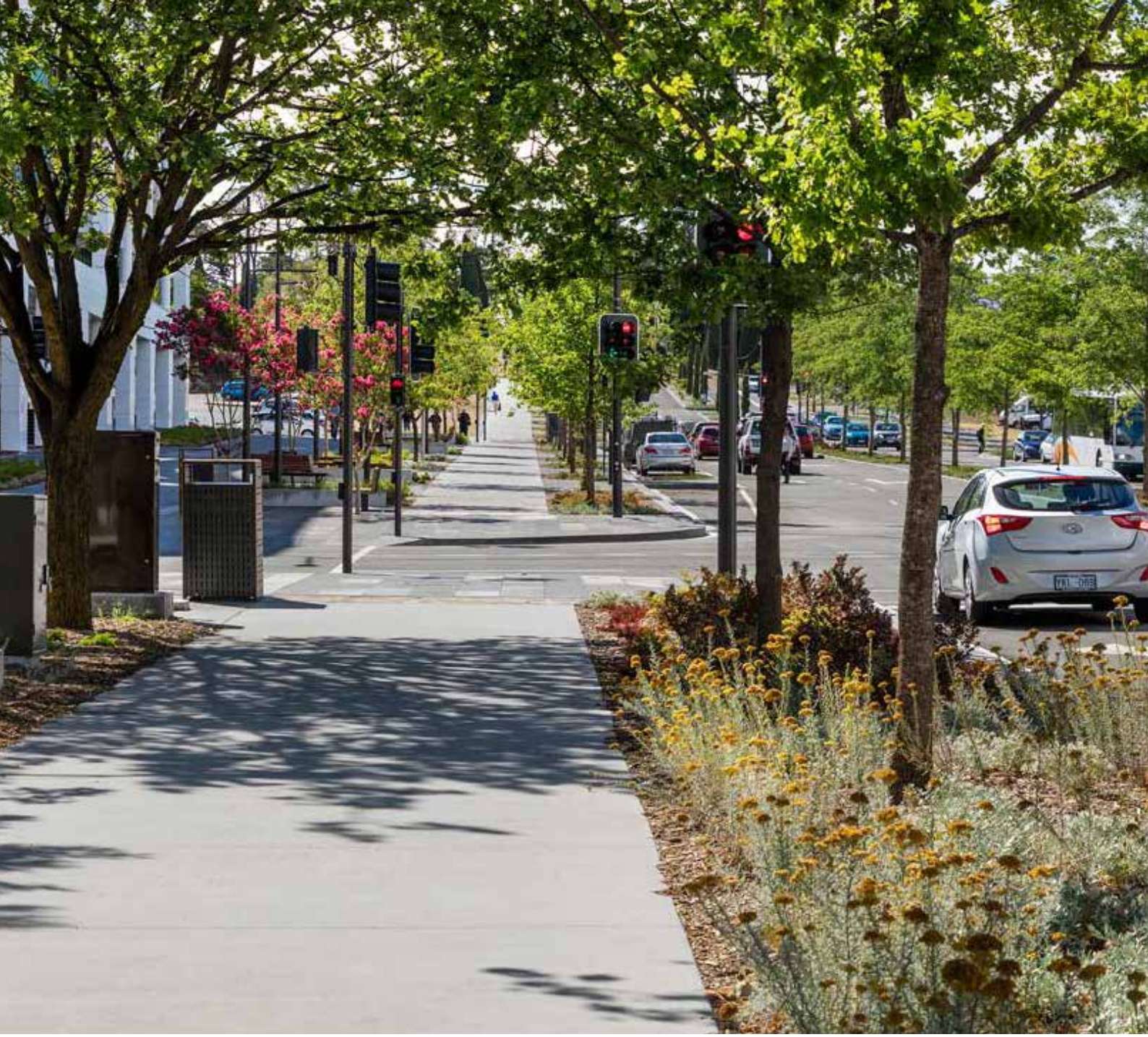
Near pedestrian areas or pedestrian/bicycle paths, lawn, porous cubes and blocks, river pebbles, stabilized soil, draining concrete and asphalt or other permeable and semi-permeable surfaces can be implemented.

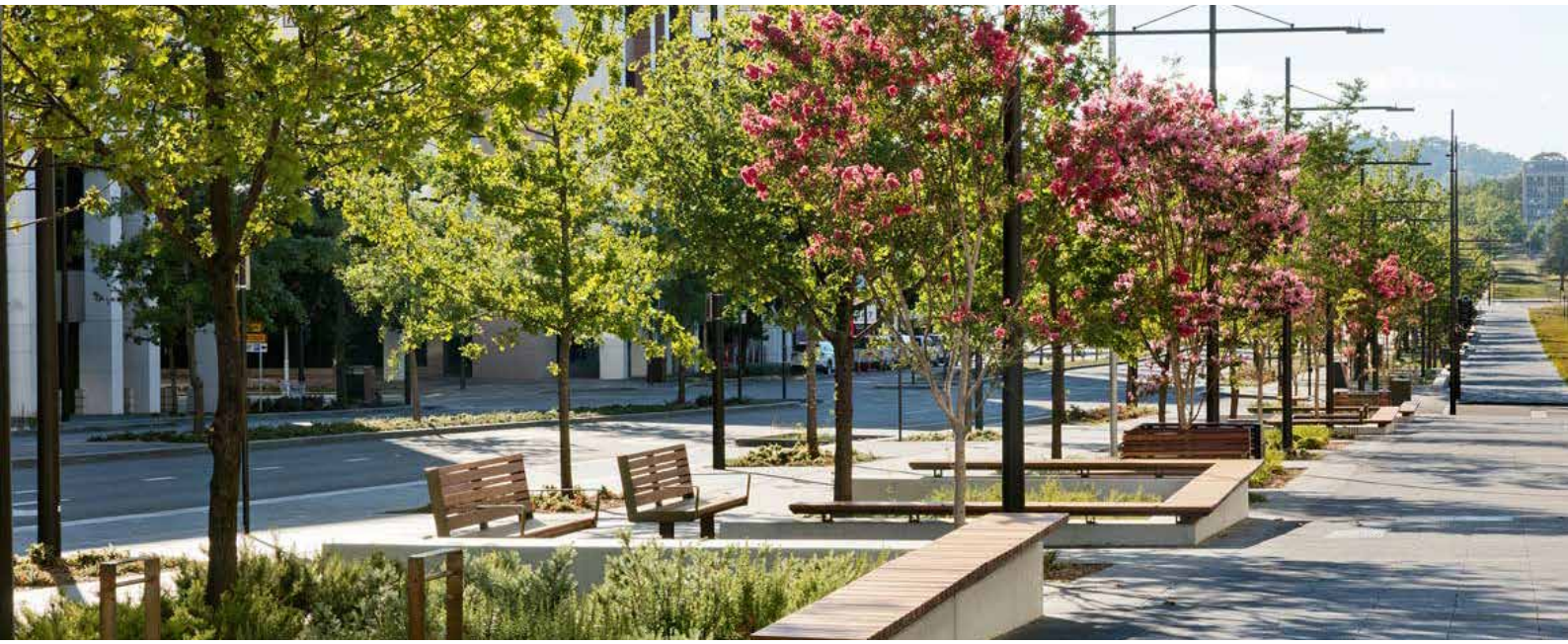
SPACE REQUIRED

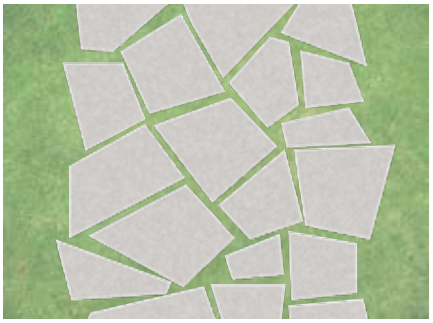
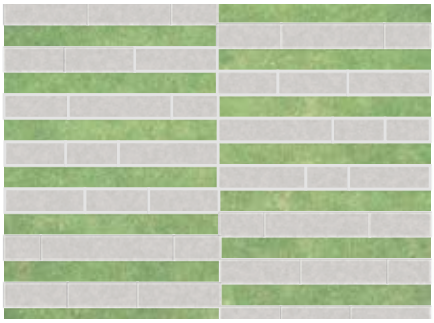
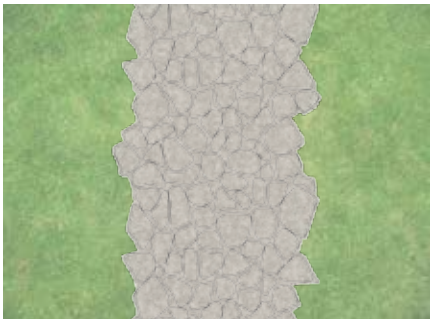
Permeable surfaces are generally used to drain water from the surface area. In some cases, they can also drain impermeable surrounding areas (e.g. roofs); in that event, the maximum ratio between surrounding surface and flooring surface is 2.

TYPE OF SOIL AND PRESENCE OF GROUND WATER

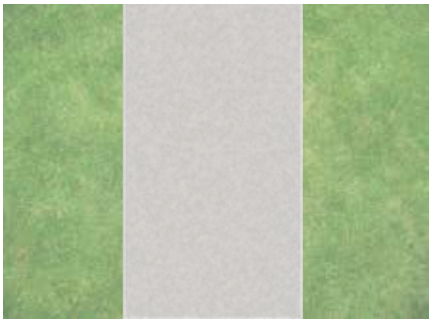
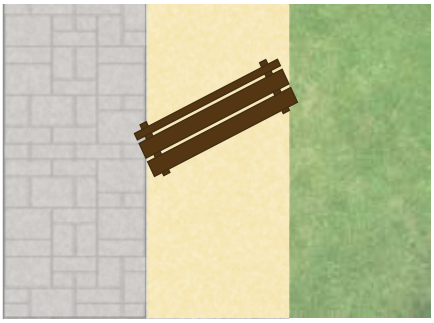
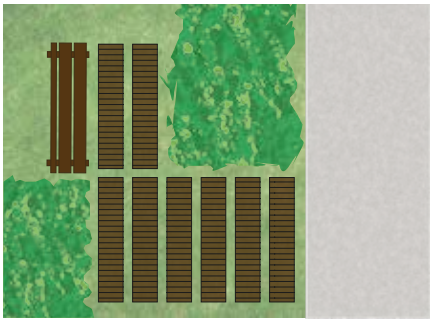
If the project foresees groundwater infiltration, permeable soil should be present underneath the surface. Alternatively, a suitable collection system to channel the water drained from the permeable surface to the sewage system or another receptor body should be installed.



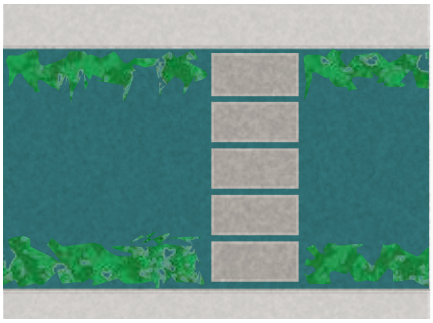
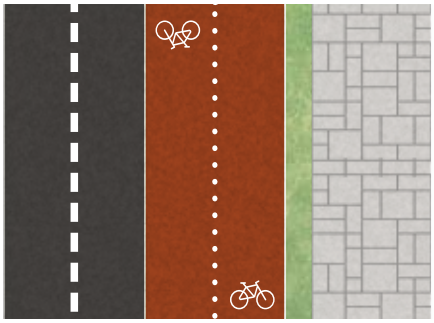
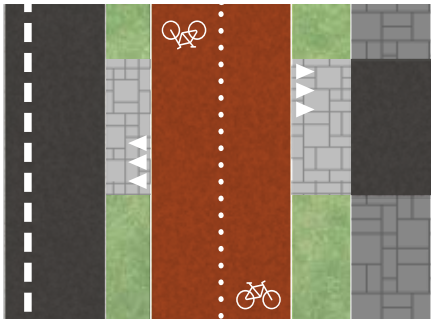







ECOSYSTEM SERVICES PROVIDED

NUTRITION BIOMASS | AIR QUALITY AND POLLUTANS REGULATION | NOISE REDUCTION | RUNOFF REDUCTION AND FLOOD | POLLINATION AND BIODIVERSITY | URBAN COMFORT AND MICROCLIMATE | PUBLIC SPACE ACCESSIBILITY AND RECREATION | IDENTITY SENSE PLACE HISTORY | BEAUTY OF NATURE

PLANT SPECIES

Paths made with draining or semi-permeable paving can be flanked by green spaces, such as channels covered with grass, rain gardens or tree-lined flowerbeds, to separate vehicle traffic from slow paths.

- TREES plants with high structures and umbrella-shaped canopies, to increase shade.
- SHRUBS avoid thorny shrubs and those with strong wooden branches (such as osmanthus).

Female plants with entomophilous pollination and low allergenicity should be preferred.

PUBLIC USAGE

Drainage surfaces can be adapted to different urban landscape contexts, and the variety of products available allows choosing the best finishes, colour and shape for each context. By effectively planning these and the functional aspects, pedestrian/bicycle paths will become more aesthetically pleasing with an improved climatic comfort, and the "heat island effect" typical of mineral materials will be reduced.

MAINTENANCE

Routine maintenance includes:

- monthly inspection of the surface, to check it is free from debris and sediments;
- checking for stagnation areas and flow difficulties, following a weather event;
- sweeping and vacuuming permeable surfaces - especially in autumn - to prevent leaf clogging.

Occasional maintenance comprises:

- cleaning and/or replacing the gap infill;
- replacing damaged elements/blocks;
- restoring depressed stagnation areas, etc.

Maintenance costs are low, since the routine interventions can be performed during standard road network and parking lot cleaning activities.
If the paving is subject to regular maintenance, their life span can be usually compared to a standard impermeable surface.

INDICATIVE COSTS

Indicatively, construction costs include:

- 30 euro/sqm for dirt roads/compacted soil;
- 70-80 euro/sqm for drainage asphalt and concrete;
- 80-100 euro/sqm for porous cubes and blocks;
- 120-150 euro/sqm for river pebbles paving.

25

SMART SIDEWALKS
manage and optimize underground utilities' maintenance

A fundamental aspect to be taken into consideration in the choice of materials and finishes of urban public spaces is that of the future maintenance needs of existing network infrastructures or the construction of new infrastructures.
Most frequently, the underground services are located under the vehicular section of the road. This widespread choice has entailed and entailed significant costs and impacts on traffic: the maintenance of cables and sewers must involve stopping or regulating traffic, cable detection activities and demolition and reconstruction costs.

A better and more efficient solution involves the choice of transferring the network infrastructures - gas, sewers, aqueduct, power line, public lighting, data wiring, video surveillance, telephony and more - under the pedestrian or bicycle pavements of the urban fabric, providing solutions easier to maintain and less impact on traffic.

The Copenhagen sidewalks are made by dry laying concrete slabs with slots and interspersed with stone or porphyry ashlars.
The underground utilities are always laid under the concrete slabs.
Thanks to the slots it is possible to lift the slabs, so that they can be removed easily and quickly, in correspondence with the underground utilities.
In this way it is possible to intervene directly on the underground services and, once maintenance is complete, to restore the practicability of the sidewalks quickly and easily.
The section is determined by the number of slabs: 2 for narrower sidewalks, 3 for wider ones. The rest of the space is closed by stone ashlars, which allow you to fill the remaining space towards the wall of the building and towards the road curb.
(Photo Luisa Ravanello)

DESIGN AND CONSTRUCTION ASPECTS

Given the complexity of networks present along the road arteries, and the related connections to homes and buildings in general, the need to intervene on the networks themselves to adapt them to new needs, enhance them, restore them following any damage, etc. is frequent.
For this reason, the pedestrian and cycle paths, which often host a series of pipes and conduits under the pavement, must be designed in a 'smart' way, limiting interference and the consequent costs of restoration in case it is necessary to intervene on the subsoil networks .

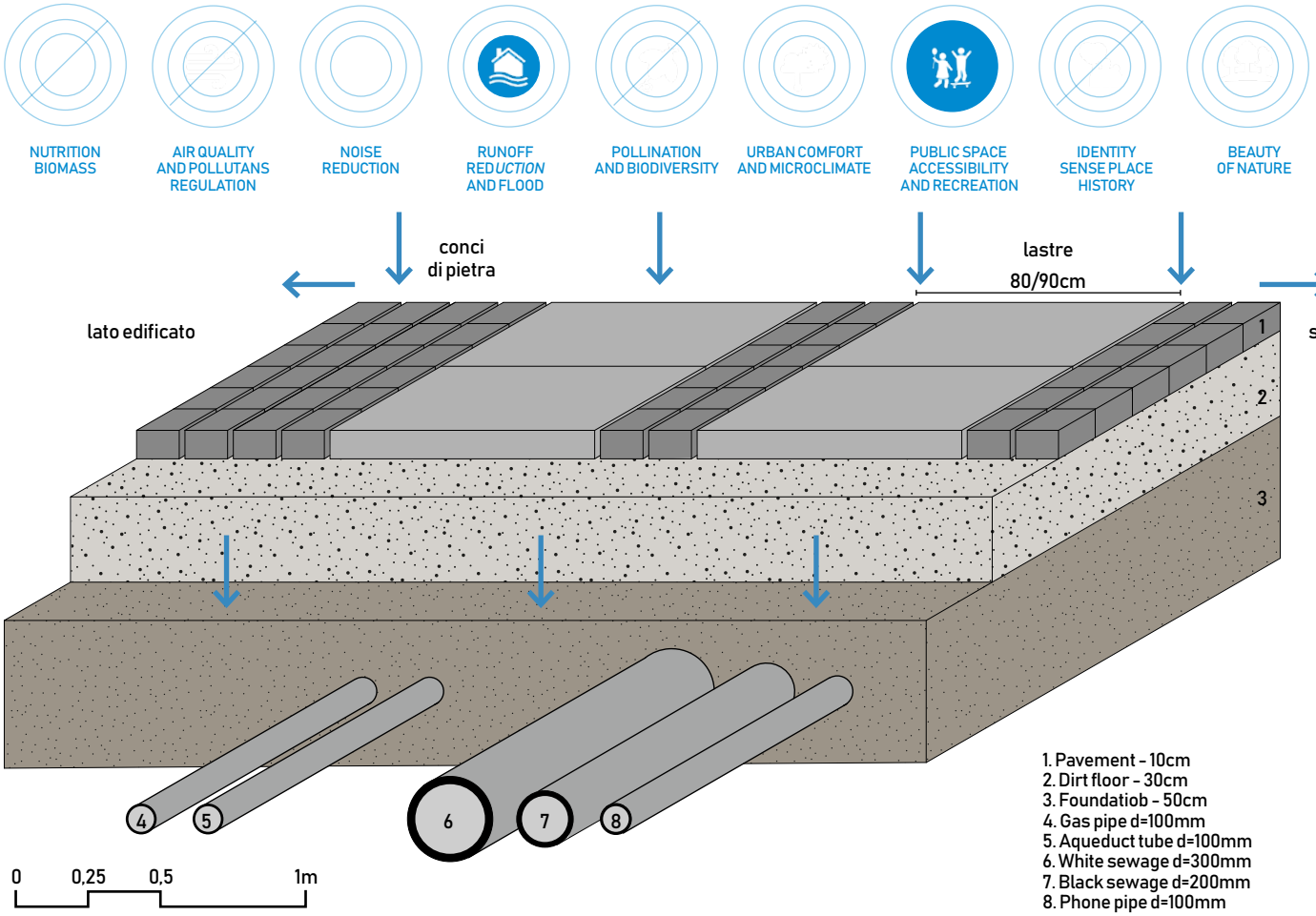
An example of the realization of a 'smart' sidewalk involves the laying of concrete slabs, equipped with slots through which it is possible to lift the slabs, or alternatively slabs laid dry, so that they can be removed easily and quickly, in correspondence with the existing utilities. In this way, once removed, it is possible to intervene directly on the underground services laid below and, once maintenance is complete, restore the routes quickly and easily and with immediate practicability.

Copenhagen sidewalks made with dry laying and concrete slabs. The underground utilities are always laid under the sidewalk slabs. In this way it is possible to intervene directly on the underground services and - once maintenance is complete - to restore the practicability of the pavements quickly and easily.

The section is determined by the number of slabs: 2 for narrower sidewalks, 3 for wider ones. The rest of the space is closed by stone ashlars, which allow you to fill the remaining space towards the wall of the building and towards the road curb.
(Photo Luisa Ravanello)

Pilot project for Heimdalsgade 22-24 in the Nørrebro district of Copenhagen. The pavement in slabs was repaved with draining concrete tiles that favor the infiltration of the first rainwater into the aquifer. Designed to be used on existing or newly built sidewalks, the tiles have a system of perforations that allow rainwater to be collected and managed, channeling it away from pipes and underground utilities.
(Project and photo by Tredje Natur)

ECOSYSTEM SERVICES PROVIDED



MANUTENZIONE

Gli interventi di manutenzione ordinaria consistono in:
- controllo mensile dello stato della pavimentazione per verificare che le lastre siano integre e che non si presentino inciampi o disconnessioni per gli usi del marciapiede;
- verifica di assenza di evidenze che possano far presagire a problematiche nelle sottostanti reti tecnologiche;
- pulizia della pavimentazione e ripristino delle fughe deteriorate;
- occasionalmente, interventi di sostituzione di elementi/lastre danneggiati, ripristino dei relativi piani di posa e fughe, ecc.

I costi di manutenzione sono ridotti in quanto rientrano nelle normali attività di controllo e manutenzione dei marciapiedi stradali.
Questa soluzione permette di facilitare le operazioni e contenere i costi della manutenzione dei sottoservizi a rete, in quanto la rimozione di lastre e il successivo ricollocamento ad intervento eseguito garantiscono costi e tempi di esecuzione assai ridotti.

COSTI INDICATIVI

I costi indicativi di realizzazione dipendono dalla tipologia di lastra o dall'elemento previsto da progetto e dalla tipologia del conseguente sottofondo, indicativamente:
- 80-100 euro/mq lastra prefabbricata posata "a secco";
- 100-120 euro/mq lastra provvista di fori per il drenaggio.

PROGETTI DI RIFERIMENTO

- Quartiere di Østerbro, Copenahgen - DK / Caso studio F 37

vegetation and trees in hostile urban settings

1. SOILS AND PLANTS
the nourishing sublayer of vegetation
2. NATURALISED MEADOW AND NATURAL MEADOW
increase biodiversity, reduce maintainance
3. FLOWERING MEADOW
increase biodiversity, reduce maintainance
4. RUSTIC MEADOW WITH DIFFERENTIATED MOWING
increase biodiversity, reduce maintainance
5. HIGH TRAFFIC LAWNS
promote sociality
manage maintainance

6 SOIL COVER AND GROUNDCOVER PLANTS
improve urban vegetation with low maintainance

7 PIONEER PLANTS
recolonize topsoil, promote biodiversity

8 AQUATIC PLANTS
phytodepuration of urban rainwater, enhance biodiversity

9 SHRUB MASSES
improve the micro-climate, absorb fine particles, promote biodiversity

10 TREES
ensure adequate spaces to plants, manage impacts of heat and rain

1

SOILS AND PLANTS
the nourishing sublayer of vegetation

Keeping soils permanently waterproofed is one of the main agents of soil degradation. Artificialisation of soils has at least four major negative, or external, effects on society and the environment:

- ⇢ fragmentation of the landscape with consequences on the flora/fauna, ecosystems, and hydrogeological structure;
- ⇢ socio-cultural damage, since the landscape is also human perception and cultural identity;
- ⇢ impoverishment of social quality since this great fragmentation often leads to the creation of isolated/marginalised areas;
- ⇢ increased costs of urbanisation and service provision. According to a recent study in the United States aimed at estimating the costs of urban sprawl, the areas with uncontrolled growth compared to those with planned growth have significantly higher economic costs for implementing and providing services.

The consequences of soil alteration affect ecosystem services such as food production, absorption, filtration and, more generally, water management, buffering power, and biodiversity conservation and are, in turn, some of the main agents responsible for both pollution in cities and climate change.
These effects must be a cause of serious concern to all, because the formation of soil is a very slow process, which takes centuries to make just 1 centimetre of fertile land.

SOILS AND PLANTS

Soil is an element in which many processes of transformation of energy and matter related to plant life take place. The availability of nutrients and the ability of the plant's underground organs to develop and ensure the life of the entire plant depend on the chemical composition and physical structure of the soil profile.

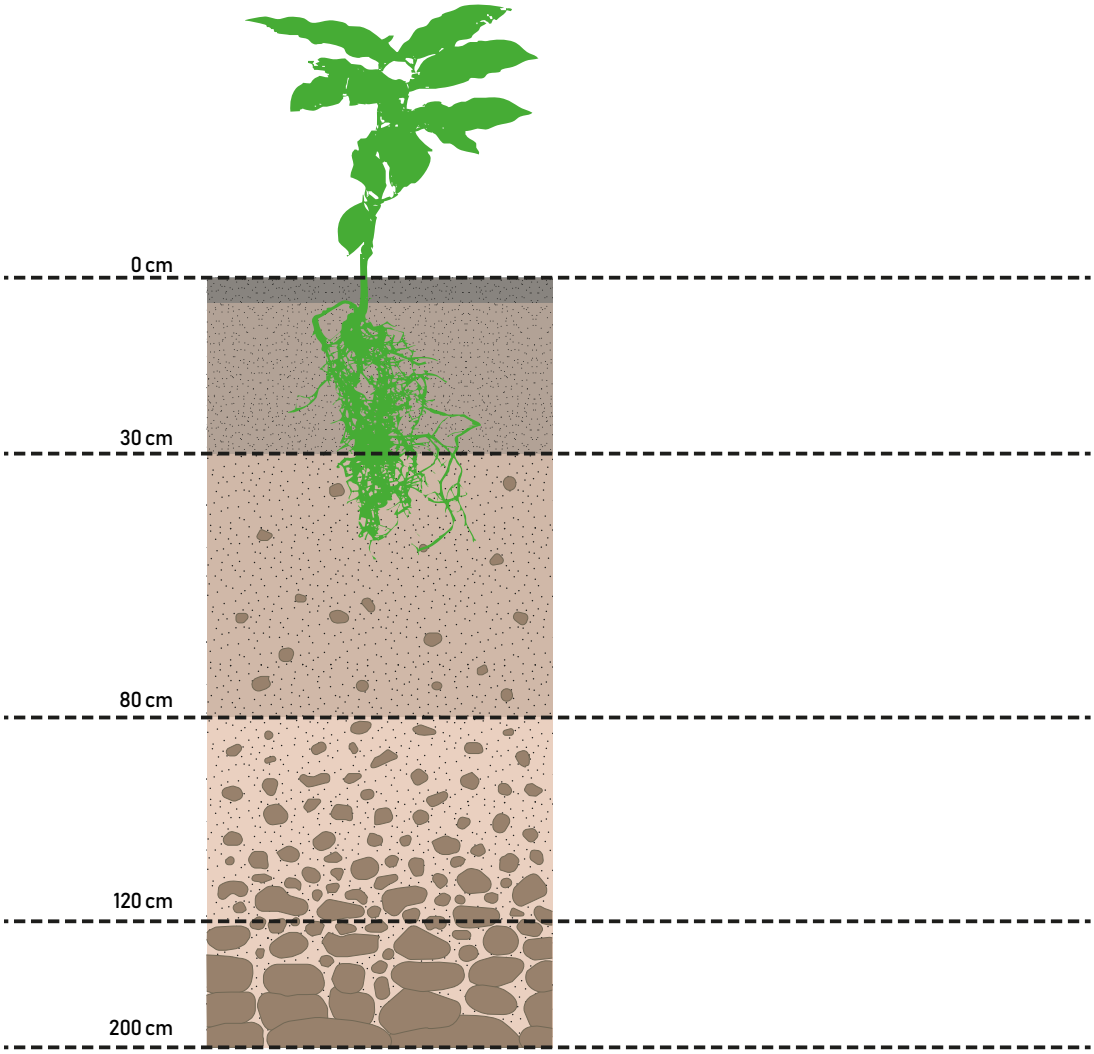
AGRICULTURAL SOIL AND DIGGING AND EXCAVATION ACTIONS

During the implementation and extraordinary maintenance of urban vegetation, the utmost attention must be paid to preserving soil fertility by adopting measures to preserve and improve the chemical and physical characteristics and the biological component of the soil. In the activity of creating and maintaining gardens, the quantity and quality of the soil are factors that directly influence the success of planting or sowing.
After planting, it is difficult and time-consuming to change the soil effectively. In most cases, new garden and green area projects are carried out on altered and heterogeneous soils. The earth material often comes from deep layers of soil and is the product of excavation resulting from the construction of buildings or other structures; in this case, the sublayer of the green infrastructure will be sterile soil in which the organic and biological component will be almost zero. It is therefore good practice to carry out sampling and analyses that establish the physical and chemical characteristics and quality of the organic substance present in the soil under examination; these must be carried out according to the sampling and analysis methods and parameters published by the Italian Society of Soil Science (S.I.S.S.).
If, following the chemical and physical analysis, the growing substrate has abnormal pH values, a non-optimal grain size or, more commonly, low organic matter values, it must be corrected and amended. In any case, the substrate for growing plants in green areas must have the conventionally defined characteristics of 'agricultural land'. If the project involves earthmoving of a certain entity, the first layer of soil must be removed and set aside for reuse at a later date. As a rule, the surface

⇢ 1 - Estratto da "Linee guida per la gestione del verde urbano e prime indicazioni per una pianificazione sostenibile", Comitato per lo sviluppo del verde pubblico. MATTM, 2017

Soil is a natural body, composed of mineral particles (sand, silt and clay), decomposed organic substances, living organisms, air and water.

The formation and evolution of the soil takes a long time: rocks and organic matter are transformed through chemical, physical and biological processes.
It is therefore a non-renewable resource if not for very long times, of the order of hundreds or thousands of years.
The texture, or granulometric composition, of a soil is defined on the basis of the proportion of the finer elements of 2 mm, the sand, the silt and the clay.
It comes with thicknesses ranging from a few centimeters to a few meters, it is organized in horizons or layers.

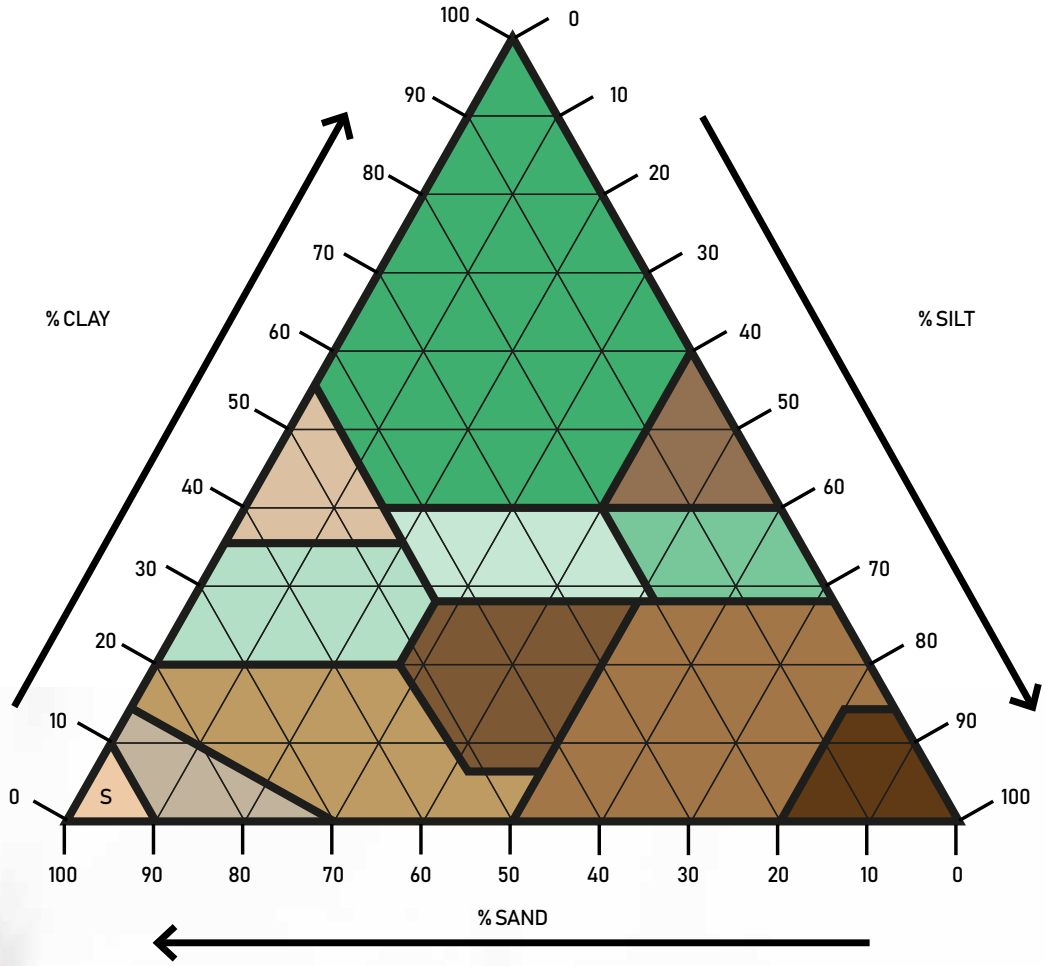


In the above diagram the soil structure is represented with the characterization of the materials present in the different horizons.
We read starting from horizon A (organ-mineral) the more superficial, where the greater the exchanges with the atmosphere and the greater the presence of organic substance. This horizon in contexts other than the pedological one (shipbuilding, floriculture, etc.) is also called 'vegetable soil'. Proceeding downwards, you meet the horizons B and C characterized by less and less altered materials.

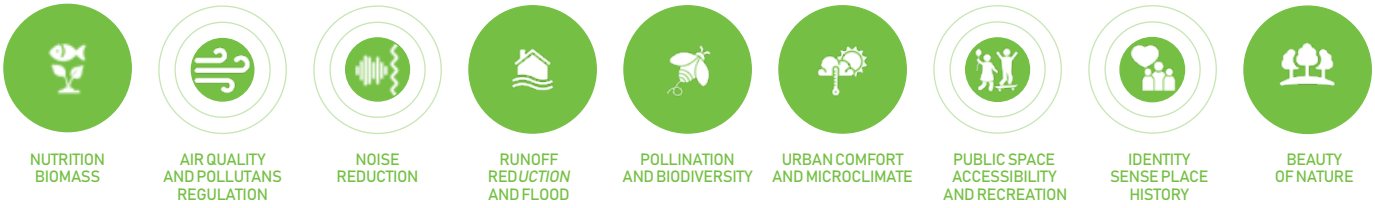
The particles that make up the soil can be divided into dimensional categories (particle size fractions). There is a great variability in the size of the particles, from the coarser ones (with a diameter> 2mm) that make up the skeleton, to those making up the fine earth, between 2 mm and a few tenths of a micron (thousandth of a millimeter).

By weaving we mean the percentage distribution of fine earth. The classification system adopted by the Emilia-Romagna Region follows the scheme proposed by the Department of Agriculture of the United States of America (Soil Survey Division Staff, 1993).

The different combinations of sand, silt and clay are grouped into textural classes. The content of sand, silt and clay influences the physical and chemical behavior of the soils.
The size of the particles influences the hydrological qualities of the soils and is in fact used for their classification. Among the soil properties influenced by the texture there are drainage, water retention capacity, soil aeration, erosion susceptibility, organic matter content, cation exchange capacity (http: //mappegis.regione.emilia-romagna.it / gstatico / documents / dati_pedol / tessitura_pianura.pdf).



ECOSYSTEM SERVICES PROVIDED



layer must be preserved for a thickness of 30 cm of fertile soil over the entire surface of the areas affected by works.
The mounds of soil must be piled by separating the fractions from different layers (excavation of the fertile surface layer and excavation of the deep layers) and with distinctly different chemical and physical characteristics. The fertile soil should be piled up in mounds that are not too bulky to avoid compacting.

IMPROVING THE SOIL

The best soil for growing plants is that defined as loam or medium texture, composed of about 40% sand, 25% silt, 25% clay and 10% skeletal soil. This composition is not frequent; however, even percentages of 10 or 15% (more or less) gives good quality results.
It is common to find compact soils, characterised by high percentages of clay and silt that cause at least three problems:

- they soils are difficult to treat and stick to tools, thus requiring more strength and energy to be worked;
- they are not very permeable and consequently generate water stagnation, which predisposes them to root asphyxiation;
- in periods of drought, they contract and form typical cracks that threaten the health and integrity of the root system.

The addition of organic matter, sand, loam stone and lime balances the grain size of a compact soil and improves the living conditions of plants. In addition, distribution of mycorrhizae and humic and fulvic acids is always useful.
Finally, it is possible to intervene by using a compressed air lance to blow air or expanded clay into the soil; the former penetrates into the soil's macropores and disintegrates it, while the latter increases soil aeration.

INDICATIVE COSTS

- 17.5 euro/m3 for generally loose, medium texture soil, coming from the active growing layer [active soil with skeletal soil of less than 10%, made up of mineral elements from the disintegration of rocks and organic elements from decomposed vegetable and animal remains (humus), in the following percentages net of the skeletal part: Clay = 22% b) Sand = 60% c) Limestone = 8% d) Humus = 10%] Free of roots and permanent weeds, pebbles, shards, etc.;
- 65 euro/m3 (if bulk): composed by amendment of soil to be regenerated with 30% organic matter and 70% from various soils sieved and ground, neutral pH;
- 10-20 euro/sqm for de-paving the surface (in case of mineral systems);
- 20-25 euro/m3 for disposal of excavated earth and rocks;
- 20 euro/sqm for irrigation system for areas planted with lawns and trees.

CASE STUDIES

- Alter Flugplatz Kalbach Urban Park, Frankfurt am Main - DE / Case study C2
- Jardin Joeux Park, Aubervilliers - FR / Case study D30
- Texture Parking Temporary Garden, Courtrai - BE / Case study D32
- Depave is Paradise, Canada- CDN / Case study E33

2

NATURALISED MEADOW AND NATURAL MEADOW
open spaces with high biodiversity

Naturalised and natural meadows are an interesting solution for extensive urban greenery, especially for the contexts of disused areas, as in addition to improving the aesthetics of the location, they enhance biodiversity, the production of food for fauna and the reduction of maintenance costs.

These meadows perform various functions in cities and public areas:
- they produce oxygen;
- they contribute to the sustainable urban rainwater management;
- they favour the lowering of surface temperatures, countering the effects of the urban heat island;
- they contribute to improving the microclimate;
- they absorb dust and air pollutants;
- they favour biodiversity and food production.

NATURALISED MEADOW

Naturalized meadows are artificial turf, created and spread also in urban areas so that grasses and legumes that do not require maintenance can take root permanently. The use of natural meadows is an excellent solution for the greening of difficult areas, such as slopes and ditches, quarries, abandoned areas and soils to be reclaimed or extensive green areas. In more difficult areas to be reached, in addition to hydroseeding, already sown and fertilised biomats and reinforced soils, made of degradable materials, can also be used; in these cases, we often see the gradual replacement of sown species with other spontaneous species, thus increasing the biodiversity of the place and improving the possibility for wildlife to settle in the area.

RECOMMENDED SPECIES

These turfs rely only on the water from rain and, therefore, the choice of plants suitable for the natural rainfall trend becomes one of the key elements for the success of the settlement. The species to be chosen depend on the habitat, consisting of special mixtures of grasses and leguminous plants with roots that grow strongly both in depth and horizontally

- MOST COMMONLY USED SPECIES Lolium perenne, Lolium italicum, Festuca rubra and arundinacea, Onobrychis viciifolia, Vicia sativa, Poa pratensis, Trifolium repens and Phleum pratense

USABILITY AND ATTRACTIVENESS OF THE PUBLIC SPACE

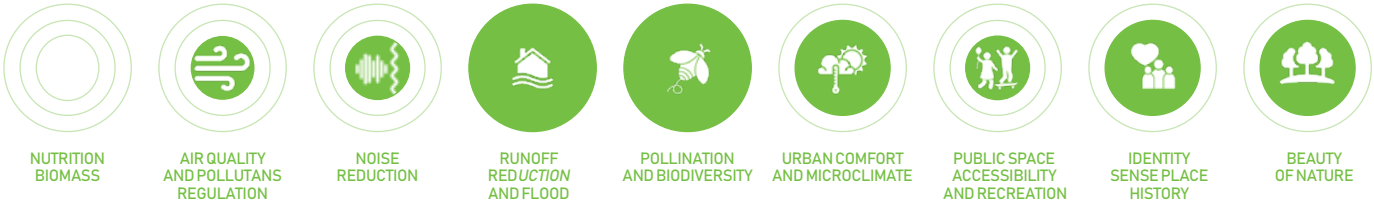
The areas affected by natural and naturalised meadows are not designed for intensive human use, but to enhance urban biodiversity.

- MEDIUM-LOW USE FOR SLOPING AREAS, no use for land to be reclaimed, medium or medium-high use for extensive green areas with appropriate mowing areas
- HOW TO IMPROVE USABILITY If naturalised or natural meadow areas in urban areas are to be used, it is necessary to define areas of selective mowing, either along paths, or in specific areas to allow stops for recreational and social moments. Three mows a year are recommended.
- VERY HIGH BIODIVERSITY
- HOW TO STIMULATE THE KNOWLEDGE OF THE RESULTING ECO-SYSTEM BENEFITS

These meadows, especially if in urban areas, can be mistaken for uncultivated and abandoned areas. It may be useful to have signs and signals on the benefits of eco-system services provided by raising citizen awareness and use for teaching in schools.


Espace biologique protégé

ECOSYSTEM SERVICES PROVIDED



APPLICATION CONTEXTS

- ALONG SLOPES naturalised meadows are suitable for moderately and very steep sloping walls, which need low or no maintenance.
- IN DISUSED AREAS naturalised meadows are suitable for former quarries and land to be reclaimed on which to favour soil remineralisation.
- IN GREEN URBAN AREAS these types of meadows should be present in urban parks in extensive areas, alternating with green areas requiring greater maintenance. This makes it possible to reduce the economic burden fpr local authorities due to reduced mowing.

MAINTENANCE

In extensive green areas, two to three mowings are carried out per year, while no intervention is carried out in other situations for the spontaneous growth of plants that will replace the chosen mix.

INDICATIVE COSTS

- 4.6 euro/kg for bags of seeds - depending on the work carried out (hydroseeding, biomats and reinforced land), the cost ranges between 2,500 and 5,000 euro per 1,000 square metres;
- 0.04 euro/sqm: mowing of green areas of between 250 and 500 square metres, for 1-2 cuts (cutting of the turf in green areas and roadsides with a rotary blade mower and with a chopper, with immediate collection of waste material, including charges for disposal and trimming of edges);
- 0.02 euro/sqm: mowing of green areas of over 500 square metres (cutting of turf in green areas and roadsides with a rotary blade mower and with a chopper, with immediate collection of waste material, including charges for disposal and trimming of edges);
- 10-20 euro/sqm for de-paving the surface (in case of mineral systems);
- 20-25 euro/m3 for disposal of excavated earth and rocks;
- 20 euro/sqm for irrigation system for areas planted with lawns and trees.

CASE STUDIES

- Flugplatz Urban Park, Frankfurt am Main - DE / Case study C4

3

FLOWERING MEADOW
open spaces with high biodiversity

Flowering meadows are an interesting solution for urban greenery, especially for extensive urban greenery and urban roadside greenery, as they favour the biodiversity of flora and fauna, reduce maintenance costs and create spectacular aesthetic effects with the changing seasons.

These meadows serve various purposes in cities and public areas:
- they produce oxygen;
- they contribute to the sustainable urban rainwater management;
- they favour the lowering of surface temperatures, countering the effects of the urban heat island;
- they contribute to improving the microclimate;
- they absorb dust and air pollutants;
- they favour biodiversity;
- they enhance the beauty of public areas.

FLOWERING MEADOW

Flowering meadows are combinations of herbaceous species, either annual or perennial, resulting from the sowing of mixtures of seeds from spontaneous species in areas climatically similar to the planting area. Flowering meadows are a good, quick solution for the greening of larger, non-treadable areas of urban parks, as they are easy to set up and maintain. In addition, they require little water and fertiliser, enhance marginal areas that are difficult to manage and create micro-ecosystems useful for biodiversity.

RECOMMENDED SPECIES

Flowering meadow seed mixtures have a variable composition and should be chosen from among those appropriate to the climate and soil where they will be planted; they are often made up of:

- ANNUAL SPECIES Anchusa, chamomile, bluebells, cosmos, cornflowers, poppies. During the meadow's first year of life, they ensure its rapid development and limit the growth of weeds, allowing the growth of perennials. They provide an exuberant flowering in the first year and sometimes cast their seeds spontaneously;
- PERENNIAL SPECIES carnations, daisies, buttercups, and meadow sage, which will make up the permanent meadow. They grow slowly and bloom from the second year after sowing;
- GRAMINEAE Some mixtures of flowering meadows include small amounts of grasses.

USABILITY AND ATTRACTIVENESS OF THE PUBLIC SPACE

The areas planted by flowering meadows are not designed for intense human use, but to enhance biodiversity, so that they can be fenced and insurmountable in urban parks.

- MEDIUM-LOW USE
- HOW TO IMPROVE USABILITY If flowering meadows are to be used in urban areas, it is necessary to define areas of selective mowing, either along paths, or in specific areas to allow stops for recreational and social moments. Alternatively, it is possible to arrange structured routes alongside the flowering meadows, preferably made of natural materials - beaten, stabilised or rammed earth.
  Periodic mowing is recommended, 1 or 2 times a year only along routes.
- VERY HIGH BIODIVERSITY
- HOW TO FOSTER AWARENESS OF THE ECO-SYSTEM BENEFITS GENERATED These meadows can be mistaken for uncultivated and abandoned areas. It may be useful to have signs and signals on the benefits of eco-system services provided by raising citizen awareness and use for teaching in schools.

ECOSYSTEM SERVICES PROVIDED

NUTRITION BIOMASS | AIR QUALITY AND POLLUTANS REGULATION | NOISE REDUCTION | RUNOFF REDUCTION AND FLOOD | POLLINATION AND BIODIVERSITY | URBAN COMFORT AND MICROCLIMATE | PUBLIC SPACE ACCESSIBILITY AND RECREATION | IDENTITY SENSE PLACE HISTORY | BEAUTY OF NATURE

APPLICATION CONTEXTS

⇢ IN DISUSED AREAS flowering meadows are suitable for former quarries and railway stations and, in general, land to be reclaimed whose soils need to be remineralised and which do not require many mowings.

⇢ ALONG THE ROADSIDE GREEN flowering meadows can be created in the flowerbeds of parking lots, in green central reservations and in roundabouts of roadside green, which are highly visible areas but whose care and maintenance must be low and not expensive.

⇢ IN GREEN URBAN AREAS these types of meadows should be present in urban parks in dedicated, defined or extensive areas, alternating with green areas requiring greater maintenance. This makes it possible to reduce the economic burden for local authorities due to reduced mowing areas. It is useful to set up protective systems such as small fences to protect flowering meadows. These meadows are ideal habitats for the local fauna, especially insects and birds. At certain times of the year, walking alongside these spaces can generate genuine shows of sounds or moving colours, as in the case of the flight of butterflies - attracted by species they enjoy to feed on - or the chirping and flying of small birds - which find protection and food here.

MAINTENANCE

Autumn sowing, which gives better results, determines the appearance of the first flowers in the following spring, while with spring sowing, the first blooms will occur in summer thanks especially to the annual species. After sowing, the first step is deep irrigation, which will be the only one for the entire annual cycle. Two mowings are then carried out, in spring and autumn after the main blooms.

INDICATIVE COSTS

⇢ 3.0-3.5 euro/kg/1,000 sqm for seeding of flowering meadows;
⇢ planting costs vary depending on the size of the area.
For the formation of turf on the ground with mechanical preparation of the bed (cleaning of the area, ploughing/spading, harrowing) with fertilisation, manual or mechanical seeding, including the supply of 100 g/sqm of ternary compound fertiliser, 30 g/sqm of seed, sowing, rolling, excluding any organic soil improver and irrigation
- ⇢ surface areas of up to 300 sqm = approx. 5.01 euro/sqm;
- ⇢ surface areas from 500 to 1,000 sqm = approx. 2.64 euro/sqm;
- ⇢ surface areas of over 2,000 sqm = approx. 1.45 euro/sqm;

⇢ 0.04 euro/sqm: mowing of green areas of between 250 and 500 square metres, for 1-2 cuts (cutting of the turf in green areas and roadsides with a rotary blade mower and with a chopper, with immediate collection of waste material, including charges for disposal and trimming of edges);
⇢ 0.02 euro/sqm: mowing of green areas of over 500 square metres (cutting of turf in green areas and roadsides with a rotary blade mower and with a chopper, with immediate collection of waste material, including charges for disposal and trimming of edges);
⇢ 10-20 euro/sqm for de-paving the surface (in case of mineral systems);
⇢ 20-25 euro/m3 for disposal of excavated earth and rocks;
⇢ 20 euro/sqm for irrigation system for areas planted with lawns and trees.

CASE STUDIES

⇢ Martin Luther King Urban Park, Paris - FR / Case study C4
⇢ Gleisdreieck Urban Park, Berlin - DE / Case study C4
⇢ Jardin Joeux, Aubervilliers - FR / Case study D30

4

RUSTIC MEADOW WITH DIFFERENTIATED MOWING
open spaces with high biodiversity

Rustic meadows with differentiated mowing are an interesting solution for urban greenery, especially for extensive urban greenery, as they favour the biodiversity of flora and fauna, reduce maintenance costs and ensure the use of flowering fields and semi-natural uncultivated areas.

Rustic meadows serve various purposes in cities and public areas:
- they produce oxygen;
- they contribute to the sustainable urban rainwater management;
- they favour the lowering of surface temperatures, countering the effects of the urban heat island;
- they contribute to improving the microclimate;
- they absorb dust and air pollutants;
- they favour biodiversity;
- thanks to selective mowing, they favour use and good acceptance by people of apparently uncultivated areas.

RUSTIC MEADOW WITH DIFFERENTIATED MOWING

The rustic meadow is a coat made up of robust grasses in the broadest sense of the term, similar to natural meadows. Due to their appearance, rustic meadows are not used in private gardens, but are excellent for areas with high degree of use, for the greening of areas at risk of landslides and with particular hydrogeological fragility; their thick and deep roots make them resistant to various adversities or critical soil factors. In urban green areas it is possible to provide for differentiated maintenance thus reducing costs: in fact, walkways or strips that flank the pedestrian paths are cut regularly, while the adjacent portions are mowed very seldom, even just two or three times a year, with the result of obtaining grasses of different heights.

RECOMMENDED SPECIES

Rustic meadows are combinations of different grasses characterised by high resistance to treading, low nutritional and water requirements, and low sensitivity to extreme temperatures. The texture of these species is less finer and softer than that of those used for meadows with decorative characteristics. The mixtures for these meadows are made up of different percentages of selected varieties of Festuca, Lolium perenne, Poa pratensis and Cynodon dactylon (common weed); 100% of the latter can be used in warmer areas. In particular:

- IN NORTHERN AND CENTRAL ITALY, FRESH AND LOOSE SOILS Lolium perenne and Poa pratensis in a 70-30 percentage;
- IN NORTHERN, CENTRAL AND SOUTHERN ITALY, ISLANDS INCLUDED, HUMID WARM WEATHER IN SUMMER AND CLAYEY SOILS Festuca arundinacea and Poa pratensis in a 90-10 percentage;
- IN NORTHERN AND CENTRAL ITALY, PARTIALLY SHADED OR SHADED AREAS Festuca arundinacea and F. rubra in an 80-20 percentage;
- IN CENTRAL AND SOUTHERN ITALY, ISLANDS INCLUDED, MEDITERRANEAN CLIMATE ALONG THE COAST, WINDY AND SUNNY AREAS, LITTLE WATER AVAILABLE macrotherms such as Cynodon, Paspalum and Zoysia.
- AREAS NOT SUBJECT TO WALKING An excellent alternative to grasses to be used in areas not subject to walking is clover, a nitrogen-fixing species, which means that it does not need fertilisation and which should never be mowed; on the other hand, it suffers from water shortage.

ECOSYSTEM SERVICES PROVIDED

USABILITY AND ATTRACTIVENESS OF THE PUBLIC SPACE

These areas are ideal for extensive low-maintenance green areas with a high level of naturalness, where use is to be ensured for the population. Selective mowing allows for crossing and dwelling, while the unmowed areas are dedicated to enhancing biodiversity.

- USE Medium and/or Medium-High
- HOW TO IMPROVE USABILITY If differentiated urban mowing areas are to be used, mowing should be designed and planned. From an operational point of view, they must be sufficiently wide at the edges of pedestrian paths, 1 or 2 meters, to give users walking there the idea of a well-kept area. In dwelling areas, mowing can be extended and follow different geometrical shapes as long as it is easy to achieve with mechanical means such as lawnmowers or tractors, minimising the need for the most expensive cuts with manual hedge trimmers. Periodic selective mowing between 5-10 times a year is recommended only along the paths and dwelling areas. The rest of the areas can be mowed periodically.
- BIODIVERSITY Very high
- HOW TO FOSTER AWARENESS OF THE ECO-SYSTEM BENEFITS GENERATED These meadows can be mistaken for uncultivated and abandoned areas and it may be useful to have signs on the benefits provided by the vegetation to the urban environment.

APPLICATION CONTEXTS

- INSIDE URBAN PARKS AND IN GREEN AREAS ALONG RIVERS AND CULTIVATED LAND

These types of meadows should be present in urban parks, especially when very large, or in monumental green areas, such as meadows that surround the walls of historic cities or that are on the edge of urban river areas or areas for cultivation and social gardens. This makes it possible to reduce the economic burden for local authorities by concentrating and reducing the mowing areas into dedicated areas. These meadows are ideal habitats for the local fauna, especially insects and birds.

MAINTENANCE

September is the best time for sowing in the northern regions, while in May sowing is carried out in the southern regions. In both cases, it is necessary to irrigate immediately after sowing and to intervene with emergency watering during the driest periods.

INDICATIVE COSTS

- 4.60 euro/kg for bags of seeds; the seeding doses vary from 10 to 30 g/sqm depending on the area and the species used;
- Planting costs vary depending on the size of the area.

For the formation of meadow on the ground with mechanical preparation of the bed (cleaning of the area, ploughing/spading, harrowing) with fertilisation, manual or mechanical seeding, including the supply of 100 g/sqm of ternary compound fertiliser, 30 g/sqm of seed, sowing, rolling, excluding any organic soil improver and irrigation

- surface areas of up to 300 sqm = approx. 5.01 euro/sqm;
- surface areas from 500 to 1000 sqm = approx. 2.64 euro/sqm;
- surface areas of over 2000 sqm = approx. 1.45 euro/sqm;

- 0.04 euro/sqm: mowing of green areas of between 250 and 500 square metres, for 1-2 cuts (cutting of the turf in green areas and roadsides with a rotary blade mower and with a chopper, with immediate collection of waste material, including charges for disposal and trimming of edges);
- 0.02 euro/sqm: mowing of green areas of over 500 square metres (cutting of turf in green areas and roadsides with a rotary blade mower and with a chopper, with immediate collection of waste material, including charges for disposal and trimming of edges);
- 20 euro/sqm for irrigation system for areas planted with lawns and trees.

CASE STUDIES

- Martin Luther King Urban Park, Paris - FR / Case study C4
- Gleisdreieck Urban Park, Berlin - DE / Case study C4

5

HIGH TRAFFIC LAWNS
open spaces with high social use

'Functional' lawns are an important investment in the cities as, in addition to aesthetic criteria, they also impose safety and wear-resistance parameters closely linked to the high quality of the products used and the accuracy of preparation, execution and maintenance.

These lawns perform various functions in cities and public areas:
- they produce oxygen;
- they contribute to the sustainable urban rainwater management;
- they favour the lowering of surface temperatures, countering the effects of the urban heat island;
- they contribute to improving the microclimate;
- they absorb dust and air pollutants;
- they promote social use, fruition and convivial use by people.

HIGH TRAFFIC LAWNS

High traffic lawns are suitable for the use of the population, for recreational and non-professional sports activities and differ from rustic meadows, which can be cut differently, because - being more intensively used by people - require a greater number of cuts.
In the budgets of local authorities, the cutting of turf is one of the most significant items and therefore it is useful in the design of green areas to understand where high traffic lawns are needed (which require a lot of mowing) and where it is possible or useful to introduce meadows and areas with greater naturalness and less maintenance.

RECOMMENDED SPECIES

The ideal height of the grass in high traffic lawns is 1.5 - 5 cm and irrigation must be provided.
The species that can be used have a tolerance that varies in terms of cutting height, so it is necessary to determine in advance mowing frequency and what the intensity of use will be.

- MOST COMMONLY USED SPECIES Agrostis, Festuca spp, Lolium perenne, Poa spp

USABILITY AND ATTRACTIVENESS OF THE PUBLIC SPACE

For them to be used, areas with high traffic lawns must be cared for and mowed frequently to allow use by children for free play and for moments of recreation, rest and conviviality.

- USE High-Very High
- HOW TO IMPROVE USABILITY The degree of use is generally high, but it isdirectly proportional to the care of the turf and the presence of equipment.
  Lawns that are not cared for and not equipped are little used. On well-kept and well-equipped lawns, instead, people feel welcome and safe: it is easy to organise a picnic because the grass is cut, there are tables and in some cases even have barbecues to organise lunches in the open air; it is pleasant to lie on the grass to talk with friends or rest, children can play in playgrounds or on the ground, and parents and elderly people find space to sit and talk together or play. We recommend mowing 12 times per year and it is essential that near high traffic lawn areas there is equipment for dwelling, trees for shade, and tables for play and conviviality.
- BIODIVERSITY Very low
- HOW TO ENCOURAGE CARE The role of public maintenance workers, but also that of the citizens, is crucial for the care of lawns. It may be useful to have signs on how to use common goods and to encourage forms of spontaneous supervision by residents, encouraging civic behaviour.

ECOSYSTEM SERVICES PROVIDED

NUTRITION BIOMASS | AIR QUALITY AND POLLUTANS REGULATION | NOISE REDUCTION | RUNOFF REDUCTION AND FLOOD | POLLINATION AND BIODIVERSITY | URBAN COMFORT AND MICROCLIMATE | PUBLIC SPACE ACCESSIBILITY AND RECREATION | IDENTITY SENSE PLACE HISTORY | BEAUTY OF NATURE

APPLICATION CONTEXTS

IN RESIDENTIAL AND TERTIARY URBAN AREAS These types of lawns should be present in urban parks and public gardens, in dedicated areas that are not extensive. This allows concentrating the efforts for numerous mowings in the points of greatest attraction, where there are seats, playgrounds, and sports equipment.

Other spaces suitable for lawns are the monumental areas, where there are particular historical and cultural constraints (views, monuments, etc.), although it is essential to provide elements for shade and/or dwelling to facilitate use. For this use, less rustic species with thinner leaves are used.

MAINTENANCE

On high traffic lawns, a high degree of maintenance and resources dedicated to mowing are essential. However, mowing is not carried out in the middle of winter and in the middle of summer, when the plants are at rest, while in the other seasons it is necessary to cut them every 15 days, with 12 mowings per year. Likewise, if the turf areas in a park are not too large (or if they are concentrated) and if they are alternated with rustic lawns and shrubs, which have a more extensive character, or in the case of selective mowing, maintenance costs are also lower. With very frequent mowing, it is possible to leave the lawn mowed and shredded on the ground, arranging disposal only for the most frequented areas.

However, these actions imply an articulated maintenance plan, which should be drawn up already at the design stage.

Proper care of meadows also includes periodic monitoring of the felt that forms over time and diseases.

INDICATIVE COSTS

- 5.0-9.5 euro/kg for bags of seeds (depending on the species); the sowing doses vary from 10 to 30 g/sqm depending on the area and the species used;
- 0.17 euro/sqm: mowing of green areas of between 250 and 500 square metres, for 10-12 cuts (cutting of the turf in green areas and roadsides with a rotary blade mower or with a chopper, with immediate collection of waste material, including charges for disposal and trimming of edges);
- 0.10 euro/sqm for mowing of green areas between 250 and 500 sqm, for 10-12 cuts (cutting of the turf with rotary blade lawnmower with chopping and release of homogeneously distributed materials, including trimming of edges);
- 0.08 euro/sqm: mowing of green areas from 500 to 2000 square metres (cutting of turf in green areas with a rotary blade mower and roadsides with a chopper, with immediate collection of waste material, including charges for disposal and trimming of edges);
- 0.05 euro/sqm for mowing of green areas between 500 and 2000 sqm (cutting of the turf with rotary blade lawnmower with chopping and release of homogeneously distributed materials, from 10 to 12 cuts including trimming of edges);
- 0.06 euro/sqm: mowing of green areas from 2000 to 5000 square metres (cutting of turf in green areas with a rotary blade mower and roadsides with a chopper, with immediate collection of waste material, including charges for disposal, including trimming of edges);
- 10-20 euro/sqm for de-paving the surface (in case of mineral systems);
- 20-25 euro/m3 for disposal of excavated earth and rocks;
- 20 euro/sqm for irrigation system for areas planted with lawns and trees.

CASE STUDIES

- Aalborg eco-neighbourhood - DK / Case study A1
- Urban park in Boulogne-Buillancourt - FR / Case study A3
- Martin Luther King Urban Park, Paris - FR / Case study A4
- Killesbergpark, Stuttgart - DE / Case study C4
- Promenade du Paillon, Nice - FR / Case study C4

6

SOIL COVER AND GROUNDCOVER PLANTS
low maintenance open spaces

Soil cover and groundcover plants are an interesting solution for urban greenery, as they are low-maintenance systems.

These plants perform various functions in public areas:
- they produce oxygen;
- they contribute to the sustainable urban rainwater management and retain humidity in the soil;
- they contribute to improving the microclimate;
- they absorb dust and air pollutants;
- they favour biodiversity;
- they reduce soil erosion due to rain and wind;
- they enhance the beauty of public areas and improve their care.

SOIL COVER AND GROUNDCOVER PLANTS

The term soil cover defines its function: they are herbaceous plants or shrubs that grow quickly in terms of width and very little in height and are able to cover the soil, limiting the growth of unwanted plants.

Soil cover and groundcover plants have been used both for ornamental purposes as many species have beautiful blooms, interesting foliage or winter fruits, and to limit the work needed to clear flowerbeds of wild herbaceous plants. More recently, the naturalistic value of these plants has also been reconsidered, since their dense network of roots allows them to perform various functions:

- they mitigate soil movements and protect it from rain and wind,
- they allow the nesting of many animals in addition to producing food for them,
- they are an excellent solution of continuity between arboreal and shrub-filled areas, imitating what happens in natural forests, which always have a low understory.

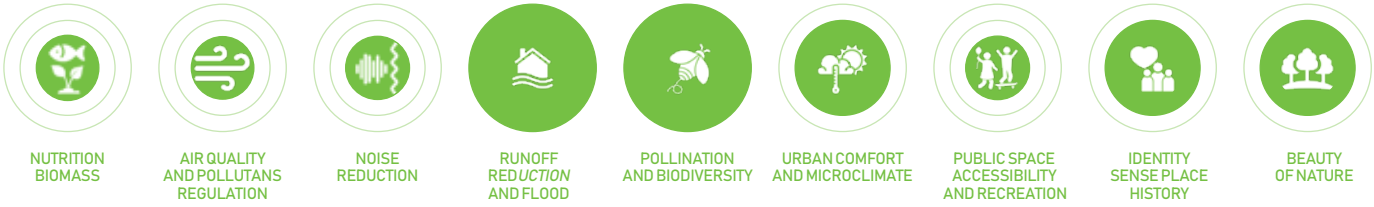
Soil cover plants do not like strong exposure to the sun, precisely because they come from forest habitats, but the original species of forest clearings, open meadows, and stony mountain slopes or slopes overlooking the sea coast need places with intense sunshine as long as the temperatures and humidity of the soil and air are suitable.

RECOMMENDED SPECIES

There are suitable plants for each type of greening.

- SLOPING SIDES, DUNES, SIDES Hypericum, Lonicera nitida, Cotoneaster salicifolius repens, Euonymus fortunei and creeping or hanging plants such as ivy and Jasminum nudiflorum;
- IN SHADY AREAS dichondra, ivy, periwinkle, Pachisandra, saxifraga;
- IN SHADY AREAS UNDER CONIFERS Lamium;
- IN PARTIAL SHADE Ajuga, globularia, hypericum, Mentha pulegium, Ophiopogon;
- IN AREAS EXPOSED TO THE SUN Achillea millefolium, Bellis perennis, Elymus arenarius, Helxine soleirolii, Hernaria, Isotoma fluviatilis, Lotus corniculatus, Phyla nodiflora, Sagina subulata, thyme, clover;
- RESISTANT TO TREADING dicondra (also mowable), Isotoma, Frankenia laevis, Phyla, clover (also mowable).

ECOSYSTEM SERVICES PROVIDED



USABILITY AND ATTRACTIVENESS OF THE PUBLIC SPACE

Areas treated with soil cover, with the exception of some species, are not to be walked on.

- USE Average or none depending on the species used
- HOW TO IMPROVE USABILITY The use of soil cover areas can be enhanced by providing them either with crossing systems - such as bridges or paving - or by flanking them with paths and high traffic lawn areas or by planting them in flowerbeds surrounded by low walls where people can sit.
- BIODIVERSITY Very high
- HOW TO FOSTER AWARENESS OF THE ECO-SYSTEM BENEFITS GENERATED These plants can be signalled by small signs for the botanical illustration of the species and benefits provided to the urban environment.

APPLICATION CONTEXTS

- INSIDE URBAN PARKS In parks soil cover plants can be planted under the trees, creating large areas that cannot be crossed, such as large cushions where mowing is possible only along the perimeter.
- INSIDE SMALL GARDENS These plants can be used as an alternative to turf, or be planted in large flowerbeds. In either case the aim is to reduce maintenance and mowing while ensuring the green area is well kept.

MAINTENANCE

Soil cover plants are challenging plants in the first year after planting to contain the intrusiveness of wild grasses, but if biomats are used, the need for maintenance is reduced or null. Pre-vegetated clods, which are less likely to have unwanted guests, are also available on the market.
They require regular irrigation in the first year while thereafter watering can be for emergencies or null.

INDICATIVE COSTS

- 10 plants/sqm - 1-2 euro/perennial herbaceous plants;
- 3 plants/sqm - 5-10 euro/each roses, soil cover and shrubs;
- 10 plants/sqm - 1-2 euro/each ivy;
- 10-20 euro/sqm for de-paving the surface (in case of mineral systems);
- 20-25 euro/m3 for disposal of excavated earth and rocks;
- 20 euro/sqm for irrigation system for areas planted with lawns and trees.

CASE STUDIES

- Jardin des Amaranthes, Lyon - FR / Case study C4
- Urban park in Boulogne-Buillancourt, Paris - FR / Case study C4
- Martin Luther King Urban Park, Paris - FR / Case study C4

7

PIONEER PLANTS
topsoil recolonisation and biodiversity

From a strictly agronomic point of view, the understory is the most superficial layer of soil teeming with life, but it also indicates the vegetation that dwells on a natural substrate. In order to identify the categories of plants best suited to withstand adverse urban conditions, we considered both the type of plant (herbaceous/woody) and the natural or anthropic methods of combination.

In urban environments, pioneer species develop on abandoned soils and grounds, but they can also be 'helped' by man in processes of renaturalisation of mineral soils. The role of pioneer species is manifold:
- they precede other species in conquering new substrates;
- they affect soil regeneration;
- they improve the biodiversity and ecological stability of the system.

PIONEER VEGETATION

A soil stripped of waterproof covering of various kinds is very quickly covered with new vegetation defined as pioneer, as it is able to settle spontaneously in poor, often barren soil, without being facilitated by plant care such as fertilisation and irrigation.
According to Faliński's definition, 'pioneer species' have certain biological and ecological properties that enable them to perform numerous functions:

- they take advantage of extreme habitat conditions to carry out their life cycle;
- they acquire the ability to adapt to extreme conditions;
- they transform extreme conditions into optimal conditions for the life of other plant and animal species;
- they precede other species in conquering new substrates;
- they determine the development of the initial phases of primary or secondary succession and the course of regeneration in forest clusters, but they tend to withdraw once the ecological stability of the system is reached.

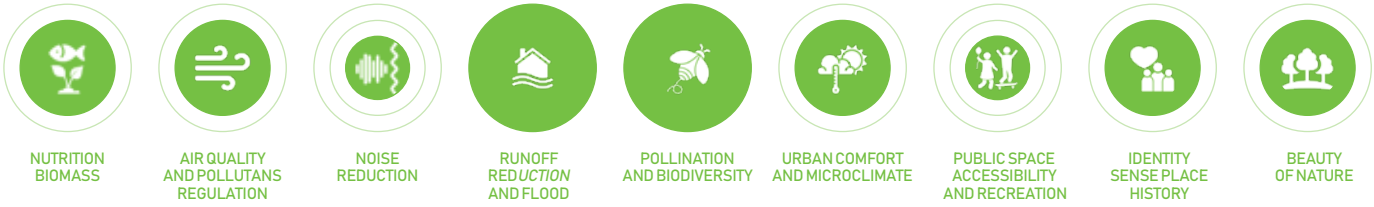
New plant settlements are therefore very dynamic, evolve over time, and unfold according to a series of stages, which start precisely from barren soil and proceed by progressively increasing the biotic complexity up to a mature stage, provided that humans allow for their natural evolution without interfering.
However, it is possible to facilitate the settlement of pioneer species by providing plant soil even in thin layers, increasing biological fertility with humus and humic acids and irrigating every two weeks in the driest period. In addition, to expedite the process, local wild herbaceous species can be sown with the addition of nitrogen-supplying legumes.

RECOMMENDED SPECIES

Pioneers are, in the first instance, lichens and mosses immediately followed by annual or perennial herbaceous plants, but in a few years, shrubby and arboreal specimens appear; in all cases, the seeds are carried by the wind, when they belong to the same species found in neighbouring areas, or by animals, when species appear whose parent plants are many kilometres away. If the vegetation needs to be planted immediately, the species listed in the following paragraphs on naturalised, flowering meadows and rustic meadows can be used.

- GRAMINEAE Arundo donax, Carex spp., Juncus, Phragmites australis, Mentha acquatica, Scirpus spp, Tyhpa latifolia.
- PERENNIAL HERBACEOUS PLANTS Alisma plantago-aquatica, Caltha palustris, Iris spp, Lythrum salicaria, Ranunculus, Thalia.

ECOSYSTEM SERVICES PROVIDED



USABILITY AND ATTRACTIVENESS OF THE PUBLIC SPACE

Urban areas affected by pioneer vegetation have a low usability, due to the spontaneous and variable growth - at times very intense - of the various species that colonise the soil. This, however, can generate a sense of neglect or - in large areas - abandonment and fear.

- USE Low/Very low
- HOW TO ENCOURAGE USE To encourage the use of areas with pioneer vegetation, it is useful to provide for some crossing paths or paths running along the edge, with greater maintenance and mowing, to make use possible or to open the view.
- BIODIVERSITY High/Very high
- HOW TO RAISE AWARENESS Given the great naturalness of pioneer species, it is useful to provide for signage along the edge of these areas for people to guide them and explain the eco-system services provided by plants that grow and evolve according to natural cycles (soil remineralisation, urban drainage, biodiversity).

APPLICATION CONTEXTS

- IN URBAN AND RESIDENTIAL AREAS In small and medium-sized desealing areas (former parking lots and waterproofed areas) where the surface layers have been crushed but the cement or asphalt aggregates have not been removed, in order to green the surfaces, also temporarily or as a temporary garden (not necessarily accessible or usable) in order to facilitate the urban drainage of urban rainwater. This action is possible after the characterisation of the debris, in compliance with the regulations on excavation soil and rocks.
- IN NATURAL AND PERIURBAN AREAS AND IN COMMERCIAL AND PRODUCTION AREAS In large desealing areas (former heliports, former airports, former parking lots, former industrial areas) where surface coverings have been crushed but cement or asphalt aggregates have not been removed, to colonise and renaturalise large artificial areas (not necessarily accessible or partially usable) with natural evolutionary processes. This action is possible after the characterisation of the debris, in compliance with the regulations on excavation soil and rocks.

MAINTENANCE

Pioneer vegetation does not require special care and maintenance, nor watering. It is possible to provide for timely and periodic mowing to maintain the usability of paths covered by spontaneous grass.

INDICATIVE COSTS

- 7 euro/sqm for integration of the top layer with wet soil;
- 2-5 euro/sqm plants (if sown very thick);
- 10-20 euro/sqm for de-paving the surface (in case of mineral systems);
- 20-25 euro/m3 for disposal of excavated earth and rocks.

CASE STUDIES

- Alter Flugplatz Kalbach Urban Park, Frankfurt am Main - DE / Case study C2
- Jardin Joeux Park, Aubervilliers - FR / Case study D30
- Texture Parking Temporary Garden, Courtrai - BE / Case study D32
- Depave is Paradise, Canada- CDN / Case study E 33

8

AQUATIC PLANTS
phytopurification of urban rainwater and biodiversity

In all blue infrastructures that are integrated with the green infrastructure, species that are resistant to stagnation are used, such as riparian plants, or aquatic species, living in
flooded habitats. The latter carry out phytodepuration services, i.e., they reproduce the principle of natural self-purification typical of aquatic environments and wetlands.

In urban environments, aquatic and riparian plants are particularly suitable along canals and waterways, in floodable basins, in lakes and ponds, in rain gardens, and swales. These species serve different purposes:

- they favour the natural purification of water and degrade dissolved pollutants;
- they contribute to oxygenating the water, reducing unpleasant odours due to stagnation;
- they increase biodiversity;
- they have a high ornamental value, helping to increase the attractiveness of public areas.

AQUATIC AND RIPARIAN VEGETATION

Aquatic vegetation has a phytodepuration function that ensures an effective purification of the water that slowly passes through it, as it is a valuable support to the bacterial colonies tasked with this, which are the real protagonists of filtering. Pollutants (nitrogen, phosphorus, etc.) from household liquids are absorbed by the
biological plant-bacteria system that returns quality water also for bathing to the wet environment. It is clear that the denser the vegetation, the more unwanted material is removed and the better the final result.
A phytopurification system has a triple action:

- it absorbs the mineral salts resulting from the decomposition of organic matter;
- it contributes to reducing pathogenic germs;
- it favours the sedimentation of suspended particles.

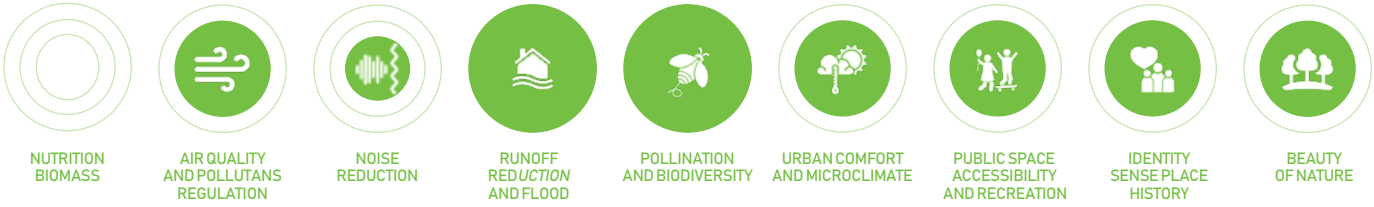
In addition to aquatic plants proper, there are species that prefer - or temporarily tolerate - a soil saturated with water: these include annual or perennial herbaceous plants, shrubs and trees capable of drawing the fertility elements they need, if present in the appropriate chemical form (nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, boron, etc.) from the circulating liquid.

RECOMMENDED SPECIES

In addition to microphytes, i.e., cellular algae, the species used are macrophytes and can be subdivided into:

- SUBMERGED Ceratophyllum demersum, Elodea canadensis (with a tendency to infest), Myriophyllum spicatum, Vallisneria gigantea
- EMERGENT Cyperus, Myriophyllum brasiliensis, Nymphaea, Potamogeton natans
- GRAMINEAE Arundo donax, Carex spp., Juncus, Phragmites australis, Mentha acquatica, Scirpus spp, Tyhpa latifolia
- PERENNIAL HERBACEOUS PLANTS Alisma plantago-aquatica, Caltha palustris, Iris spp, Lythrum salicaria, Ranunculus, Thalia
- HERBACEOUS PLANTS, BUSHES AND RIPARIAN TREES Impatiens noli-tangere, filipendula, marsh fern, iris, cornus, frangula, willow shrubs, viburnum, bald cypress, alder, poplar, willow trees.

ECOSYSTEM SERVICES PROVIDED



USABILITY AND ATTRACTIVENESS OF THE PUBLIC SPACE

The areas involved by aquatic vegetation can have a great ornamental value and be very attractive for people, especially children, fascinated by the colours and animals that live there (small amphibians, butterflies, birds, etc.). However, these areas have a low level of use, due both to the presence of water or damp soils, and to the vigorous growth of species that can generate a sense of neglect.

- USE Low
- HOW TO FAVOUR USE To facilitate the use of wetlands and in the presence of aquatic vegetation, walkways, small crossing bridges, or viewpoints where you can look out and paths along the edges should be used, alternating impenetrable areas with lookout, dwelling and crossing points.
- BIODIVERSITY Very high
- HOW TO RAISE AWARENESS Given the infesting and occlusive nature of certain species, it is very important to have specialised staff with whom to choose the vegetation, and to provide signs dedicated to the public to explain the advantages and eco-system services provided by plants for the benefit of human health and water quality (oxygenation, phytodepuration, biodiversity).

APPLICATION CONTEXTS

- IN URBAN AND RESIDENTIAL AREAS In green areas, gardens and public parks and in all sustainable urban drainage systems (SUDS)
- IN COMMERCIAL AND PRODUCTION AREAS Along canals and watercourses, flood relief tanks and in all sustainable urban drainage systems (SUDS)
- IN NATURAL AND PERIURBAN AREAS Along canals and waterways, wetlands.

MAINTENANCE

When using aquatic vegetation in SUDS systems, regular monitoring is required during the vegetation period to eliminate excess vegetation. Consider a periodic maintenance per year, with medium-low maintenance and costs.
The phytopurification plants proper are managed instead by specialised companies, which are also responsible for controlling the incoming and outgoing waterflows.

INDICATIVE COSTS

- 20-25 euro/sqm or 4-5 euro/plant: flowering phytopurifying paludal species, submerged and/or superficial and/or floating (4-5 plants per sqm, e.g.: Iris Pseudacorus);
- 10-15 euro/sqm or 4-5 euro/plant: phytopurifying paludal reed species, submerged and/or superficial and/or floating (2-3 plants per sqm, e.g.: Phragmites australis, Tyhpa latifolia, Sparganium erectum);
- 5-10 euro/sqm: submerged oxygenating and phytopurifying species (1-3 bunches per sqm, e.g.: Elodea Canadensis, Myriophyllum Spicatum).

CASE STUDIES

- La Confluence eco-neighbourhood, Lyon - FR / Case study A2
- Eco-neighbourhood and urban park in Boulogne-Buillancourt - FR / Case study A3
- Martin Luther King Eco-neighbourhood and Urban Park, Paris - FR / Case study A4
- Alter Flugplatz Kalbach Urban Park, Frankfurt am Main - DE / Case study C2
- Nature-based solutions "Lungo il Canale di Medicina (BO)" - IT / Case study F3

9

SHRUB MASSES
low-maintenance green areas with a high level of biodiversity

Shrub masses are an interesting solution for urban greenery, since they perform different eco-system services at the same time and require low maintenance.

These plants perform various functions in public areas:
- they produce oxygen;
- they contribute to the sustainable urban rainwater management and retain humidity in the soil;
- they contribute to improving the microclimate;
- they absorb dust and air pollutants;
- they favour biodiversity;
- they reduce soil erosion through root systems;
- they enhance the beauty of public areas and improve their care.

SHRUB MASSES

A shrub, or bush, is a perennial woody plant characterised by a very short central stem from which new branches shoot from the foot, new branches that tend to be erect, forming the foliage close to the ground; therefore, it differs from trees, which are characterised by a single, erect trunk that grows in height, with side branches shooting from the trunk that have diameters usually smaller than those of the trunk and are distributed in a specific way along the vertical axis.
Bushes are used for ornamental purposes as single specimens or in small groups placed in flowerbeds or in the middle of a meadow or to form different types of hedges and shrub masses:

- naturalistic,
- to mark off spaces,
- to cover the ground,
- as fencing and for protection.

In order for a hedge to serve its purpose efficiently, whatever it may be and whatever its shape, it should be possible to distinguish at least three different layers within it in terms of height once fully grown, which should be basal, interlayer and top layer.

RECOMMENDED SPECIES

Naturalistic hedges, ideal for areas flanking swales and for renaturation in general, are masses of spontaneous shrubs typical of the place where they are planted.
They are called FIELD HEDGES because in the past, before the intensive mechanisation of agriculture, they would divide the various plots of land and mark off property, skirting the headlands and the drains, where the roots secured the land along the slopes and the canopies limited the growth of the grass in the canals with their shade. Therefore, naturalistic hedges consist of species that can resist both excess water and dry spells or, in any case, the water trends that characterise the places where they settled. Some European directives recommend planting them to create ecological corridors and, above all, for the birds that nest and find food here all year round. For this reason, they are not pruned or treated with phytosanitary products. In the plains of northern Italy and in European continental climate zones they are formed as follows:

- basal layer composed of thorny bushes up to 2-3 metres high, usually blackthorn, hawthorn, dog rose, and herbaceous vegetation;
- interlayer comprising shrubs, such as hazel, cornel, elder, viburnum, privet and euonymus ranging between 2 and 5 meters in height;
- top layer comprising tree canopies, such as willow, poplar, plane, alder and maple trees.

The HEDGES MARKING OFF SPACES are usually arranged in rows, too often to form a wall of plants even when not necessary, with a linear and regular course, in a single or double row, composed of shrub species with a density of 1 to 3 plants per linear metre, whether of the same or different species. They are widely used in formal gardens - to create flowerbeds and/or separate lawns from flowering or fruit herbaceous or shrubby species - and along the boundaries of condominium gardens.

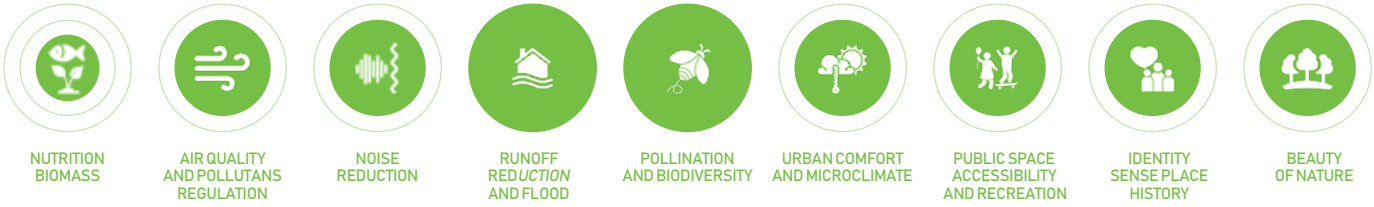
- IN HISTORICAL GARDENS, the most commonly used species are boxwood, laurel, and myrtle among the evergreens of medium to low height, or beech and hornbeam among the taller deciduous trees.
- IN CONDOMINIUM GARDENS, the most commonly used species are, unluckily, euobymus, symphoricarpos, privet, cherry laurel, cotoneaster, pyracantha, pittosporum and photinia among those of medium to low height and Arizona cypresses, thujas and Leyland cypresses among the tallest, all plants whose heights and natural diameters are from 3 to 20 times those required by pruning.

  With the exception of historic gardens, where the choice of species to plant depends on the need to respect philological coherence, the species to be planted must be the ones proportionate to the available space.
- IN LONG AND NARROW BORDER FLOWERBEDS, less than 100 cm, it is better to use creepers that reach the height of the fencing net, possibly strengthened by a weave of steel wires; on the other hand, if the available space is greater, the same species used in naturalistic hedges can be successfully planted, including some "exotic" plants with the same environmental and care requirements.
- IN MODERN GARDENS, shrubs are used to cover the ground just below the foliage of the trees; as mentioned in the paragraph on groundcover, this arrangement simulates the dynamics of the forest with numerous aesthetic and environmental advantages and reduces costs for care, especially in the medium to long term. For this purpose, short, wide shrubs are suitable for covering the ground limiting the settlement of unwanted grasses by adding, compared with mulch, often very interesting blooms; for example, the short varieties of leadwort, Cornus canadensis, Cotoneaster, euonymus, Gaultheria, Lonicera, Mahonia, hydrangea, pittosporum (to be used at the edges of the shade cast by the trees) and viburnum are suitable for this purpose, as they withstand quite well or even seek the resulting partly shaded conditions.

BUSHES are little used for defensive purposes, consisting of thorny shrubs also called 'armed', while they could be used instead of nets to mark off areas to be protected against intrusion by humans. Crataegus, pyracantha, trifoliate orange, roses and buckthorn are almost ubiquitous species, but in the driest zones Euphorbia, Pereskia, Agave, Carissa, Echinopsis, and various Cactus species are preferred. Depending on the species or variety used, it is also possible to obtain a striking ornamental effect, for example by planting Rosa multiflora shaped like a fountain, up to 4 metres high and more than 2 metres wide, which has an intense bloom in May and is very inexpensive, as it is used in nurseries as rootstock for finer varieties. The bird species and, in particular, Turdids are fond of the fruits produced by many of these species in which they nest and find nourishment in the winter, during which these useful insectivores are satisfied with the berries remaining in the territory and helping, in spring and summer, to decrease the populations of insect pests that harmful for plants.

Food plants for bird species. Pyracantha coccinea, Ilex aquifolium, Rhamnus alaternus, Prunus cerasus, Crataegus azarolus, Laurus nobilis, Celtis australis, Crataegus monogyna and C. oxyacantha, Lonicera alpigena, Lonicera losteum, Sorbus torminalis, Prunus avium, Cornus mas, Cotoneaster nebrodensis, Berberis vulgaris, Sorbus aria, Ficus carica, Phyllirea latifolia, Frangula alnus, Euonymus europaeus, Morus alba, Morus nigra, Juniperus communis, Diospiros kaki, Viburnum lantana, Viburnum tinus, Pistacia lentiscus, Ligustrum vulgare, Malus florentina, Malus sylvestris, Prunus cerasifera, Myrtus communis, Corylus avellana, Hippophae rhamnoides, Prunus padus, Viburnum opulus, Pyrus amygdaliformis, Amelanchier ovalis, Pyrus pyraster, Prunus spinosa, Sambucus nigra, Cornus sanguinea, Sorbus domestica, Sorbus aucuparia, Rhamnus cathartica, Taxus baccata, Pistacia terebinthus.

ECOSYSTEM SERVICES PROVIDED



USABILITY AND ATTRACTIVENESS OF THE PUBLIC SPACE

Areas planted with shrubs and bushes are not suitable for walking.

- USE Average or none depending on the species used
- HOW TO IMPROVE USABILITY The use of vegetated masses can be facilitated by means of meadow clearings, by providing elevated crossing routes or accompanying routes along the edge. When the shrub masses are particularly dense and impenetrable, they can arouse fear in people and it may be useful to provide lighting systems along the paths.
- BIODIVERSITY Very high
- HOW TO FOSTER AWARENESS OF THE ECO-SYSTEM BENEFITS GENERATED The benefits provided to the urban environment by bushes and shrubs are really high, not only compared to the regulation services, but also to support the biodiversity of animals that find safe habitats here. Therefore, it is very important to have signs to explain the benefits of vegetation and to respect its habitats.

APPLICATION CONTEXTS

- IN URBAN PARKS They can be planted in parks to create more natural areas for the benefit of birds.
- IN SMALL GARDENS These plants can be used to outline the edges and boundaries of gardens.

MAINTENANCE

The maintenance of the shrubs usually includes annual pruning, which is essential for almost all species used for flowering, but if a hedge or shrub mass is properly designed, pruning can be limited to intervals of several years and often be aimed at eliminating dry or damaged branches or rejuvenating the plants.

INDICATIVE COSTS

- 5-15 euros per plant (very variable);
- 40-50 euros/sqm: forming and planting of shrubs, including understory and mulch layer (as an indication, depending on the size of the plants, 1 to 3 plants per square metre can be considered);
- 20 euro/sqm: irrigation system for areas planted with lawns and trees.

CASE STUDIES

- Jardin des Amaranthes, Lyon - FR / Case study C4
- Urban park in Boulogne-Buillancourt, Paris - FR / Case study C4
- Martin Luther King Urban Park, Paris - FR / Case study C4

10

TREES
plants in hostile urban environments

Trees are one of the most important solutions to the problems of urban environments, since they serve several purposes in adapting to and mitigating climate change and provide various eco-system services, from regulation, through production, to culture.

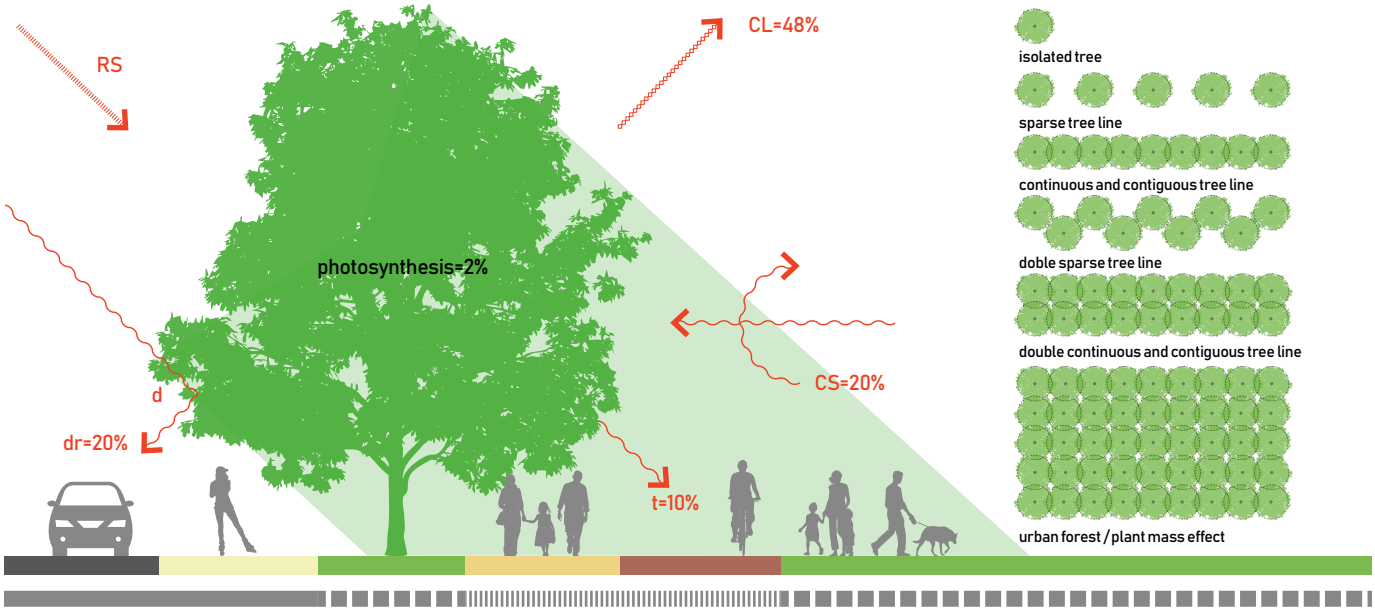
Trees in public areas serve various purposes:
- they produce oxygen;
- they contribute to sustainable urban rainwater management and counter runoff;
- lower temperatures to counter the heat island effect;
- they contribute to improving the microclimate;
- they absorb dust and air pollutants;
- they favour biodiversity;
- they reduce soil erosion through root systems;
- they serve the purpose of soil phytoremediation;
- they favour the beauty of public areas by generating context value and increasing the real estate values of the areas in which they are planted;
- they encourage a sense of identity and belonging to the place and the psycho-physical well-being of people.

There are many benefits that trees bring to citizens and the environment and these depend on many factors and can affect the regulation of heat and water, the aesthetic enhancement of the city and the regulation of greenhouse gases and pollutants.

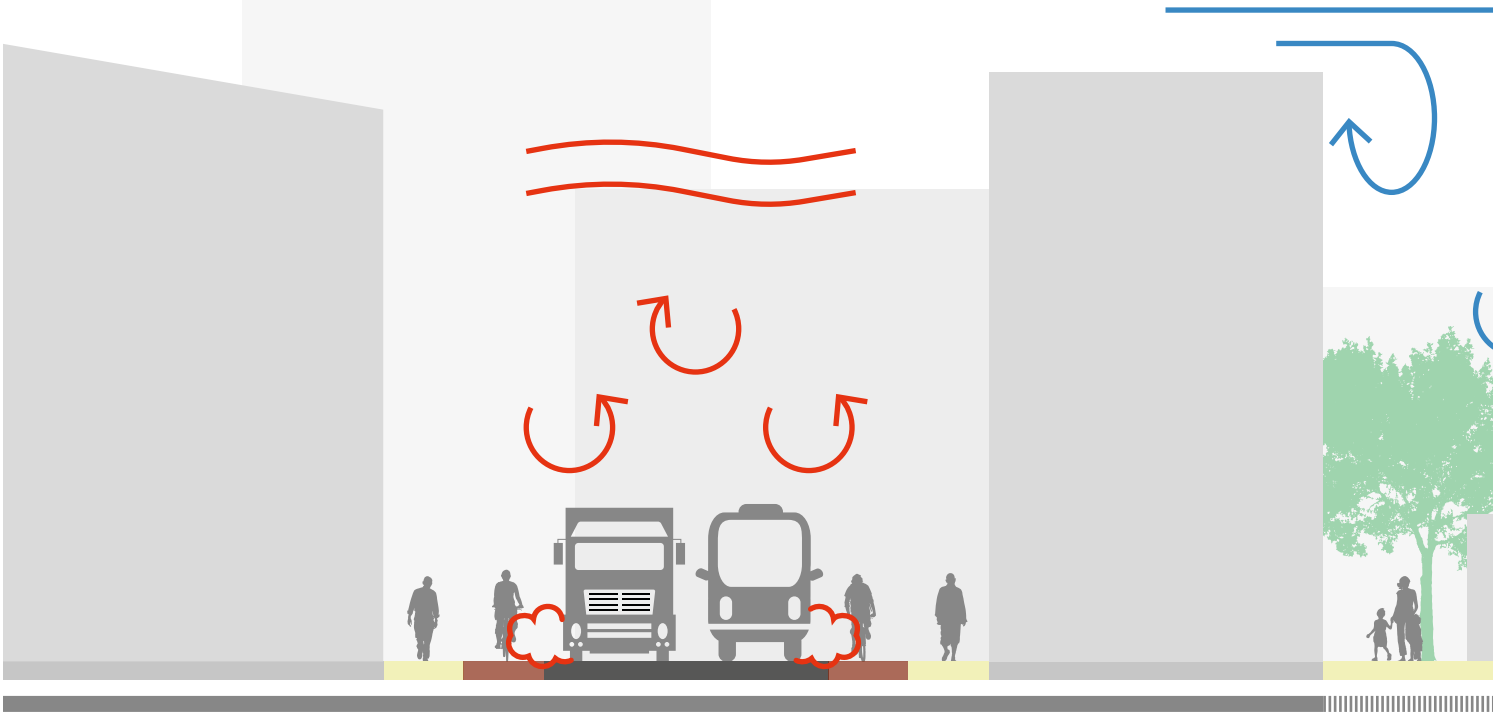
TREES, EVAPOTRASPIRATION AND WIND TO MANAGE HEAT

The cooling effectiveness of a vegetative mass is generated by the sum of the effect of evapotraspiration and shading and is proportional to the continuity of the first and the contiguity of the second.
The same number of trees have greater thermoregulatory efficiency as their distances are, compatible with growth needs, dependent on the species and variety they belong to.
Therefore, depending on the morphology of urban space, trees can be present as a single individual, organized in rows (single, double, group or mixed) or as a vegetated mass.
Along the routes the row is used, while in the squares, gardens and parking lots both the rows (even double) and the vegetated masses that generate a forest effect. The overall use and planting of trees in different forms gives continuity to the green infrastructure of the city.
In the arrangement, the size of the radius of the tree's head, which will be half of the sixth plant, must be taken into account to prevent the increase in the head of a tree from interfering with the canoe of the neighboring one.
In built-up urban structures, in windless conditions , the heat island determines an external-inland breeze that concentrates pollution and does not allow heat dissipation.
Green urban structures (particularly concentric and diffuse urban structures), on the other hand, lower the air temperature, triggering urban breezes ranging from green to built. The general effect of energy exchanges is the moderation of the microclimate thanks to the formation of thermal winds generated by the mass presence of trees.

The vegetation, depending on the arrangement, interferes with the wind speed:
- IF PLACED IN A BARRIER PERPENDICULAR TO THE DIRECTION OF THE WIND affects the thermal load of buildings and is beneficial in winter reducing the speed of cold winds coming mainly from the north;



Plants use a minimal part of solar radiation (RS) for photosynthesis (2%), but reflect about 20% back (dr) and transmit 10% (t) to the ground, re-emitting 20% as 'sensible heat' (CS) and 48% as 'latent heat' (CL) through a natural mechanism that lowers air temperature: evapotranspiration (the emission of water vapor). One plant provides the necessary oxygen for the life of 10 people. The benefits that draw an individual that walks protected by the trees are numerous: direct shade, lower air temperatures, and the fact that people 'exchange' heat with an element that has a lower temperature (the foliage of the tree or the shaded walls of buildings).
Along the pathways, rows are generally used, while in squares, gardens, and parking lots, both rows (even double) and masses of vegetation are used, which create a forest effect.
The overall use and planting of trees in its different forms provides continuity to the green infrastructure of the city.
When arranging the trees, we must keep in mind that the size of the tree's crown radius which will be half of the planting pattern in order to prevent that the growth of a tree's foliage interferes with that of another.
(Rielaborazioni originali from Scudo, De la Torre, Josè / Illustration REBUS, *Cities for people* exhibition)

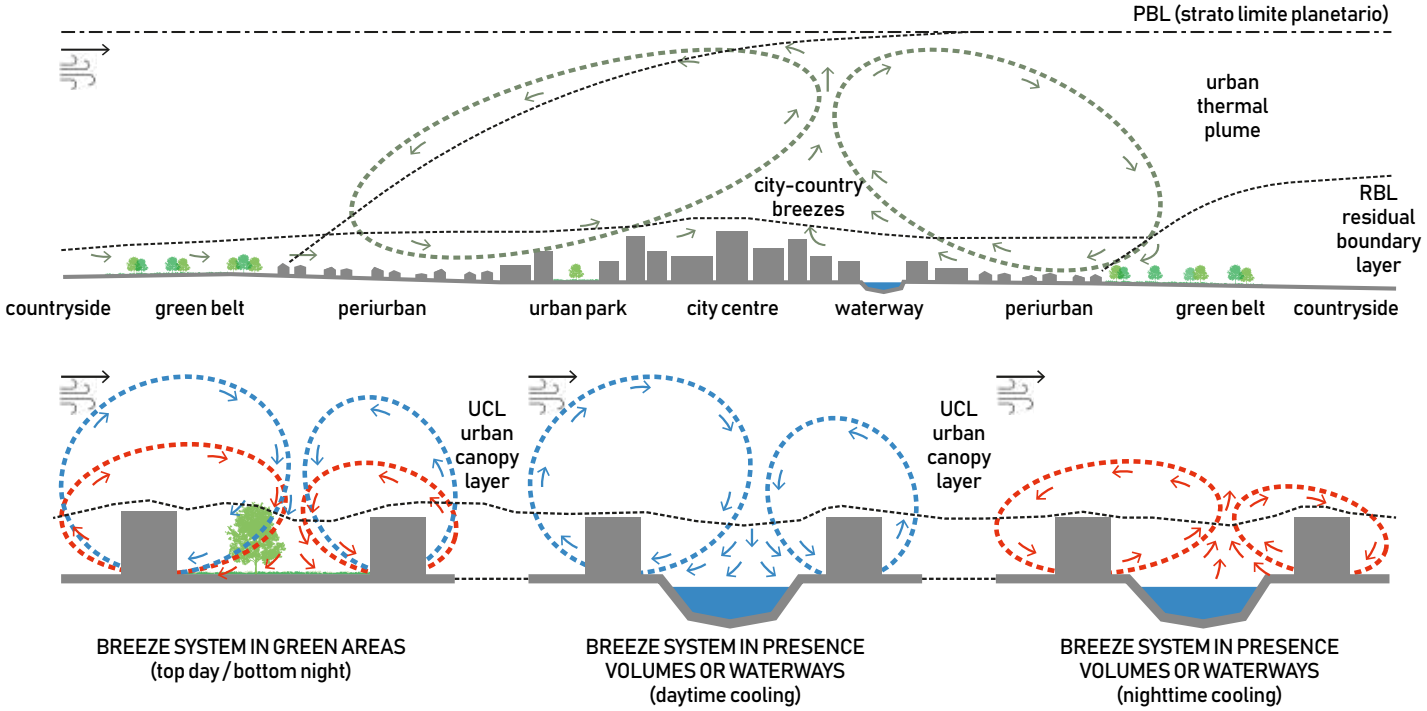


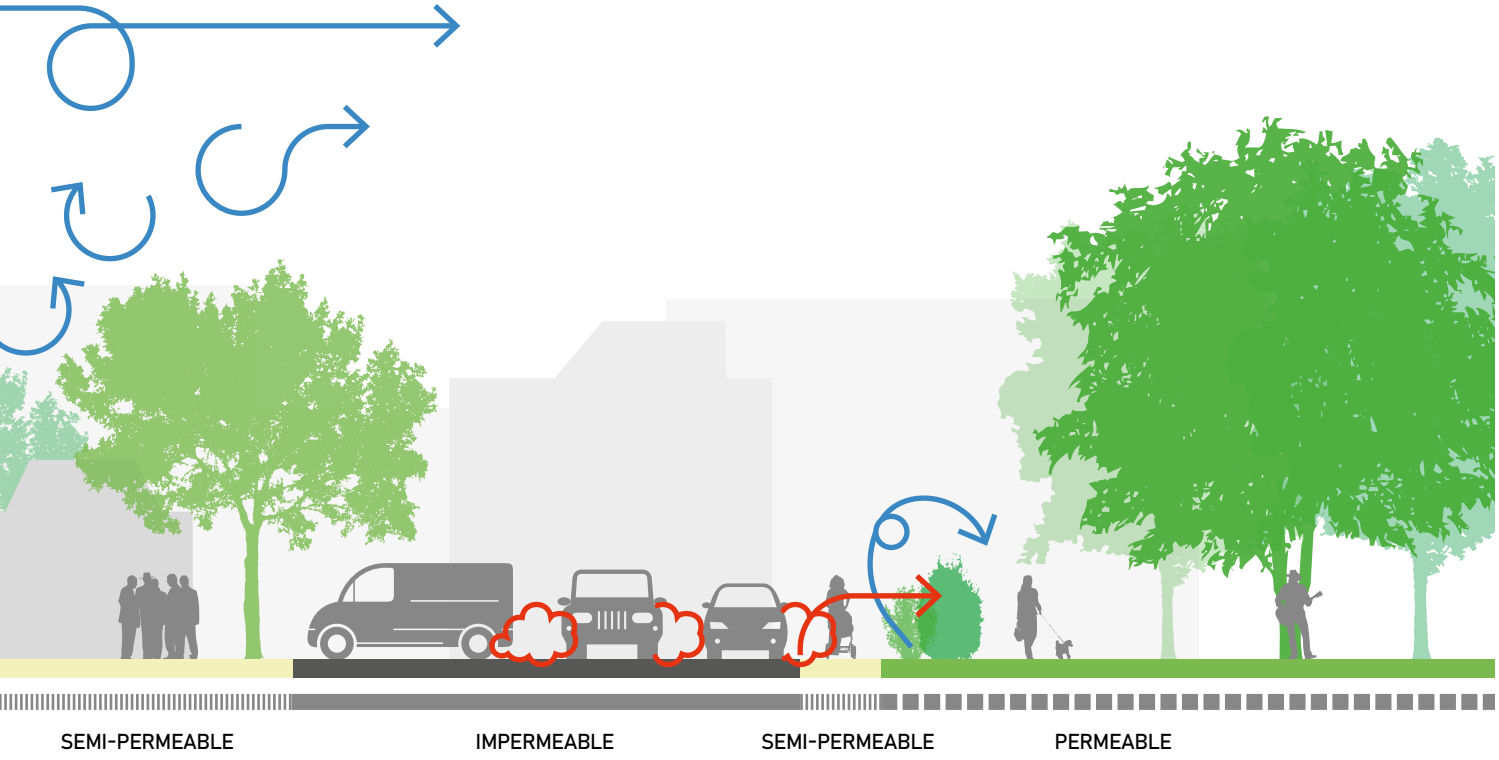
IMPERMEABLE

On top. The figure shows the characteristic development of the secondary circulation in the planetary boundary layer limit above a city. The air that is located above the building heats up and decreasing in density rises creating a thermal, while the air from the suburbs is drawn back to the city center for fluid dynamics and the lifting process is renewed. The air that reaches the top of the mixing layer cools due to the thermal gradient (-9.8 °C / km) and becomes denser and moves towards the ground by closing the secondary transport cell.

In the left part of the figure a typical urban area without vegetation is reproduced where the pollutants emitted by motor vehicle traffic remain trapped between the walls of the building due to the low atmospheric dispersion. On the right side of the figure there is an urban system not strictly confined and the elements of anemological flow, interacting with surface structures with different characteristics, trigger turbulent motions that facilitate diffusion, and coming into contact with the plant surfaces can give rise to the deposition of air pollutants.

Left, central. The figure represents the classic circulation produced by a cold puddle, generated by the presence of vegetation between buildings, where the vertical movement of the air, triggered by the greater enthalpy of the building, always returns to the surface by virtue of





continuity fluid dynamics. In this case, too, a local circulation system is triggered, determined by the different surface temperatures, or by the built-vegetation thermal differential.

Left, bottomo. The first figure shows atmospheric dynamics similar to the previous one where the role of a cold pool is represented by the presence of free surface water. The heat engine is substantially the same as the one where vegetation is present, as during the daytime the water has a lower temperature than the surrounding building.

The second figure shows atmospheric dynamics similar to the previous one where the role of a cold pool is represented by the presence of free surface water. The heat engine is substantially the same as the one where vegetation is present, as during the daytime the water has a lower temperature than the surrounding building.

The third figure represents the dynamics of the air mass during the night where the water temperature exceeds that of the surrounding buildings because the heat loss of the latter is much faster having lower thermal inertia. As can be easily seen, the atmospheric motions have the opposite direction to those of the previous figure.

IF PLACED IN A BARRIER PARALLEL TO THE WIND DIRECTION 'LEADS' THE BREEZES TOWARDS SENSITIVE TARGETS, such as the historic centers, typically highly built and almost devoid of green structures and refreshing airflows. The goal is to channel summer winds from the southeast and southwest (but it is essential to check conditions locally, as buildings change atmospheric flows).

In order to cool down, it is also advisable trees with high evapotraspiration, in order to achieve the lowering of the air temperature in the breeze cells.

The effectiveness of tree-building in thermoregulation is then closely dependent on spatial relationships between plant and plant.

TREES AND REMEDIES FOR POLLUTION

Emissions of air-polluting gases and dust - due to vehicle traffic, industrial and energy production, waste treatment, urban transformations, heating and cooling of buildings - have a climate-warming activity, as well as polluting.

The main gaseous compounds that pollute and affect the climate are particulate matter (PM10, PM5, PM2.5), carbon dioxide (CO2), nitrogen (O3), monoxide and nitrogen dioxide (NO, NO2), sulfur dioxide (SO2), which has been added according to recent research also IPA, Aromatic Polycyclic Hydrocarbons, such as benzene (C6H6), naphthalene (C10H8) and others.

Soil and water can also be contaminated in a widespread way by atmospheric depositions and,

directly, by spills into rivers, seas and soils from compounds such as arsenic, mercury, nickel, copper and chlorinated compounds.
Pollution causes an alteration of the natural chemical composition of soil and water, causing a chemical-physical and biological imbalance that severely compromises the chances of survival of micro and macro fauna and flora, resulting in substances that are also harmful to humans.
Plant species have a mitigating power over pollutants and are distinguished from each other in different 'specializations':

- reduction of pollutants in the atmosphere, through the mechanism of photosynthesis;
- polluting compounds are eliminated through absorption and subsequent metabolisation;
- capture ultrafine powders (PM10, PM5, PM2.5), thanks to the presence of hairs, roughness and waxes of the leaf surface that function as a biological filter;
- phytorimedio, consisting of the extraction from the soil of the polluting compounds to accumulate them in the roots and leaves (phytoextraction) or in the biodegradation of organic contaminants of the soils by exploiting the synergy with the microorganisms present around and within their roots (phytorizodegradationation), which determines the so-called 'phytostabilization'.

In addition, there is a significant increase in the number of water pollutants in the area. The result is environmental recovery at a reduced cost compared to conventional chemical-physical techniques. The application of plants is particularly effective along roads and parking lots and the choice of species requires qualified personnel.

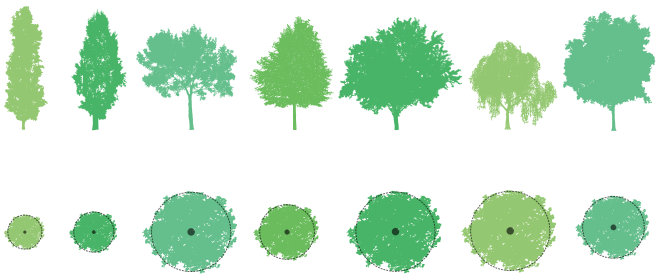
TREES AND URBAN QUALITY OF THE PUBBLIC SPACE

The choice of a tree species comes from the combination of the shape of the urban space and the morphological characteristics of the plants, which include size, bearing, foliage colors and seasonal variations and the presence of flowers and fruits.
Bearing and size are important, because it is through these two elements that the size and shape of the shadow is defined, that is, the main requirements that space must have in order to allow an activity to be carried out in the appropriate environmental conditions.
Therefore, the choice of plant species according to their shape is able to determine the thermal effects of the green area. The conditioning element in the choice of tree species, however, always remains the potential for survival and growth of trees, dependent on the space available for roots and canopy.
Trees must be chosen according to their role, the space that hosts them and their bearing, which is different for the different tree species.
The bearing and size requirements are fundamental in the design of the urban space and once established you can choose the plants according to location, climate, color variation, rusticity and urban context.

- RESIDENTIAL Trees to shade the sidewalk, hedge to shade the building and maintain privacy, parking lots in shadow and shielded from view;
- RESIDENTIAL WITH PRIVATE GARDEN Trees to shade the pavement and waterproof surfaces;
- TERTIARY ACTIVITIES Trees to shade the pavement and building, hedge to shelter from vehicular traffic.

Finally, given that the trees reach the greatest growth in several years, it is appropriate to accompany the planting with shrubs and/or faster growing species.
In the choice of plants there is another determining factor, related to species. The current 'model' of tree choice prefers native species that grow well. However, the variety of species is very small compared to the types of plants that can be used to produce the effect of 'oligoculture' (presence of a few species), including the simultaneous emission of large quantities of pollen. In cities, which

The choice of tree species derives from the union between the shape of the urban space and the morphological characteristics of the plants, which includes size, crown form, foliage color and their seasonal variation, and the presence of flowers and fruits.
In heavily trafficked areas, the trees and shrubs must guarantee shade for the pedestrian spaces, at least in the hottest part of the day and for façades that are more exposed to solar radiation.
Along the streets, beyond providing shade, trees and plants also help to mitigate pollutants.
(Illustration REBUS, *Cities for people* exhibition)



are artificial places, to choose plant species it is necessary to operate according to the dictates of Urban Ecology, a science that studies living organisms in the urban environment. So, today, to plant the right tree in the right place it is possible to expand the concept of 'native' in the strict sense by adopting also some of those species that in the city live long and luxuriantly without the need for pruning or agropharmaceuticals. This option should always be carried out with qualified agro/forestry personnel.
Finally, the way of care to be reserved for plants is decisive not only for the duration of their lives – which in the city is shortened by a lot – but also in all those preventive phases of planting in urban contexts and in construction sites, habitats that are more hostile than ever for any living being, especially for those who are not able to move to provide for their needs.

TREES AND INTERFERENCE WITH UTILITIES

Trees in urban environments are affected by intense conflicts with buildings, roads, infrastructure and utilities and, in most cases, construction and maintenance needs of buildings take precedence over the protection of green areas affected by the construction sites. Municipal regulations for green areas set out rules for the preparation and management of construction sites in areas with trees or other vegetation and to determine methods on how to intervene underground near trees. However, there are not always adequate controls by the Public Administration on the conformity of projects and works at the construction site with regard to plants and this can generate conditions of risk both for the health of the trees and for the safety of citizens.
A preventive approach to plant protection and to ensure maximum performance of the services they provide to the health of the urban environment is always the best one. Therefore, it is necessary to identify expert figures both in the design phase of public works and in the construction site phase for their construction and implementation.

NEW PLANTINGS

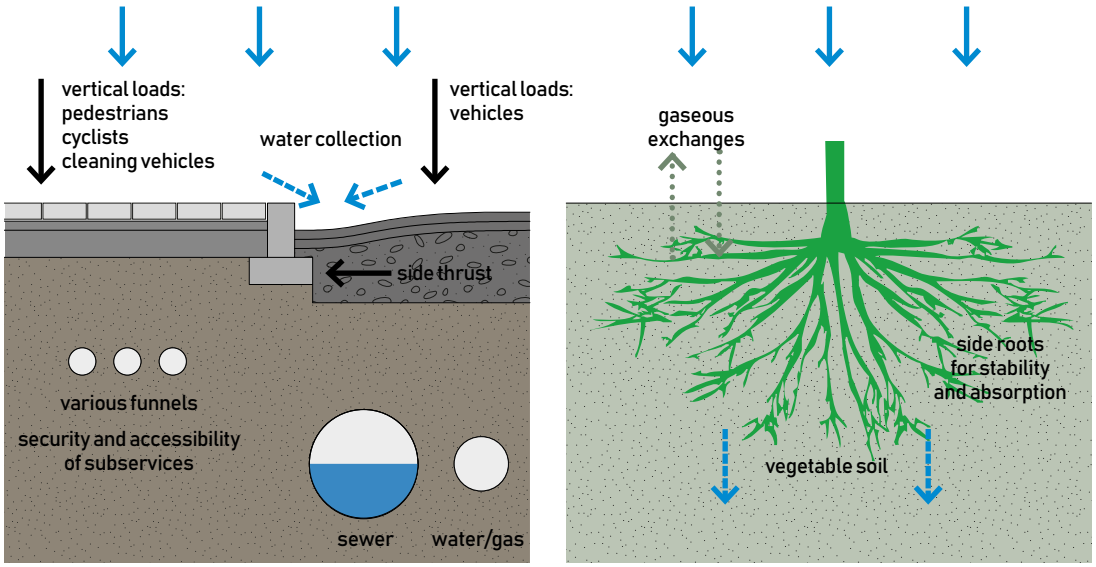
When planting trees, it is of fundamental importance to plant them at the right time:

- DECIDUOUS TREES must be planted in the dormant season, usually between late October and March;
- EVERGREEN BROAD-LEAF TREES keep leaves all year round and they lose water in a period when the root system is struggling to retrieve it; therefore, they are to be planted in the period preceding seasonal development, before the growth of new shoots. For example, the optimal period for citrus fruit is the summer period, which also coincides with pruning for fructification purposes;
- CONIFERS are to be planted in March-April.

If the plants are bare-rooted, it is better to avoid the middle of winter, because frosts could be fatal; it is advisable to trim the roots with a clear cut and disinfect them with copper salts. Plants grown in pots are sold on the market and, if well cultivated, they can be planted at any time of the year, but it is necessary to prevent damage due to bad weather events, paying greater attention to those plants planted in the periods indicated above, especially with regard to water deficit.

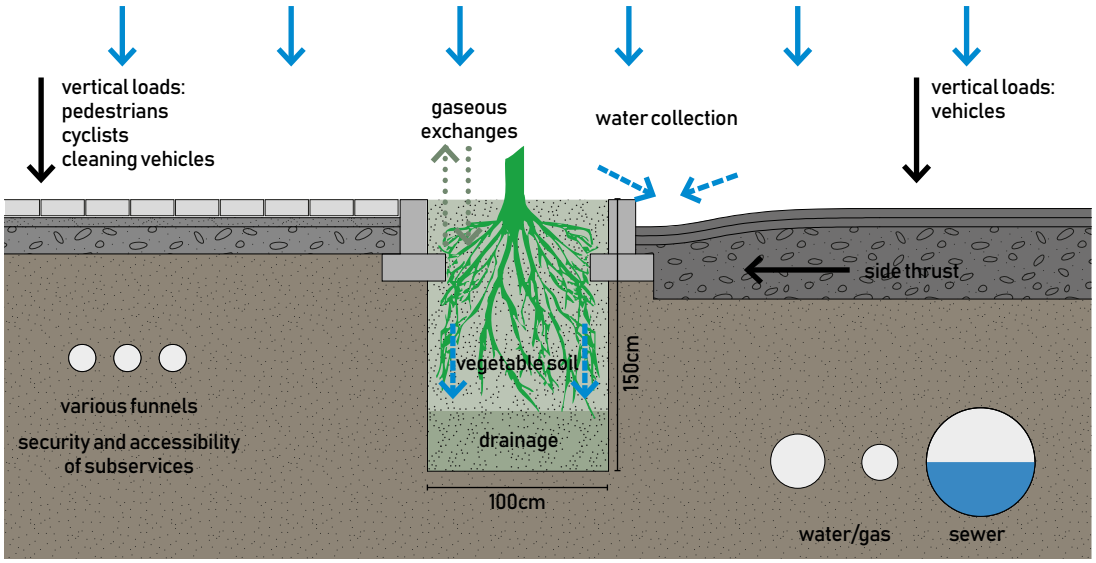
PLANTING HOLE

The preparation of the planting hole is an operation to be carried out in the autumn before planting, in order to allow good aeration, optimal soil disintegration caused by frost and adequate absorption of water. The size of the hole should be at least 1.5-2 times the size of the root ball, but projects attentive to the needs of vegetation should have a volume of soil equal to 18 cubic meters for each specimen planted, while numerous studies have shown that the ideal underground volume is equal to 3 x 3 x 3 metres. These measures are not always possible in regeneration contexts, but with the assistance of an experienced agronomist it is possible to determine the optimal conditions in different cases.



THE NEEDS OF INFRASTRUCTURE AND SUBSERVICES COMPARED TO THOSE OF TREES AND VEGETATION

In the design of roads and sidewalks it is essential to take into account both the spaces necessary for the operation and maintenance of subservices, and the dimensions that allow an adequate growth of trees and urban greenery, so that there is no interference in the coexistence of the different systems.



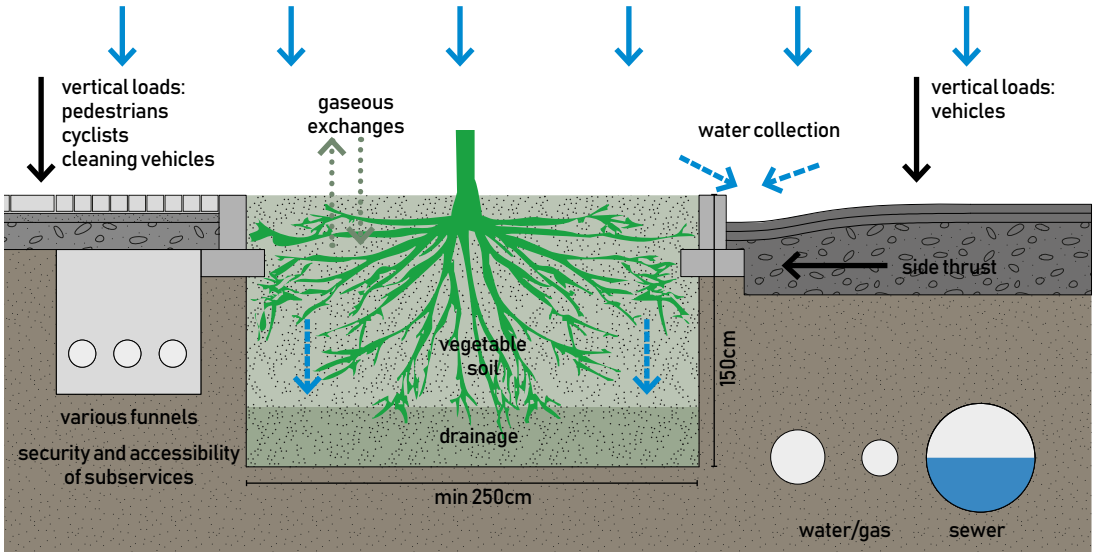
DESIGN PROPOSAL #1

The coexistence between infrastructure and trees is possible thanks to flower beds of minimum size L100xH 150 cm where to plant a tree of III size.

The road pavements must be delimited by kerbs and the trench of laying subservices positioned at a proper distance from the flower bed.

The flower bed must be filled with debris-free plant soil to allow gas exchange, infiltration, and the supply of meteoric water from the sidewalk.

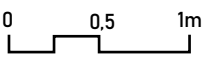
A drainage bottom should be provided when filling the flower bed hole.



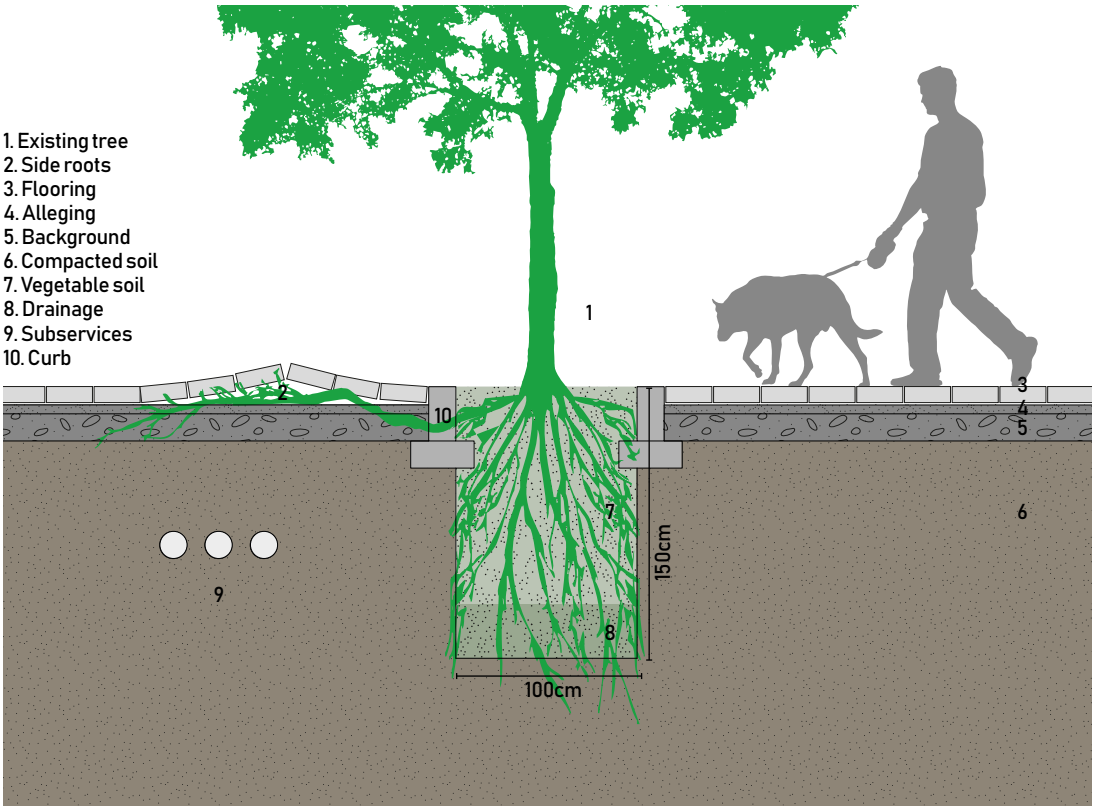
DESIGN PROPOSAL #2

It is possible to make even more performing the coexistence between infrastructures and trees by creating flower beds of minimum size L250 xH150 cm that filled with vegetable soil can accommodate a tree of II size.

it is advisable to delimit the road pavements from the shaft hole with disputed kerbs and to organize the laying of the subservices at a due distance from the flower bed, possibly in an inspectable cavedium or with easily removable flooring/slabs.

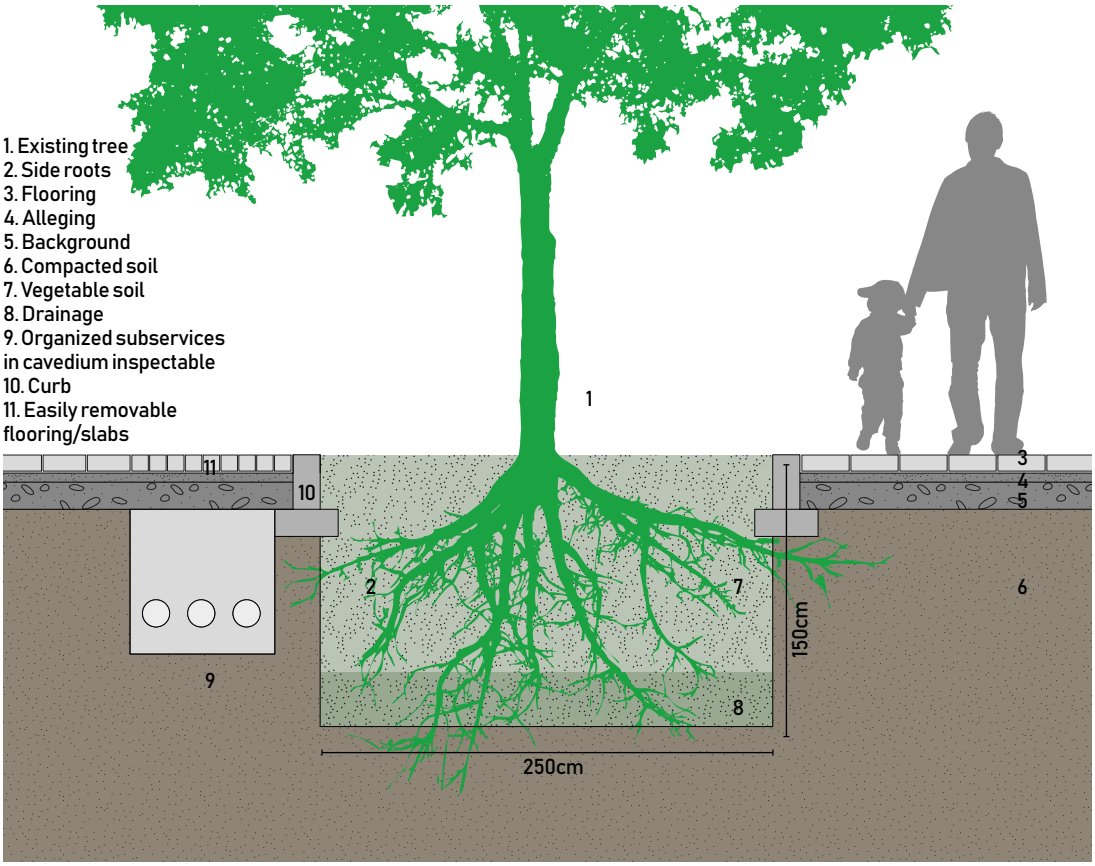


At the base of the tree-lined buildings, on the quays on the sides of the roads and in the parking areas, there must always be a free, un paved space of permeable soil that allows a regular development of the radical system with a reduction in damage due to the growth of roots in adjacent paved surfaces.
An effective organization of excavation dimensions, deep and wide, ensures that the root system does not conflict with flooring and subservices.



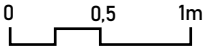
PLANTING SPACES INADEQUATE FOR PLANT GROWTH
In the city, trees, roads, sidewalks and subservices often struggle to live together, with mutual inconvenience and inconvenience: asphyxiation and constriction to the detriment of the correct development of the root system, lifting of flooring and curbs, possible damage and interference of the underground lines.

In the absence of an adequate amount of permeable vegetable soil, to grow the roots of the plant make room, even on the surface. For this reason it is appropriate to properly evaluate excavation sections and laying systems that allow the plant to live and grow to generate comfort and shade of protection for people.



ADEQUATE PLANTING SPACES FOR PLANT GROWTH
The effective organization of the dimensions and functions of each other manages to sum up the different needs, ensuring future maintenance without causing damage or disruption.

Roots up to 3 cm in diameter can be cut; the cut must be carried out in a clear way and followed by perfection dressing. Excavations must not remain open for more than 2 weeks and, in the event of interruption of work, the roots must be covered and kept moist. The final filling should be carried out with a mixture of soil and sand in a 2:1 ratio and care will be taken not to pollute the root area with debris and excavation residues.



When digging it is advisable to make holes in the walls breaking very compact soil that has formed while digging in order to help the lateral expansion of the roots. The remaining space should be filled with soil - fresh, loose, composed of peat, sand, humus and fertilisers - which should be well compacted at the end of the work.
In preparing the hole, in order to avoid water stagnation that could cause root asphyxiation, good drainage of the bottom is provided for, especially in the areas with heavy, clayey and asphyxiated soils. Often the bottom of the hole is prepared with a bowl shape, but this is a mistake because in this way the water is kept too close to the rhizosphere; it is much better to make a central ridge and go deeper along the sides to allow continuous drainage of excess water. Drainage is achieved by placing a 15-30 cm layer of gravel on the bottom of the hole, covered with a sheet of jute to prevent soil particles from blocking the pores of the draining material. In addition to removing the water, it is necessary to provide for the water supply, which must be regular in the first three years of life during periods of drought and only in emergency cases in the following five years; a corrugated tube is then placed all around the root ball, supplied by a special system, which distributes the water to the bottom of the root ball.
It is a good idea to mulch the soil at the base of the tree with organic materials, creating a layer of at least 4-5 cm; this practice favours better conditions of humidity in the superficial layers of the soil, hinders the growth of unwanted species and is an excellent stimulant for microbiological activities in the soil, also promoting the formation of mycorrhizae.

SUPPORTING THE PLANT

Immediately after planting, the root system does not fulfil one of its main tasks, i.e., to anchor the plant to the ground. It is necessary to support the plant, or rather the root ball, with appropriate tutoring systems, to ensure stability for the root system. Once, not too long ago, stakes were used as tutors, but numerous research studies have shown that they are not entirely functional to good anchoring of the roots to the ground, which is stimulated by a slight oscillation of the stem when the plant is young. Systems for anchoring the root ball have therefore evolved. They are made by hand using poles stuck in the ground and placed between the root ball and the walls of the hole, or in a more technological way using various systems, some of which are biodegradable.

PRESERVING THE ROOTS, TRUNK AND CANOPY OF TREES

One of the problems that most affects the planting of trees in urban contexts is the presence of utilities such as water, gas, sewage and electricity. In choosing the trees to plant, it is necessary to put together the needs of plants and urban infrastructure: a complex effort because it means combining the needs and characteristics of all existing and planned utilities with those of vegetation.

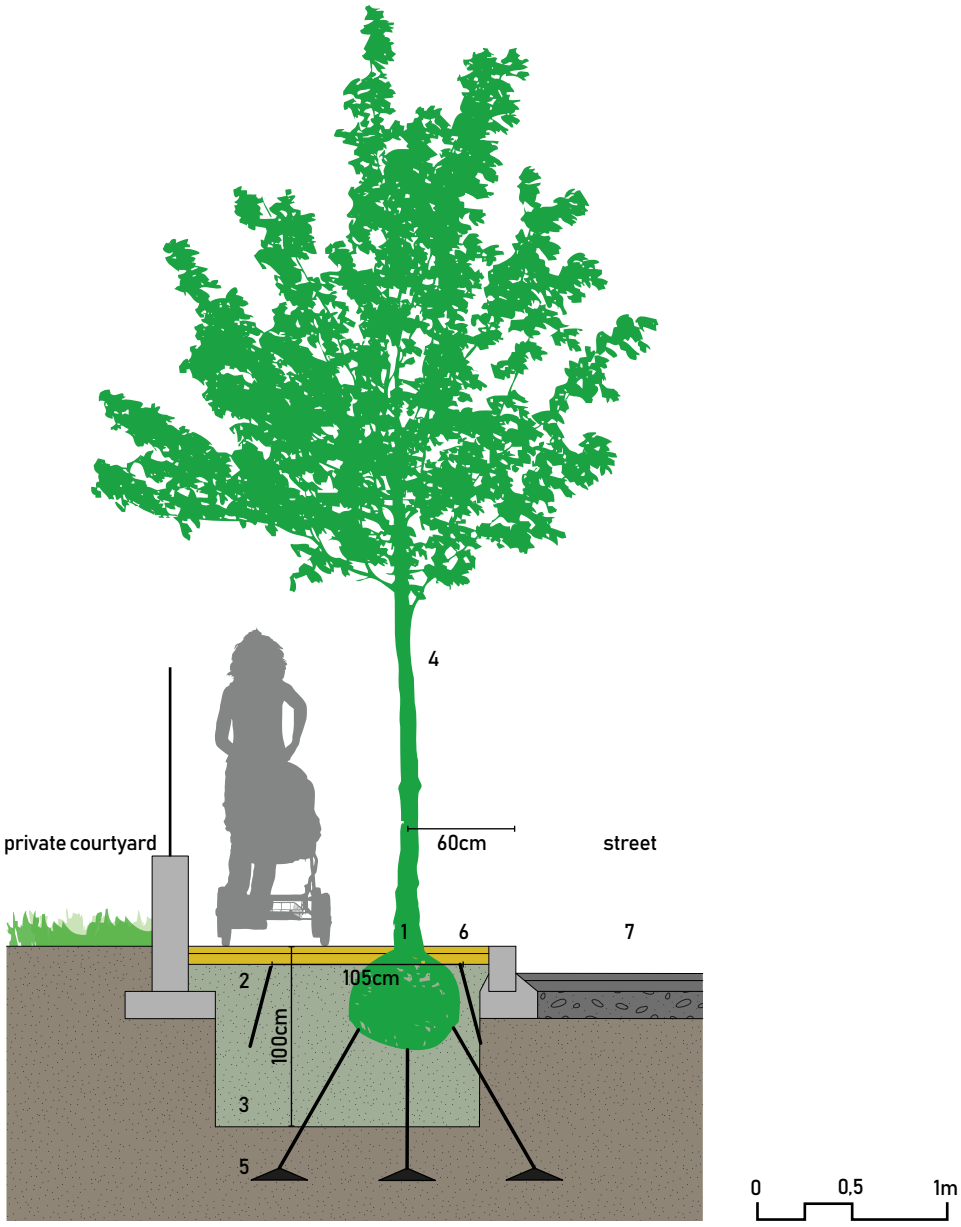
- PROTECTING ROOTS AGAINST TRAMPLING. Firstly, attention should be paid to protecting the hypogean portion of plants against trampling, which causes soil constipation, first, and root asphyxia, later, adopting systems that protect roots.

- RESPECT FOR ROOT SPACE. At the base of trees, on roadside pavements and in parking areas, there must always be a free, unpaved space of permeable soil that allows the root system to develop regularly and reduces damage due to the growth of the roots in the adjacent paved surfaces. Flowerbeds for roadside trees must be as wide as possible, have a non-constipated or cemented draining bed and be deep enough to allow lateral expansion of the plant root systems in the profile below the paved surfaces. In the various regulations

Scheme for the correct planting of trees of 2nd or 3rd magnitude at narrow sidewalks.

Different rooms built at the base of the tree-lined rooms. On the quays, on the sides of the streets and in the parking areas, there must always be a free space or at least an un paved space, of permeable soil that allows a regular development of the radical system with a reduction in damage due to the growth of roots in paved surfaces. Sequentially: soil flower beds vegeted on the side of the road and along mineral paths, earth flower beds adjacent to stabilized or mineral soils, soil protection grilles, draining flooring made by conglomerate composed of stone grit, recycled rubber and polyurethane binder

for greenery, municipalities establish minimum surfaces and permeable areas for the plant depending on its size.
As regards lateral expansion, it is much greater than the projection of the canopy on the ground. Therefore, in order to ensure a useful increase in the permeable, unpaved surface, in the absence of any other constraints, the flowerbed intended for trees can be extended longitudinally, while keeping the minimum width indicated unchanged. The best conditions for the development and adaptation of trees are obtained by placing them in a continuous flowerbed of the indicated width, free from impermeable pavements, and greened or covered with inert material for draining purposes (gravel, pebbles, etc.).



1. Draining gravel or Flexipave to let the tree trunk expand freely
2. Deflector (inclination min 45°-30°)
3. Vegetable soil
4. Tree of III size
5. Root anchoring system
6. Semi-permeable flooring
7. Asphalt




PROTECTION OF ROOT SPACE. If the plant area needs to be protected against compaction, the surface must be covered with suitable draining protective material:
- non-passable for vehicles: gravel, crushed stone, cobbled pavement;
- passable for vehicles: prefabricated 'grid' elements made of cast iron or other suitable material.

In order to support the growth in diameter of the trunk, the grids must be built in concentric and removable modular elements that allow the progressive expansion of the central opening.

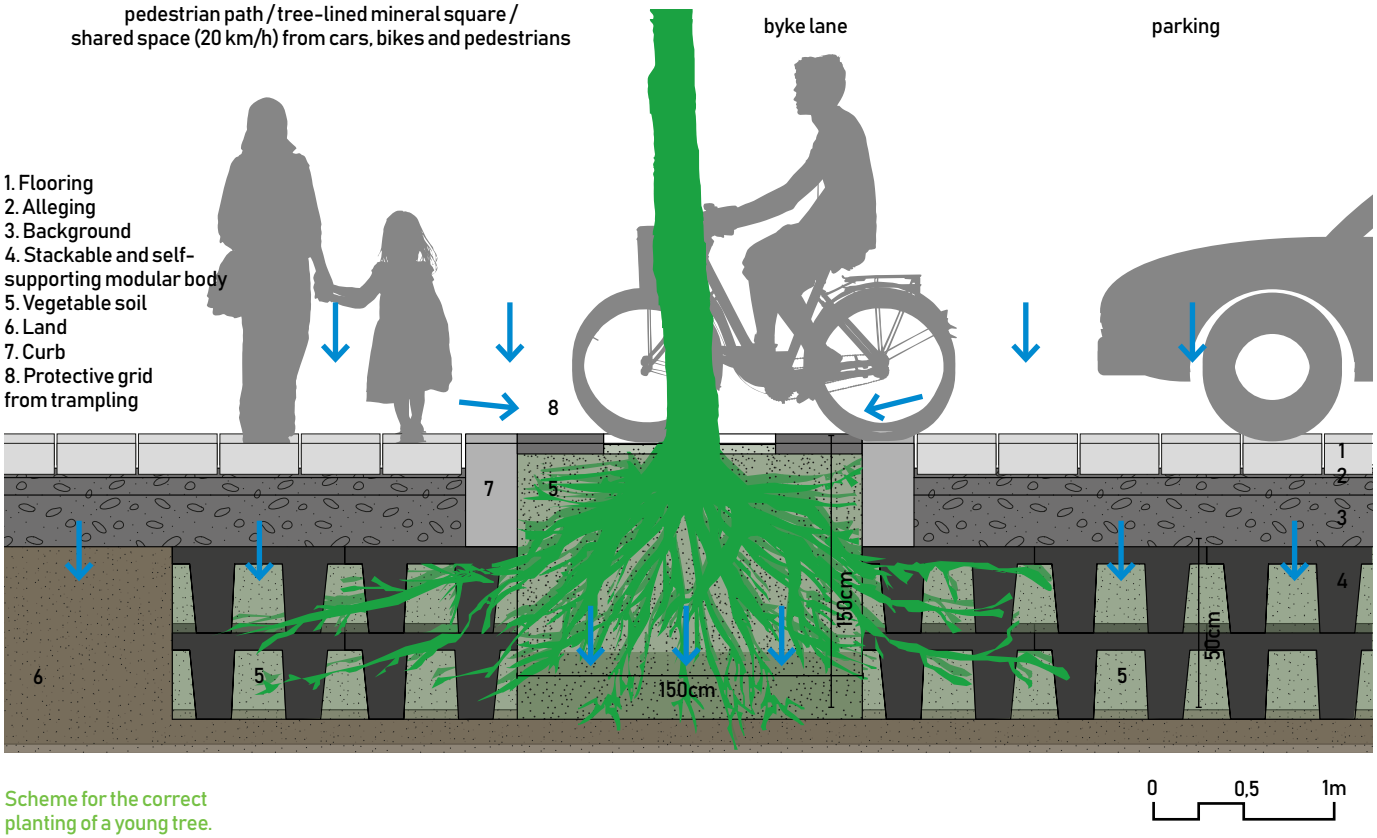
PROTECTION OF THE TRUNK AND CANOPY. It is necessary to keep the trunk of the trees safe for years to come, through protections made of steel, cor-ten, wrought iron, cast iron, wood and cement of different shapes and sizes; some shapes perform additional functions, such as allowing people to sit. Over time, the protections consisting of two vertical halves, to be assembled and screwed after positioning around the tree, or the simpler ones shaped like an inverted U to be positioned near the kerb of the flowerbed respecting the root system, are useful.

Compared to the canopy, it is essential to choose the right plant for the urban space undergoing transformation, to avoid continuous pruning that can only weaken the tree.

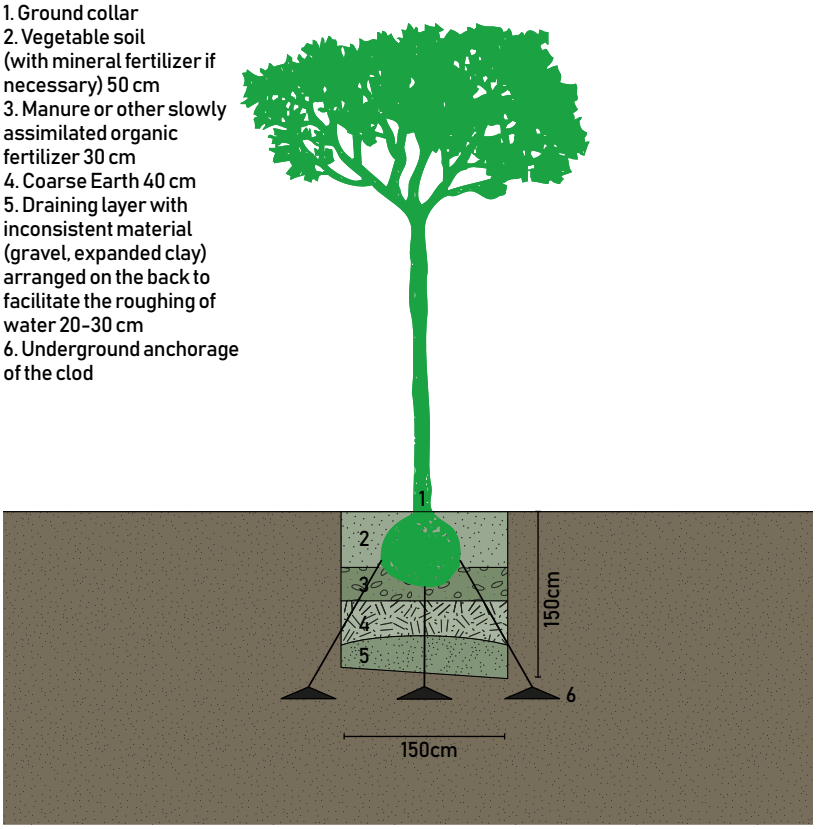
SINGLE OR DOUBLE-ROW TREES AND TREE-LINED AVENUES

In the creation of tree-lined avenues, the width of the space devoted to the plants on the side pavements and the distance of the buildings from the planting site of the trees are of primary importance. All these factors taken as a whole determine the type of tree to be used, with due regard for the distances from the expected or existing overhead or underground utilities. In the presence of utilities, overhead lines or street lamps, the choice of species is to be assessed considering both the expansion of the plant's root system and the size of the canopy once it grows fully and is not subject

Structural modular system for planting trees in mineral contexts, such as paved squares, paths or parking lots or shared urban public spaces at controlled speeds (shared spaces at 20 km/h) PVC boxes are modular and stackable elements that support loads due to both pedestrian and vehicular traffic.
The skeletal and open structure of the elements allows the growth of the root system of the plant.
Combined with permeable flooring, they allow greater drainage of rainwater.



Scheme for the correct planting of a young tree.



For the tutoring of trees it is advisable not to adopt the traditional system - consisting of the use of 2-4 wooden poles to which the shaft shaft is tied - and to replace it with the anchoring of the clod, at the level of the rizosphere. This system, underground and lost, consists in surrounding the clod with steel cables to which three anchors are connected through as many steel cables; the anchors, made of steel or wood, designed to withstand significant tensile loads, are fixed to the ground at a depth ranging from 1.5 to 2 meters depending on the depth of the hole and the size of the earth bread to be anchored.
The system blocks the earth clod preventing it from rotating and allows the epigea part of the tree to oscillate, thus stimulating the emission of strong support roots and favoring greater future stability of the specimen.
Underground anchoring has many advantages over traditional anchoring:
⇢ does not require maintenance once laid, nor removal once rooting has taken place;
⇢ is invisible, does not give problems of aesthetic impact, does not hinder operations on the ground and is not subject to vandalism;
⇢ is not necessary to monitor ligatures, which in the traditional tutoring system can cause bottlenecks.

Calculation of the area of relevance of the trees. The Municipal Green Regulations identify often different ways for the identification of the area of relevance of the plants. The system proposed here is very simple and directly connects the diameter of the core with the area of relevance for which the second grows as the first grows. It will always be very important to consider the different areas of protection for planting.

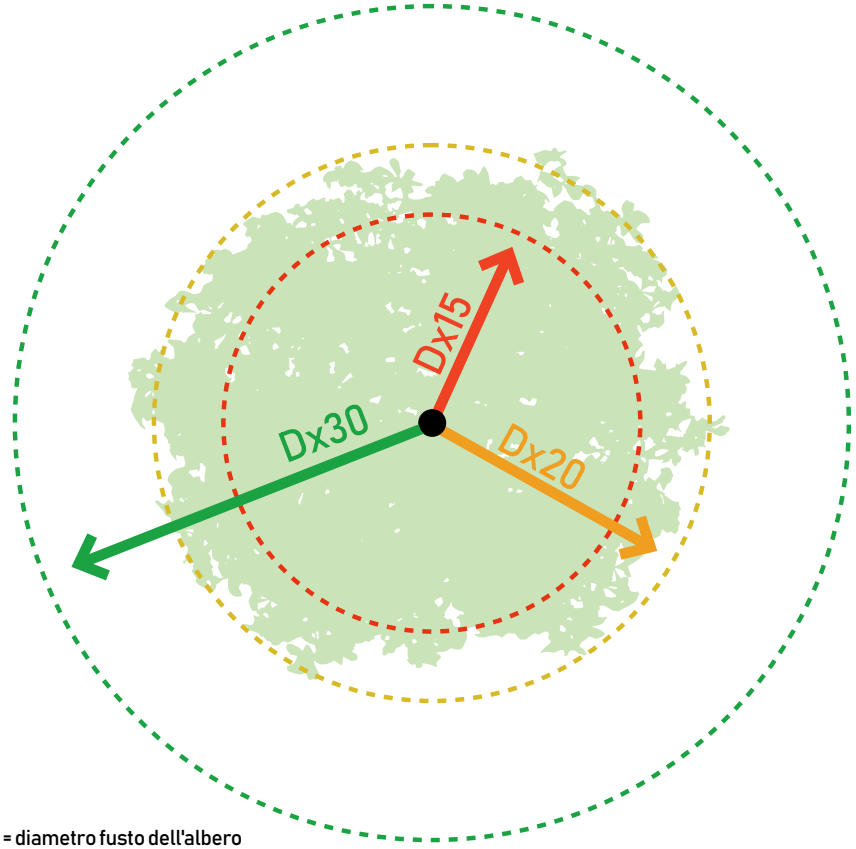
to maintenance pruning. Do not plant trees near high-voltage power lines that may come close to power lines once they grow fully.

The main constraints to be taken into account when designing tree-lined avenues are the following:

TRAFFIC In order to prevent trees from interfering with the clear view of the road and vertical signs once they have grown, adequate distances must always be kept from roadways. Near intersections and driveways, trees must be sufficiently set back to ensure good visibility and manoeuvring operations for road safety.

HEIGHT OF THE FIRST CROTCH At the time of planting, the height where the canopy starts, i.e., the crotch, must not be less than 2.50 m from the ground. As the tree grows, the canopy should be progressively raised by pruning, leaving at least 4.5 metres of free space between the branches and the roadway.

DISTANCES Tree-to-tree and tree-to-building distances depend on the size of the canopy of the fully grown tree. Along the roads, the distances between trees of the same species are equal to the potential diameter of the canopy of the tree once fully grown, while in the case of different species the sum of the respective canopy rays is calculated. The distances between trees and buildings, overhead lines, public lighting poles, and road signs are equal to the radius of the canopy, unless otherwise regulated by the competent authorities. Distances from buildings must be adapted to the potential growth of the trees. It is also necessary to evaluate any conditioning caused by the shading of buildings on the trees and vice versa.



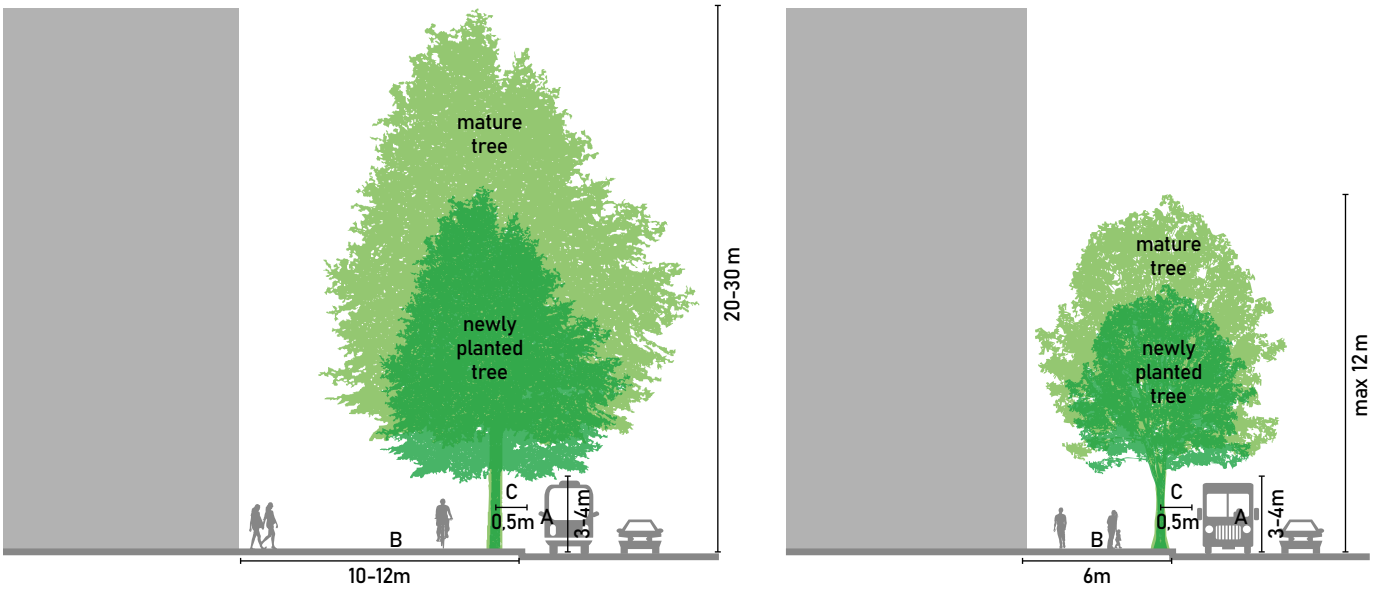
D = diametro fusto dell'albero

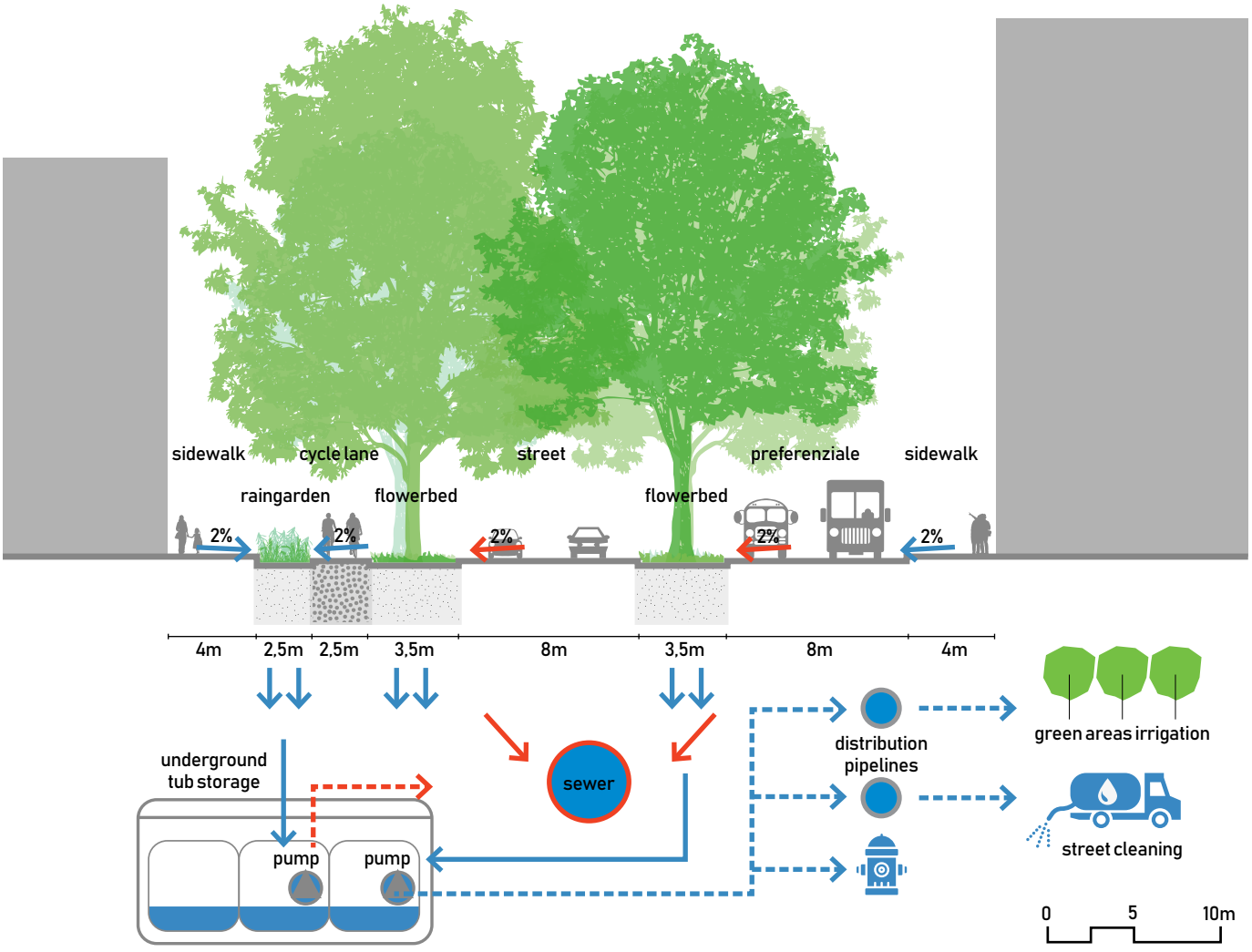
TOTAL PROTECTION ZONE =
15 times the diameter of the fetus.
No excavations, storage of material and passage of vehicles are required in this area.

HIGH PROTECTION ZONE =
20 times the diameter of the fetus.
Excavations can only be carried out by hand and for a circumference of no more than 90° (not cumulative over the years). When roots larger than 3 centimeters in diameter are present, they must be underpassed with pipes (push pipes or through manifold tubes) and protected from drying. If it is essential to get rid of roots, those up to 3 cm in diameter and no further can be cut; the cut must be carried out in a clear way and followed by perfection dressing.

LOW PROTECTION ZONE =
30 times the diameter of the fuse.
Excavations can be carried out by machine, but they must not remain open for more than 2 weeks; in the event of interruption of work, the roots must be covered and kept moist.

At the end of the work, the final filling should be carried out with a mixture of soil and sand in a 2:1 ratio and care will be taken not to pollute the root area with debris and excavation residues.


mature tree
newly planted tree
20-30 m
C
0,5m
A
3-4m
B
10-12m
mature tree
newly planted tree
max 12 m
C
0,5m
A
3-4m
B
6m


sidewalk
cycle lane
raingarden
flowerbed
street
flowerbed
preferenziale
sidewalk
2%
2%
2%
2%
2%
4m
2,5m
2,5m
3,5m
8m
3,5m
8m
4m
underground tub storage
pump
pump
sewer
distribution pipelines
green areas irrigation
street cleaning
0
5
10m

Do not plant trees in front of house entrances or where the canopy of an existing tree may interfere with the future growth of the new plant unless it belongs to a suitable species.

PROPERTY BOUNDARIES In the urban environment, the minimum distances provided for by article 892 of the Italian Civil Code are not sufficient. The easily available tables for the classification of trees into groups of sizes 1, 2 and 3 indicate the potential growth dimensions of trees and these tables must be taken into account when planting. As a general indication, some types of projects for the creation of tree-lined avenues have been identified. For each of these, it should be borne in mind that, as already mentioned, the trees planted need an underground volume of 18 cubic metres or, even better 3 x 3 x 3 metres, and that the ideal solution involves creating a continuous flowerbed that allows communication with the rhizosphere, possibly paved with draining material to be used for walkways and/or cycle paths.

BOULEVARDS. They are similar to "urban slip roads", i.e., roads with independent carriageways or roads separated by central reservations, each with at least two lanes. They are distinguished by the presence of two lateral tree-lined rows and a central tree-lined strip separating the two carriageways. Each row stretches on a sufficiently wide strip of greened ground, equal to at least 5 metres in the case of staggered double rows.

TREE-LINED AVENUES IN ROWS ON CONTINUOUS STRIPS. This type of avenue is characterised by the presence of two rows of trees, one on each side, planted on buffer strips of greened ground at the base of the trees (with a width of 3 meters for large trees) within which no excavation work must be carried out and therefore neither public utility lines nor underground pipelines must be laid. It is the best solution from an aesthetic and functional point of view and is optimal in terms of plant growth conditions.

TREE-LINED AVENUES IN ROWS ON FLOWERBEDS. As an alternative to the continuous strip, the base of the trees is made of unpaved flowerbeds of the indicated size (see table - Space reserved for trees), protected by a root grid, broken gravel or other draining material, with due respect for the distances from utilities. Intermediate spaces can be used as parking spaces; in this case it is advisable to provide suitable systems for protecting the trees on the sides of the parking areas.

TREES AND CONSTRUCTION SITES

In construction site areas, it is absolutely necessary to adopt measures aimed both at avoiding direct damage to the trunks and canopies and at respecting the pertaining areas, since there are many plants that fall after ten years from the execution of the works and it is difficult to trace the cause of their death to building works that do not respect the existing green heritage.
The various precautions include:

PROHIBITION OF TRANSIT OF HEAVY VEHICLES IN THE PERTAINING AREA IF NOT ASPHALTED. If this is not possible, the area involved in the transit must be temporarily covered with drainage material with a minimum thickness of 20 cm, covered with wooden boards, metal or concrete plates or a 20-cm-thick layer of lean concrete laid on a sheet of plastic;

PROTECTION OF TRUNKS AND CANOPIES. If the construction work involves the emission of large quantities of dust, it is necessary to provide protection for the trunks and canopies with suitable material, such as sheets and boards.
No concrete mixers or other construction machinery may be used in the canopy projection area on the ground, except for roadside trees located in already asphalted areas. In the same area, the compaction of soil with a vibrator must be prohibited and the use of the road roller must be reduced to a minimum;
Also, washing water of concrete mixers, especially those containing cement dust, must not be poured into the canopy projection area.
On asphalted surfaces close to trees, the temporary storage of packaged materials or materials on sheets, but not in bulk, is permitted; storage near the trunk or in the permeable area under the canopy is not permitted.

EXCAVATION. Excavation to lay underground technological systems must respect the areas pertaining to the trees. In particular:

- excavations in the root zone must be carried out by hand;
- when there are roots with a diameter of more than 3 centimetres, it is necessary to pass under them with tubes (push pipes or through ducts) and protected from drying out;
- if it is essential to remove the roots, those up to 3 cm in diameter and no more can be cut; the cut must be done in a clean manner and followed by proper dressing;
- excavations in the root zone must not be left open for more than two weeks; if work is interrupted, the roots must be covered up and kept moist;
- final filling must be carried out with a mixture of soil and sand in a ratio of 2:1 and care must be taken not to pollute the root area with debris and excavation residues.

ECOSYSTEM SERVICES PROVIDED

NUTRITION BIOMASS

AIR QUALITY AND POLLUTANS REGULATION

NOISE REDUCTION

RUNOFF REDUCTION AND FLOOD

POLLINATION AND BIODIVERSITY

URBAN COMFORT AND MICROCLIMATE

PUBLIC SPACE ACCESSIBILITY AND RECREATION

IDENTITY SENSE PLACE HISTORY

BEAUTY OF NATURE

MAINTENANCE

No maintenance of the trees is required, if the planting system is adequate to the bearing and growth of the plant. Pruning should be carried out only when necessary and always respecting the plant's posture, avoiding pollarding that weakens branches.

INDICATIVE COSTS

- from 100 to 1,000 euros per plant: costs vary according to species and age;
- from 40 euros (2 cubic metres) to 360 euros (18 cubic metres): supply and laying of understory for trees;
- 20 euro/sqm: irrigation system for areas planted with lawns and trees.

CASE STUDIES

- Urban park in Boulogne-Buillancourt, Paris - FR / Case study C4
- Martin Luther King Urban Park, Paris - FR / Case study C4

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