DIFFERENT APPROACHES FOR COMMON ADAPTATION PROBLEMS

Guidelines for municipalities from the learnings of LIFE CITYAdaP3

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Different Approaches for Common Adaptation Problems (Task D1.1)

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Editorial Team:

María Huertas. EuroVértice Consultores

José Pablo Delgado. EuroVértice Consultores

Marta Reguilón. EuroVértice Consultores

Collaborators:

- Elvira Badenes. Municipality of Alcantarilla
- José Antonio Fernández. Municipality of Alcantarilla
- Luis Bernardeau. Municipality of Lorquí
- Carmen Mondéjar. Municipality of Molina de Segura
- Susanna Ferrari Bergomi. Municipality of Reggio Emilia
- Elisabetta Sgarbi — Department of Life Sciences — University of Modena and Reggio Emilia
- Elisia Nardini. Municipality of Reggio Emilia

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1. Introduction

LIFE CITYAdaP3

According to the last IPCC (Intergovernmental Panel on Climate Change) report (Sixth Assessment Report, 2023), the impact of the increase of 1.1 degrees C of global temperature is already visible in every region of the world. Climate impacts on people and ecosystems are more widespread and severe than expected, and future risks will escalate rapidly with every fraction of a degree of warming. Also, the report states that adaptation measures can effectively build resilience, but that more finance is needed to scale solutions.

LIFE CITYAdaP3 tackles this issue, by creating innovating mechanisms to finance climate change adaptation actions based on public-private partnerships. The project consortium is made up by the municipalities of Alcantarilla, Lorquí and Molina de Segura, in Spain and Reggio Emilia in Italy, the CSR Chair of the University of Murcia and the company EuroVértice Consultores. In addition, the project is led by the Federation of Municipalities of the Region of Murcia-

Climate impacts are accelerated in built-up areas, surrounded and filled with infrastructures, where temperature, wind and precipitation show special trends. In the future, on-going urban land take, growth and concentration of population in cities, as well as an aging population, will contribute to increase further the vulnerability of cities to climate change.

Considering that adaptation of cities is of highest importance, LIFE CITYAdaP3 focuses on the urban environment, and has developed an action protocol for involving companies in the collaboration with municipalities for the co-financing of urban climate change adaptation measures.

What will you find in this document?

Cities and urban systems are the places most responsible for climate change, but at the same time, they are the places where its effects are felt the most. Climate change impacts in cities are mainly determined by common hazards, such as rising temperatures and heatwaves, flooding, water scarcity and droughts, and decreasing biodiversity.

LIFE CITYAdaP3 includes four municipalities, three in the Region of Murcia (Spain) and one in the Region of Emilia Romagna (Italy). Despite sharing some common characteristics of the Mediterranean climate, south-eastern Spain and northern Italy face different hazards and are experiencing the impacts of climate change differently. Even among the Murcian municipalities the situation is very varied, as the environmental, social, and economical characteristics of each area influence which are the main climatic risks and how climate change impacts each territory.

The development of the Sustainable Energy and Climate Action Plan (SECAP) or Local Climate Change Adaptation Strategies allows to identify which is the site-specific situation in relation to climate change in each municipality, and which actions should be done to improve it. LIFE CITYAdaP3 project has served to implement different pilot actions in the 4 municipalities. Although the solutions designed have been different, there are many commonalities in the hazard they address and in the way they have been approached, which allow a comparison to be made on the advantages, disadvantages and lessons learned from using each.

This document will compare the different approaches followed by municipalities to solve common problems and expects to be able to provide guidelines for other municipalities that experiment similar climate hazards. In this way, it hopes to serve as a catalogue of solutions useful in decision-making.

2. The common hazards

Rising temperatures and heatwaves
According to NASA, the Earth's average surface temperature has risen about 1.18°C (2.12°F) since the late 19th century, with the majority of this warming occurring in the last few decades[1]. Also, multiple studies have found that heatwaves are becoming more frequent, longer-lasting, and more intense due to climate change[2]. A temperature increase between 2 and 4°C is expected in the Mediterranean region during the 21st century. Consequently, heat waves will increase their duration up to 15 or 20 days. The Urban Heat Island effect makes temperature in cities to be up to 10°C higher than in the rural surroundings[3]. Climate change scenarios point to an increase in the number of mega heatwaves (in length, frequency or intensity).
Flooding
The more frequent and intense precipitation is leading to an increased risk of flooding. The observed increase in river floods events and damages in Europe is well documented and is likely to be one of the most serious effects from climate change in Europe over coming dates[4]. This increase and intensity of rainfall is also a consequence of the urbanization process of cities (felling of trees, elimination of permeable soil, changes in river beds, occupation of wadi beds...). It is therefore necessary to analyse and map flood zones, establish preventive measures for areas at high risk of flooding and not to build on them. This will not prevent events from occurring, but it could prevent further damage to people or infrastructure. If no mitigation and adaptation measures are taken, economic losses will increase from €7.8 billion/year at present to nearly €50 billion/year with 3°C global warming by the end of this century[5]. In addition, the current number of people exposed to flooding could increase from 172,000 per year to 482,000 per year [6].
Water scarcity and droughts
With 3°C global warming, drought frequency is projected to double over nearly 25% of the Mediterranean and 15% of the Atlantic region. Droughts induce a complex web of impacts that span many sectors of the economy. With global warming, droughts will increase in

[1] https://climate.nasa.gov/evidence/

[2] IPCC. (2018). *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change.*
Hansen, J., et al. (2012). *Perception of climate change*. Proceedings of the National Academy of Sciences, 109(37), E2415-E2423.
Perkins-Kirkpatrick, S. E., et al. (2017*). Increasing frequency, intensity and duration of observed global heatwaves and warm spells.* Scientific Reports, 7(1), 1-12.

[3] Lorenzo Mentaschi, Grégory Duveiller, Grazia Zulian, Christina Corbane, Martino Pesaresi, Joachim Maes, Alessandro Stocchino, Luc Feyen. (2022). *Global long-term mapping of surface temperature shows intensified intra-city urban heat island extremes.* Global Environmental Change. Volume 72, 102441, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2021.102441.

[4] European Commission, Directorate-General for Environment. (2021*). Impact of climate change on floods – Survey findings and possible next steps to close the knowledge and implementation gap: final a survey-based study*. Publications Office

[5] Feyen, L., Ciscar, J.C., Gosling, S., Ibarreta, D. and Soria, A. (editors) (2020). *Climate change impacts and adaptation in Europe.* JRC PESETA IV final report. EUR 30180EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-18123-1, doi:10.2760/171121, JRC119178.

[6] European Commission, Directorate-General for Environment. (2021*). Impact of climate change on floods – Survey findings and possible next steps to close the knowledge and implementation gap: final a survey-based study*. Publications Office

frequency and intensity, and last longer, in southern and western parts of Europe, while drought conditions will become less extreme in northern and north-eastern Europe[7]. At the same time that global warming brings with it an increase in the frequency and duration of droughts, it also brings rainfall with greater strength and duration. Therefore, it is necessary to establish water retention and storage measures to meet the demand needs.
Decreasing biodiversity
Biodiversity loss are one of the biggest threats facing humanity in the next decade (European Commission, 2020). The value of biodiversity in urban areas has often been underestimated, but these spaces provide important habitats for multiple species, in particular for plants, birds and insects. Urban ecosystems host more than 25,000 species in Europe, 179 of them targeted by the Habitats Directive. An analysis of this data, developed by the BiodiverseCities project, has shown that a core set of 130 species are observed in the majority of urban areas in Europe. Among the 31 most common urban birds, five are classified having a decreasing population trend and one is classified as "Near Threatened" by the International Union for Conservation of Nature (IUCN; Maes et al., 2021).

3. Assessing different approaches to mitigate common hazards

i. Shadow generation

The generation of shadows in cities is an effective strategy for mitigating the urban heat effect, as it helps to reduce ambient and surface temperatures and improve thermal comfort. The design and selection of solutions to generate shadow can be done incorporating natural and/or artificial elements, and depend on the characteristics and needs of the location where they are needed.

Different options have been tested as part of the pilot actions' projects of LIFE CITYADAP3.

- Generation of shadow through planting vegetation.

The most recommended option for generating shadow is planting trees, as it has other multiple associated benefits for climate change adaptation (improvement of air quality, increase of biodiversity…). The strategic placement of trees in cities can help cool the air by 2 to 8 degrees Celsius, thus reducing the urban heat island effect[8]. In addition, the correct placement of trees around buildings can reduce the need for air conditioning by 30% and reduce winter heating bills by 20 to 50%[9].

Any urban element capable of generating shading is capable of reflecting, diffusing and absorbing solar radiation. Studies show that tree leaves, in general, are capable of reflecting 10% of visible and 50% of infrared solar energy, while they can absorb 80% of visible and 20% of infrared solar energy. Consequently, the resulting radiation transmitted through their leaves would consist of 10% of the visible energy plus 30% of the infrared solar radiation[10]. The

[7] Joint Research Centre. European Commission. (2020). *Impacts of Climate Change on droughts*. JRC Peseta IV project.
[8] Doick, Kieron & Hutchings, Tony. (2013). Air temperature regulation by urban trees and green infrastructure.
[9] McPherson, Gregory & Simpson James R. (2003). Potential energy saving in buildings by an urban tree planting programme in California. Urban for Urban Green 2: 073–086. 1618-8667/03/02/02-073 $ 15.00/0
[10] Kotzen, Benz (2003). *An investigation of shade under six different tree species of the Negev desert towards their potential use for enhancing micro-climatic conditions in landscape architectural development*. Journal of Arid Environments, Volume 55, Issue 2, Pages 231-274, ISSN 0140-1963, https://doi.org/10.1016/S0140-1963(03)00030-2.

magnitude of solar attenuation varies according to each tree species and its structural characteristics, such as leaf density, height, crown diameter and proximity between elements. From the point of view of solar radiation control, the most interesting trees would be deciduous trees. The geometrical characteristics of trees that influence their shading capacity are total tree height, trunk height, crown diameter and height.

Considering all this benefits, the placement of vegetation for temperature reduction has been included in most of the pilot actions implemented with LIFE CITYAdaP3.

In Alcantarilla, trees have been planted to generate shadow along the multimodal pathway, in the places that allowed it. Different vegetation adapted and native to the area has been planted in the flowerbeds as a fundamental part of the multimodal platform. This vegetation helps to reduce the "heat island effect" through the evaporation of water, but also acts as an environmental purifier by eliminating existing pollutants from the atmosphere. Two tree species have been selected *Morus alba* and *Celtis australis*.

Figure 1. Trees planted along the path of Alcantarilla

In Molina de Segura, the urban path study has been carried out by evaluating the physical characteristics of the streets, measuring a series of parameters that will make possible the planting of trees and/or the placement of plant elements that provide shade. In order to choose the species to be planted, a selection of 10-15 autochthonous tree species was made. This has been considering their capacity of adaption to adapt urban areas to climate change and with a view to improving the thermal comfort of the population. A reduced height influences their shading capacity, while an excessive height in proportion to the width of its crown, in addition to generating unwanted shade on the facades of buildings, leads to difficulties in planting in stressed or medium-sized streets. However, an excessive height (provided that the width of the crown is proportionate) is not an obstacle to the provision of species in open spaces.

In the Nelson Mandela Park, the trees have also been revised and renewed with the aim of creating shadows and humid environments. For the new species selection, only native species were considered. Eventually, the following species were selected: *Pinus halepensis*, *Pinus pinea*, *Ceratonia siliqua*, *Arbutus unedo*, *Quercus rotundifolia*, *Celtis australis*, *Laurus nobilis*, *Juglans regia*, *Tamarix boeana*, *Tamarix canariensis* and *Salix fragilis*.

Some parameters valued in the contribution to shade generation are the density of the trees, their dimensions and the size of their canopy projection. To one extent or another, this affects temperature reduction and CO2 absorption.

The basic conditions for an effective planting of trees in the city are also based on the vegetative rest period of the species, since it can vary according to the climatology of each area and to its annual variations. In addition, the trees must be healthy, without symptoms of pests and must be well formed and hardened. The aerial part must have a terminal guide and the number of branches at the withers must not be more than five or less than three. The trunk should be single and straight, and the withers should start at least 2.5 m from the collar. The root ball of the plant shall be made of solid soil and at least three times the diameter of the trunk. Planting substrate shall be used to guarantee the necessary conditions for the development of the tree.

In Reggio Emilia, the need for shade was one of the criteria to be taken into account in the selection of the spaces in which to act. The four parks selected for reforestation were particularly affected by the heat island effect or needed shade, due to their use by the population, especially in the points where public structures related to leisure are concentrated.

In particular, the project provided for the use of trees is around the children's play areas and rows of trees along cycle-pedestrian paths with the aim of ensuring the shading of these zones. These are usually very exposed to direct solar radiation and therefore difficult to use by citizens in the summer. With the aim of creating shadows in the shortest time possible, larger trees have been planted and at a smaller distance from each other, compared to what done in other reforestation interventions.

The project of Reggio Emilia was not limited to the selection of potentially more resistant species suitable for providing shading and increasing soil evapotranspiration, but also on plant associations that can be more resilient to future environmental conditions (scarcity of water, extreme events…). The planting of new trees in new rows, but also in micro-forests and rural hedges, bring benefits in terms of air, water and soil quality through the evapotranspiration mechanism and shading, contributing to lower air/soil temperatures.

The plant species that have been chosen for the rows of trees should be able to better withstand the increase of temperatures, occurring in all seasons, the intense and prolonged summer heat waves, and the increasing frequency of dry summer and winter. Particular attention was paid to the leaves and crowns shape, in order to ensure significant effect in adaptive terms. In this regard, several native and Mediterranean plant species were chosen, undemanding and potentially well adaptable to the urban environment.

- Generation of shadow through artificial structures

In the places where placing vegetation for shadow generation resulted impossible or not sufficient, alternative natural shading has been sought in Alcantarilla by means of the proximity of the multimodal platform to adjacent constructions.

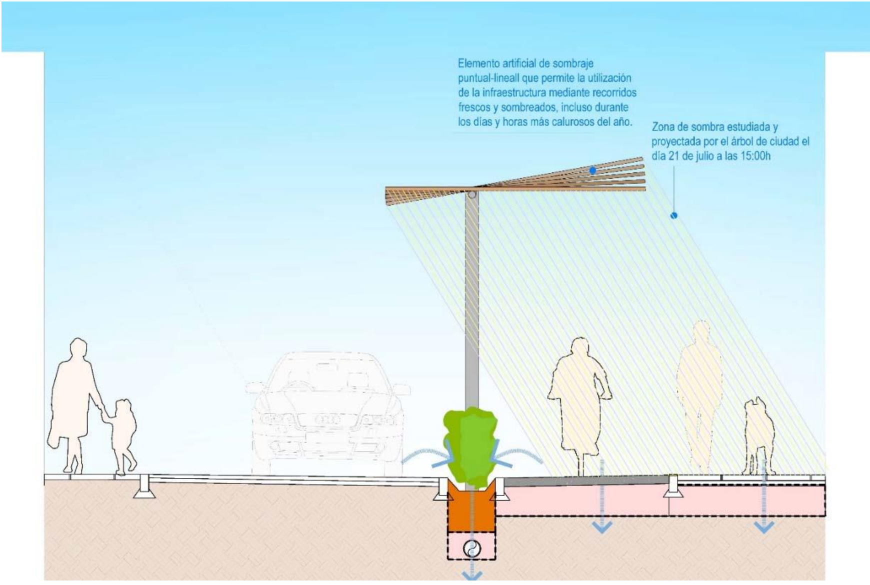

Figure 2. Infographic of the design of the shade structures placed in Alcantarilla.

For open areas or when the shade of buildings was not sufficient, an "urban tree" has been designed. This is a wooden light element, easy to install, modular and adaptable to different orientations and situations, to which different elements can be attached depending on the needs, such as solar lighting.

The combination of vegetation, shade cast by buildings and city trees has transformed the route into a fresher area for pedestrian and cyclists. Even during the central hours of the day, the percentage of the shaded surface of the route exceeds 70%.

A positive aspect of this option is that it allows a combination of the artificial structure with vegetation, including climbing plant species. This improves the performance of the element as a measure to fight urban heat island effect.

Figure 3. "City trees" wooden structures accompanied by pots with climbing plants, maximizing their ability to produce shade.

In Lorquí, similar structures have been installed, as the locations where the pilot actions were developed didn't allow planting trees. In addition, in order to increase the shading area, a thin heather was placed in some cases on top of the structure. This is a sustainable and inexpensive material, adaptable to the curves of the structure, which allows light to pass through and serves as a temporary form until the climbing plants grow.

Figure 4. Shade structures placed in Lorquí.

ii. Re-naturalization (plant-species)

The importance of re-naturalizing cities is universally recognized for multiple reasons.

On the one hand and speaking about environmental benefits, urban greening has a positive impact on biodiversity conservation, air quality and climate change mitigation and adaptation. Urban areas tend to have reduced biodiversity due to habitat loss and fragmentation. Introducing and enhancing natural elements within urban environment improves ecological connectivity and create urban wildlife habitats. Moreover, vegetation in cities helps to reduce air pollution by capturing particulate matter, absorbing pollutants and producing oxygen, which contributes to improving public health. As well, urban green spaces play a role in mitigating (sequestering carbon dioxide through photosynthesis) and adapting (reducing flood risk and temperature) climate change[11].

On the other hand, re-naturalizing cities improve citizens' wellbeing, enhance quality of life and improve thermal comfort of urban dwellers. Also, proximity to green spaces and natural elements has been shown to increase property values and attract businesses, promoting economic development. As well, it can lead to cost savings in energy consumption, stormwater management and healthcare[12].

However, there is an open debate between the use of autochthonous and exotic species in urban areas. The following are some of the most common arguments put forward by both sides[13][14][15].

From the biodiversity and ecological perspective, proponents of using native species argue that they are essential for preserving and enhancing local biodiversity. Native plants have co-evolved with local wildlife, providing habitat, food sources and ecological interactions that support the overall health of ecosystems. Exotic species can act as predators of native fauna, alter the habitat (by physically and chemically modifying the soil), compete for food and space, hybridize with native species, introduce new parasites and diseases... In the other hand, the critics of using exclusively native species argue that urban areas are already highly modified environments and that, introducing a mix of native and non-invasive exotic species can increase plant diversity and create more resilient and functional urban ecosystems.

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[11] European Commission. (2022). *Proposal for a Regulation of the European Parliament and of the Council on Nature Restoration*

[12] Gómez Lopera, F. *(2005). Las zonas verdes como factor de calidad de vida en las ciudades. Ciudad y Territorio Estudios Territoriales, 37(144), 417–436.*

[13] Marinšek, Aleksander; Bindewald, Anja; Kraxner, Florian; La Porta, Nicola; Meisel, Petra; Stojnic, Srdjan; Cocozza, Claudia; Lapin, Katharina (2022). Handbook for nonnative tree species in the Urban Space SN - 978-3-903258-56-3

[14] Martin A. Schlaepfer, Benjamin P. Guinaudeau, Pascal Martin, Nicolas Wyler (2020). *Quantifying the contributions of native and non-native trees to a city's biodiversity and ecosystem services*. Urban Forestry & Urban Greening, Volume 56, 126861, ISSN 1618-8667, https://doi.org/10.1016/j.ufug.2020.126861.

[15] Castro-Díez, P., Vaz, A.S., Silva, J.S., van Loo, M., Alonso, Á., Aponte, C., Bayón, Á., Bellingham, P.J., Chiuffo, M.C., DiManno, N., Julian, K., Kandert, S., La Porta, N., Marchante, H., Maule, H.G., Mayfield, M.M., Metcalfe, D., Monteverdi, M.C., Núñez, M.A., Ostertag, R., Parker, I.M., Peltzer, D.A., Potgieter, L.J., Raymundo, M., Rayome, D., Reisman-Berman, O., Richardson, D.M., Roos, R.E., Saldaña, A., Shackleton, R.T., Torres, A., Trudgen, M., Urban, J., Vicente, J.R., Vilà, M., Ylioja, T., Zenni, R.D. and Godoy, O. (2019), *Global effects of non-native tree species on multiple ecosystem services.* Biol Rev, 94: 1477-1501. https://doi.org/10.1111/brv.12511

This is especially important considering the climate change scenarios, that predict a change in the multiple meteorological factors that will affect plants and animals. Advocates for native species emphasize their adaptation capacity to local environmental conditions, such as climate, soil and hydrology. They argue that native species are more likely to thrive in urban settings without the need for excessive maintenance, irrigation or chemical inputs. n the other side, supporters of using exotic species suggest that some non-native species may be better adapted to urban stresses, such as pollution, compacted soil and limited water availability. They argue that these species can help green urban areas more rapidly and withstand challenging conditions.

Another aspect to consider when deciding which species to plant in urban areas is the aesthetic value that they provide. However, aesthetics is subjective for the population. While some believe that native species contribute to the sense of place, preserve local traditions and enhance the cultural value of urban landscapes, others think that exotic species can introduce novel colours, forms and textures to urban environments, creating visually appealing landscapes.

A very important factor to take into account is the invasive potential that introducing exotic species can have. Non-native species can escape cultivation, outcompete native plants and disrupt local ecosystems, leading to the loss of biodiversity and ecosystem services. However, it is true that only some non-native plants are invasive. It is impossible to know whether an alien species may become an invasive species. Variations in climate can cause alien species to find optimal conditions for expansion, moving away from human control and having devastating effects on natural ecosystems. A careful selection and management could prevent their negative impacts, but the risk never disappears.

Finding a middle ground between using native and exotic species is often suggested. As with every urban intervention, a context-specific approach is needed, considering ecological goal, local conditions, and potential impacts on biodiversity. This approach may involve prioritizing native species for ecological restoration and sensitive areas while using non-invasive exotic species to enhance aesthetic value and resilience in urban landscapes. The balance between native and exotic species can vary depending on local circumstances and the specific goals of urban greening initiatives.

The pilot actions in Lorquí, Alcantarilla and Molina de Segura have included only native species. In Reggio Emilia, part of the innovativeness of the project resides in the trial of different combination of native and non-native plant species, but paying great attention to exclude potentially invasive, non-native species.

One of the devices included in the parks' reforestation has been the "micro-forest". This idea starts from the assumption of the so-called "Miyawaki method", which involves densely planting different plant species in a small area, creating a multi-layered forest structure that mimics natural forests (see next paragraph). This technique pretends to be self-sustaining and emphasizes the use of different plant species and organic practices to promote biodiversity, improve soil quality, conserve water resources, and provide ecological benefits.

Three types of micro-forests have been tried as part of the project that differ in the combination of plant species:

- The “native micro-forest” is composed only of native species, characteristics of the woods of Po plain - the geographical area of reference; these species are generally well adapted both to soil and climatic conditions of the geographical area of reference, are undemanding and able to easily propagate in the surrounding areas.
- The “adaptive micro-forest”, with the inclusion of new species, mainly of Mediterranean area (considered suitable for future climatic conditions - adaptive) growing in bushes or dry meadows, generally withstand to long, hot and dry summers, in order to assess the possible adaptation to the climatic changes.
- The “edible micro-forest”, in which many fruit plants are planted, to complement the forest system; here, there are also many herbaceous species that, especially in the first phase of the food forest growth, will be fundamental to ensure the correct formation of a substrate rich in organic components.

Therefore, the very nature of the intervention implies the inclusion of native and non-native species.

Particularly, in the choice of the species that make up the “adaptive micro-forest”, a vast selection of Mediterranean species, but not belonging to the list of the invasive species, has been placed with native species, in order to evaluate the possible adaptation to the climatic conditions typical of the territory. The selection of the species has been carried out taking into consideration species already present in the territory that have shown interesting evolutionary adaptations in similar contexts. Criteria such the rate of growth (important aspect for carbon sequestration), the development of the root system (especially important for interventions near anthropogenic structures), the persistence of leaves (deciduous), a characteristic of particular interest in relation to the mitigation of atmospheric and acoustic pollution, resistance to pollutants (especially in strictly urban areas) and longevity, have been taken into account.

For selecting the species to be included in the Food Forest (edible forest), a cultivated system inspired by the forest was defined. For the choice of the species, plants capable of providing wood, enrichment of the soil and, more generally, structure to the landscape elements have been used. Other medium-sized plants have been planted, including a wide range of fruit plants (plums, apricots, citrus fruits, figs, pomegranates), which have a limited development but are able to provide edible fruits. Bushy plants have also been used, which have a woody stem but remain small in size: they are aromatic plants, i.e., rosemary, sage, lavender, but also raspberries, currants, blueberries, blackberries. Different herbaceous species complete the composition of the edible forest, which, especially in the first phase of the forest realization, can play an essential role ensuring the correct formation of stable meadows.

For the constitution of this type of micro-forest, predetermined planting proportions were used which assume, in particular: 45% use of dominant tree vegetation, 32% use of dominated tree vegetation and 23% use of shrub vegetation.

iii. Re-naturalization (Landscaping)

As discussed above, the Reggio Emilia project (Adaptive parks) has tried to go beyond the traditional measures of reforesting as climate change adaptation. The focus has been shifted to the importance to introduce plant associations which can potentially establish a resilient balance to future climatic conditions (water scarcity, extreme events...), in accordance with the characteristics of the areas that are inhabited.

The concept underlying the adaptative parks of Reggio Emilia is based on the idea to test the effectiveness of four main landscape-environmental "devices" in countering the effects of climate change:

- micro-forests;
- rural hedges;
- polyphytic meadows;
- rows of trees.

Their composition and articulation within each individual project are designed according to the general objectives set for the adaptation action and, at the same time, addresses the issues of the use and maintenance of green spaces.

The definition of the devices takes as reference some methodologies studied for some time in the scientific field and validated by a series of concrete experiences. They have been implemented (or are being implemented) in Europe and in the world in different climatic and environmental contexts (including the projects known as Afforestt, Boomforest, Urban-forest, Forestcreators and others).

The innovation component mainly concerns the experimentation in Reggio Emilia of alternative plant associations to test and monitor their resilience to climate change and the impact on indicators capable of contrasting heat islands in the cities (by means shading, soil regeneration and increasing evapotranspiration).

Figure 5. Summary sheet of the landscape-environmental devices proposed by the project. (Some of the photos used in the image are taken from the following sources: www.afforestt.com, www.boomforest.org, www.urban-forest.com, www.forestcreators.com)

A further characteristic element of the interventions proposed in Reggio Emilia is the project to create a wetland area into the “Biagi Park”. It exploits the possibility to derivate water from a nearby channel during summer season, with the aim to carry out a further mitigating action on the microclimate of the area. This action is in agreement with European, National, and Regional recommendations to evaluate the potential contribution of wetlands in counteracting heat islands.

The species chosen to be planted in this area include more properly aquatic species, plants of wetlands periodically immersed and also grassland species, with the aim of establishing over the years, a stable meadow near the wetland. This project should be considered experimental as will be very interesting to observe how the different introduced species will be able to adapt, cope with water level fluctuations and with the environmental conditions of the site of introduction.

The complete pilot action project can be requested by the website to the LIFE CITYADAP3 team, but this document includes a brief summary of its main features.

The four different landscaping “devices” are:

- Micro-forests

The common trait of micro-forests recalls the fundamental concepts of the reference model of Miyawaki, which can be summarized as it follows: in the very high planting density (at least 3 young plants per square meter) on plots no larger than 200 square meters, in the extreme differentiation of the species (at least 30) and of the plant levels that will make up the forest (4), as well as in the almost total planned absence of maintenance (pruning, weeding, irrigation systems, etc.).

This method has already demonstrated its effectiveness in various contexts (also which tend to be arid, such as Sardinia) where a growth rate of young plants has been found ten times more intense than the usual forestation techniques derived from single-crop models. Within 2 years, the micro-forest stabilizes in an almost impenetrable structure capable of self-sustaining its own evolution and defending itself from external pathogens without any human intervention.

The advantages connected to this practice, especially in the urban area and in view of the optimization of public green management, are therefore potentially considerable both in economic terms (planting of young and inexpensive plants; reduction of management costs) and in relation to expectations of "prompt effect" that are often sought in this type of intervention. Alongside these considerations of a more pragmatic nature, the extremely positive effects on environmental and ecological indicators related to biodiversity and the health of the soils underlying this type of intervention should be emphasized.

Some experiments, including the one carried out by the prestigious Wageningen University in Zaanstadt in the Netherlands, have already verified these impacts on the urban environment by comparing different types of micro-forests with different combinations of species. In this experimental process they have also demonstrated a further potential of the "method", that is the possibility to involve citizens in the phases of both planting and monitoring and care of the new forests.

- Rural hedges

Hedges have always performed various functions, especially in agricultural fields that can be useful in urban areas: to signal the boundary between the different properties, to protect from noise, wind or from pollution, to contain erosion and consolidate the soil, provide fruit to the population, provide nourishment and possible shelter for the local birdlife and represent a place for the conservation of the insect fauna.

The rural hedges are conceived as a “multispecific” plant structure, that is composed of a vast number of species, generally with a strong prevalence of shrubs, but with the simultaneous presence of woody and herbaceous plants. The particular conformation of their foliage and the morpho-structural characteristics of the different species that compose them have a direct effect on the shading produced, on their effect as windbreak, the absorption of polluting particles, the consolidation of the soil, the limitation of the erosion surface and the dispersion of soil fertility.

The complexity of the hedge, with the presence of trees, shrubs and herbaceous layers, allows the landscape element to accommodate different ecological niches.

- Polyphite meadow

The polyphytic meadow is essentially a combination of several grass species and forage crops that are growing in the same land. These types of meadows have not suffered in time tillage and are maintained through periodic mowing. They are characterized by a good floristic richness. Polyphyte meadows can be grown both in dry conditions and through irrigation management.

As part of this project, which operates largely in areas on the border between urban and countryside, the introduction of the polyphytic meadow assumes not only an environmental and ecological value (with a significant increase of biodiversity), but also a cultural meaning: to raise awareness of old, good cultivation practices and to play an educational role for citizens and young generation.

- Rows of trees

It can be defined as a linear and, generally, regular row of woody plants planted by humans, which usually consists of tall trees, arranged in single or parallel rows.

The row formation is used mainly with the aim of ensuring shading at roads and paths exposed to intense sunlight, although it has other multiple benefits. The areas of interest are those mainly located in the points used by citizen for recreation and play and cycle-pedestrian paths.

The presence of trees is able to significantly improve the microclimate of the affected area, allowing a temperature drop in the summer season by some degrees. Rows of trees, however, also have a counteracting effect to pollutants, absorbing gases and retaining particulate matter and heavy metals.

The tree species have been chosen as much as possible among those able to better withstand the increase in temperatures, the intense and prolonged waves of summer heat, and the increasing frequency of dry summer and winter periods. Particular attention was paid to the leaves and crowns shape, in order to ensure significant effect in adaptive terms. The goal is to create shaded areas in the most used spaces for the pedestrian/cycling passage and play areas. Several native species were chosen, undemanding and potentially well adaptable to the urban environment.

This option is widely used for the shading of paths and cycleways, and has also been chosen in the case of Alcantarilla.

In the case of Molina de Segura, the Nelson Park has been reforested without taking any of these “devices” into account. The municipal technicians and the awarding company have made a specific reforestation design taking into account the characteristics of the park, the population and environmental needs and the requirements of the species. Species of different sizes and morphological, physiological and aesthetic characteristics have been incorporated, with the aim of generating a design as similar as possible to the natural ecosystem of the area.

Two main criteria have been followed:

- In the area of the flowerbeds bordering paths and roads, a linear planting of trees and shrubs has been followed, to provide shade to the walker and a close visual aesthetic.
- In the interior of the flowerbeds a random zig-zag distribution has been chosen, which gives more naturalness to this green area. The choice of species has been focused on

creating different ecological formations: pine forest, arbutus, tamarisk, carob, walnut, arbutus, mastic trees...

In the planting phase of the Nelson Mandela Park project, the vegetation structure was defined in a conceptual drawing phase, without specifying the species, which allowed to recognize and recreate the arrangement of the space, remaining faithful to the pre-existing environmental factors, without imposing the needs of the plant on those of the site. Once the structure was defined and reviewed, the specific species for each flowerbed were defined. The criteria followed in this planning were:

- Aesthetic criteria. The planting in the green area of the Nelson Mandela Park fulfills an ornamental function, for which a harmony between the species has been established, based on the chromatism of the leaves and their texture. An attempt has been made to create harmony between different species according to their location in bioclimatic levels.
- Ecological criteria: native species to the Region of Murcia were chosen, many of which are found in natural areas close to the park. This has a positive effect by favoring the fauna associated with this habitat, as well as their ability to move and colonize new spaces. The aim is to create masses of vegetation that form a single habitat to support an important wildlife community.
- Sustainability criteria. There are many good reasons for planting trees, shrubs and herbaceous plants in our cities: aesthetic, social, comfort, etc. improvements. A low energy cost of gardening maintenance was searched, given that this energy is largely generated from fossil fuels and has an impact on greenhouse gases and urban air pollutants. Also, low-water-use species were planted. Intentional grouping of plants with similar water requirements was designed, as this saves great quantity of water at the end of the year. Moreover, the microclimatic effects of plantations were considered. Their effect is local, but they can have a powerful impact on the thermal comfort of the user of the public space or nearby buildings, or even on parked vehicles, which can reduce their energy consumption levels.
- Management criteria. The drafting of a planting project in a green area will include an assessment of the work and maintenance costs, with the aim of clarifying the suitability of the species chosen and their distribution.

Therefore, there are many elements and characteristics to take into account and, as in the rest of the solutions, the choice of the ideal measure depends on evaluating multiple variables specific to each case.

iv. Soil permeability

Soil permeability plays a crucial role in managing stormwater in urban environments. When rainfall occurs on impervious surfaces, such as roads and buildings, it leads to rapid runoff. This runoff can overwhelm stormwater infrastructure, cause localized flooding, and lead to increased pollution, as it carries pollutants into water bodies. Permeable soils facilitate natural water infiltration, significantly reducing urban flood risks[16].

[16] Johnson, A., Smith, B., Davis, C., & Thompson, R. (2022). Exploring the Impact of Soil Permeability on Urban Stormwater Management. Environmental Science & Technology, 56(3), 1234-1242. doi: https://doi.org/10.3390/w13010004

There are different ways of improving soil permeability in urban areas: replacing conventional impermeable pavements with permeable alternatives (vegetated or not), improving tree cover and implementing sustainable drainage systems. As well, all actions that involve planting trees improve soil permeability through root growth and soil aeration. Tree roots create channels and improve soil structure, allowing water to infiltrate more easily and preventing soil compaction.

In Alcantarilla, one of the most important actions carried out has been the use of permeable pavements for the construction of the multimodal platform, so that rainwater can pass through them and percolate to the underlying natural soil. Permeable concrete and porous concrete slabs were proposed. For more information about the technical specifications of the materials, the technical projects of the pilot action can be consulted in the LIFE CITYADAP3 website.

The pedestrian walkway has been made of a modular concrete pavement with a high drainage capacity. The material is made of high-strength concrete with siliceous, granitic or basaltic aggregates, using up to 20 % of recycled material. Thanks to sunlight and due to its surface treatment, the pavement is also able to remove pollutants through an oxidation process activated by the sun's energy. The paving was laid on a thick bed of draining gravel on a geotextile sheet, for the water natural filtration into the ground. This system has the characteristics of permeability and capacity to laminate and purify urban runoff water to a greater degree. Moreover, the pavement is non-slip, decontaminating and made of recycled material.

The cyclable platform has been executed by a continuous porous concrete paving for exteriors. This concrete also incorporates green photoluminescent aggregate, with an attenuation time of 6-8 hours in total darkness conditions. This platform was also constructed to have a 2% slope towards the flowerbeds so that any surface water that may accumulate and does not filter through the material, is transported to the floodable flowerbeds, achieving a natural filtration of this water into the ground. The surplus that the land is not capable of absorbing is collected by means of a PVC drainage system. The excess water is carried to nearby floodable gardens, avoiding puddles and flooding in the event of torrential rains.

Flowerbeds have been placed adjacent to the pedestrian-cyclist platform, separating vehicular traffic from the pedestrian area and collecting runoff. In streets with reduced space, they have been located in the place of the existing parking strip in that area. They consist of a 100 cm layer of topsoil, which serve as the base for the planting of both shade trees and shrub vegetation, on top of a layer of selected granular filtering material. There, a concrete drainage pipe has been placed to capture excess water that the ground cannot filter, evacuating these surpluses to the flood gardens placed in squares and gardens. In cases where the width of the street didn't allow to respect the minimum width dimensions, only shrub vegetation was planted, as they require less space for their life cycle.

The situation in Lorquí is very particular and serves to demonstrate the importance of a good prior analysis before implementing a civil works action on the ground. It is necessary to indicate that the city centre is built on "cabezos" (small hills), which are essentially composed of marly soil, whose alteration can cause strong weathering and hydro expansivity phenomena.

The instability of this terrain makes it necessary to carefully evaluate the materials to be used, taking into account three factors: permeability, flexibility (adaptation to ground movements) and the load they place on the soil. Therefore, at the top of the "cabezos", materials must be light, flexible and with low permeability, so that they can withstand the movements of the ground and do not allow water to pass through, making it even more unstable.

Concrete pavements are characterised by being very rigid and respond poorly to differential ground movements leading to cracks. This, together with the high load they transmit to the ground and the surface run-off of water, leads to instabilities and alterations in the soil on the slopes. Therefore, the proposal was to use materials which, with a reduced load, can be capable of waterproofing the area in order to guarantee that water does not percolate and produce alterations in the ground. As a solution, bituminous pavements with reduced aggregate size and low thickness were selected. Hot asphaltic mixtures for wearing courses are composed of a combination of a hydrocarbon binder, aggregates with a very accentuated grain size discontinuity in the sand, mineral powder and, possibly, additives, so that all the particles of the aggregate are covered by a homogeneous film of binder, which makes it highly impermeable.

Also, along the hills, there were various reinforced concrete surface channels that were in poor condition due to the instability of the soil. The problem lies in the fact that they are continuous and rigid structures, which means that small movements cause cracks that lead to leaks and water loss, with repercussions for the environment. The proposal to solve this problem consisted of installing tongue and groove longitudinal drainage elements such as gutters and downpipes. These are arranged by means of couplings and overlaps, which means that they respond to the movements of the ground independently and therefore do not therefore do not suffer breakages that reduce their functionality.

Sustainable Urban Drainage Systems (SUDS) are stormwater management and urban planning techniques that aim to mimic natural hydrological processes in urban development by controlling runoff in the urban landscape. These systems aim to reduce the quantity of water in the final discharge and improve the quality of the water discharged into the natural environment, achieving integrated water cycle management solutions linked to the environmental protection of the receiving waters. There are several typologies: slowing and conduction systems; storage and filtration systems; transport systems and passive treatment systems.

In the Nelson Mandela Park (Molina de Segura) three types of sustainable urban drainage systems (SUDS) were installed to control the flow of rainwater, with the aim of temporarily retaining the runoff generated by heavy rainfall, laminating the peak flow, reducing the effects of flooding on the Chorrico road, avoiding the dragging of soil from the flowerbeds and using this water to irrigate the trees planted in the park. These are:

1. Vegetated gutter: it is a type of sustainable drainage conveyance systems, which are devices whose mission is to convey stormwater to other larger transport rainwater to other major treatment systems or to appropriate discharge sites. They are linear

conveyance systems and as such are usually placed on the sides of roads, in some cases being themselves the collection points for runoff water to be conveyed to the next management system.

2. Infiltration trenches: Infiltration trenches are a type of storage and filtration system and are used as a strategy to control the amount of runoff flow in medium to high density residential areas. They collect and store runoff water until it infiltrates into the natural ground and can incorporate vegetation, offering an important aesthetic view in the city. The minimum distance to the water table 1.2 meters to allow exfiltration to take place.
3. Infiltration wells: also fall under the typology of storage and filtration systems. A specific element for capturing surface water for storage and infiltration. They can be installed in the urban environment in tree surrounds, roundabouts or green areas, or as a complement to infiltration ditches, thus allowing the infiltration of a greater volume of water and avoiding the possible overflow of the ditch. The infiltration pit must be filled with granular drainage material to filter runoff water before infiltration into the ground. Filter and separation geotextiles are often used to wrap the granular material, and emergency drains are used to send the excess to the sewerage system in the event that the design capacity is exceeded.

Moreover, at the Nelson Mandela Park, dynamic penetration tests with continuous recording have been developed, which are a type of field test whose function is the geotechnical characterization of a soil. These tests provide a continuous measurement of the penetration resistance, starting at the surface level up to the maximum depth to be reached with the test, or until the drive is rejected. They are low-cost and highly representative tests, especially for granular and mixed soils, and are an important source of data on soil strength.

Knowing the characteristics and studying the permeability coefficient of the soil is of great importance to plan the measures to be developed in it. In the case of ornamental trees, the ideal is to have soils with an upper limit of 25 cm/h, i.e., soils with low water retention capacity should be avoided. On the other hand, the lower limit should not be less than 5 cm/h, since the susceptibility to waterlogging is very high. More information on these tests or their results can be requested from the LIFE CITYADAP3 team through the website.

v. Land stabilization

From a general point of view, slope stabilisation solutions have to be selected depending on the specific characteristics of the terrain and the needs of the project.

Although only solutions for ground and slope stabilisation have been implemented in Lorquí, its particular casuistry has meant that over the last decade multiple solutions have been tested with varying degrees of success, which has helped the municipality to reach the following learnings:

- Concrete walls are a common solution for slope stabilisation as they offer high stability and strength. In addition, they are relatively easy to construct and can be customized to suit specific ground conditions. However, concrete walls can be expensive and can be unsightly, rigid and rather impermeable.

- Concrete gunning involves the application of a shotcrete layer on the slope to be stabilised. The advantages include its high strength and durability, which makes it suitable for very steep slopes or conditions of high exposure to weathering. However, concrete gunite can be expensive and requires specialised equipment for its application. Again, it would be a rigid solution with little or no permeability (depending on what solution is sought for drainage), which increases surface runoffs.
- Gabion walls are structures built with wire mesh boxes filled with stone or other fill material. They are an economically and aesthetically attractive solution, as they are relatively inexpensive and can be adapted to the ground conditions. However, gabion walls are not suitable for very steep slopes or conditions of high exposure to weathering. By their very composition they are fully draining and allow for minor ground movements. They also require sufficient space for being placed, so they are not ideal for small scale actions.
- Geogrids are flexible mesh structures designed to be placed on the slope surface and anchored to the ground with nails or staples. They are an effective solution for slope stabilisation with moderate slope steepness, and are relatively easy to install. However, geogrids may be less effective in conditions of high exposure to weathering or on very steep slopes.
- Geocells are three-dimensional structures made of materials such as plastic or geotextile, which are filled with soil, stone or other fill material. They are effective for stabilising moderately steep slopes, and can be less expensive than other solutions such as concrete walls. However, geocells may require more long-term maintenance than other solutions.
- Biodegradable blankets are a more environmentally friendly solution for slope stabilisation as they are made of biodegradable materials such as straw or coconut fibre. They are a suitable solution for moderately steep slopes and can be less expensive than other solutions such as concrete walls. However, biodegradable blankets may require more long-term maintenance and may not be suitable for high weathering conditions or when there are steep slopes or structural problems.

It must not be forgotten the operational limitations that the very configuration of the Lorquí hills gives a highly urbanised area, lack of space and steep slopes. For this reason, the advantages and disadvantages of the solutions from a constructive point of view must also be taken into account. In any case, if the construction analysis is approached in terms of economic performance, each solution will have its own associated costs, which will depend on factors such as the amount of material required, the difficulty of access to the work site, the type of machinery and equipment required, and the cost of labour. For example, it should be noted that the construction of a concrete wall may be more cost-effective above a certain volume, as the cost of the machinery required for its construction is higher. On the other hand, solutions such as gabions or geogrids can be more economical in terms of materials and labour.

Same happens when classifying these solutions according to their environmental sustainability. Some options have a higher environmental impact than others, but the specific carbon footprint of each of them depends on several factors, such as the amount of materials used, the transport distance of the materials and the energy used during construction.

The experience of the last years has allowed the municipality to draft conclusions on which solutions are more appropriate for their specific context. In general, for a loamy terrain such as Lorquí, the most suitable options for backwater drainage and adaptation to ground movements may be geogrids, gabion walls and geocells. These options can allow backwater drainage and distribute loads effectively, which reduces the possibility of slope failure. In addition, these options have greater flexibility and ability to adapt to ground movements compared to concrete-based solutions.

In any case, it is important to keep in mind that the choice of one solution or the other should be based on a detailed analysis of the specific project requirements, including site conditions, performance requirements and economic feasibility. As there are so many factors involved in the decision, a summary has been drawn up that prioritises the different solutions according to weights (from 0 to 10) assigned to each solution taking into account structural, environmental, constructive, economic criteria...

Table 1. Multicriteria analysis for comparing land stabilization options in the case of Lorquí.

	CRITERION							
SOLUTION	Structural	Environmental	Presence of water or ground movements	Slope	Construction	Economic	Total	Average
Concrete walls	10	2	3	8	5	2	30	**5,00**
Gunits	6	3	2	7	7	3	28	**4,67**
Geogrids	6	6	7	8	8	8	43	**7,17**
Geocells	4	8	7	6	8	6	39	**6,50**
Biodegradable blankets	2	10	7	6	9	10	44	**7,33**
Gabion walls	8	7	6	7	7	4	39	**6,50**

Based on this, a series of conclusions can be drawn that can facilitate the approach of one solution or another:

- The most economical and environmentally advantageous solution, as is logical, is the use of biodegradable blankets, although their use is limited by their low structural capacity.
- The use of geogrids or geocells can be a similar solution, although they offer certain advantages such as increased structural capacity and durability. However, they imply a higher cost and the use of less environmentally sustainable materials, even if recycled materials are used. Between the two, the installation of geogrids is unavoidable when dealing with steep slopes (>35°) as long as the geocells are to be filled with topsoil and/or gravel.
- When the priority is to find solutions that ensure the structural stability of the slope, or when dealing with areas where high slope stresses are concentrated (>50°), the

ideal solution would be the use of gabion walls due to their drainage capacity and/or adaptation to ground displacements.

- Based on the above, the use of concrete walls would only make sense when dealing with structurally very complex situations (very vertical slopes, lack of space, concentration of stresses, etc.) and always being very careful with their execution, where an effective drainage system for the back of the wall must be ensured.

These conclusions are summarized in Figure 6.

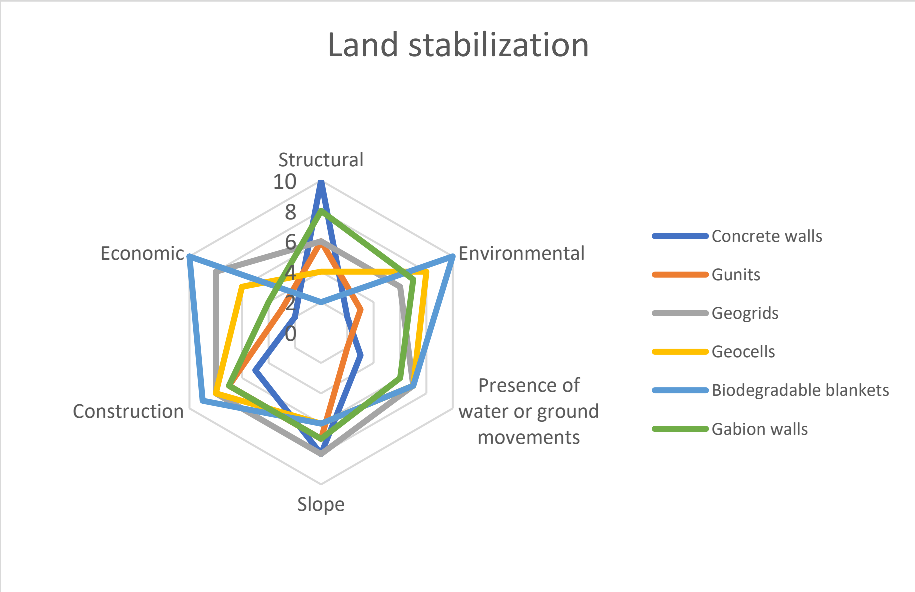

Figure 6. Multicriteria assessment for selection of the most appropriate land stabilization solution for Lorquí

This detailed analysis should be carried out by any entity before undertaking civil works for soil stabilisation. One way is to study soil loss through the analysis of the parameters of the Universal Soil Loss Equation (RUSLE). This has been carried out in Nelson Mandela Park. For more information on this study, please contact the LIFE CITYAdaP3 team through the form provided on the website.

The evaluation of the different solutions taking into account different criteria (environmental, structural, geological, topographical, economic...) maximises the probability of success of the works. Tools such as the multi-criteria assessment can also help to provide a complete and evaluated vision of the most appropriate solution for each situation.

4. Guidelines for other municipalities

Shadow generation	
Artificial	**Natural**
Ideal option when conditions don't allow planting trees. Possibility to use sustainable materials (wood, natural textiles...), so the carbon footprint is not high. Possibility of combining it with plants, increasing their benefits for temperature reduction.	Better option when space and conditions allow it, as it has multiple associated benefits and provide a great variety of ecosystem services. Importance of selecting the correct species and ensuring their management.
Re-naturalization (Plant species)	
Autochthonous	Exotic
The use of native species is specially recommended in rural areas or urban and peri-urban areas that are close to natural spaces. In that way, the risk of introducing exotic species in wild areas is minimized. Native species improve local biodiversity. They have co-evolved with local wildlife, providing habitat, food sources and ecological interactions that support the overall health of ecosystems. Autochthonous species have a high adaptation capacity to local environmental conditions, such as climate, soil and hydrology. Native species contribute to the sense of place, preserve local traditions and enhance the cultural value of urban landscapes Autochthonous species don't have invasive potential.	When using exotic species, invasive species must be avoided. This requires a review of the lists of invasive species at regional, national and European level. It is recommended to use species that have already proven their effectiveness and have been traditionally used in urban environments. Non-invasive exotic species can increase plant diversity and create more resilient and functional urban ecosystems. Some non-native species may be better adapted to urban stresses, such as pollution, compacted soil and limited water availability. These species can help green urban areas more rapidly and withstand challenging conditions. Non-native species can introduce novel colours, forms and textures to urban environments, creating visually appealing landscapes. Non-native species can escape cultivation, outcompete native plants and disrupt local ecosystems, leading to the loss of biodiversity and ecosystem services. A careful selection and management of exotic species is needed

	to avoid their potential negative impacts.

Re-naturalization (Landscaping)				
Micro-forest	Rural Hedges	Polyphite lawns	Tree lines	Customised design
Allows the optimization of public green management, which is therefore beneficiary both in economic terms (planting of young and inexpensive plants; reduction of management costs) and in relation to expectations of "prompt effect" that are often sought in this type of intervention. These interventions are widely documented in literature, and have manifested great positive impact on the environmental and ecological indicators related to biodiversity and the health of the soils. The correct selection of species is essential and must be carried out by a	Ideal option for spaces of limited space, as they allow for multiple combinations of species, layers and sizes. They work as "ecological corridor" within highly anthropized environments and can exert a significant influence on the microclimate. They regulate the flow of the wind (windbreak activity), reducing its speed and limiting the “evapotranspiration”. The presence of root systems favors the consolidation of the soil and limits surface erosion. The action of the root systems also allows greater water absorption, stabilizing the aquifers through the supply of surface water. Lastly, hedges represent a fundamental reservoir of biodiversity.	The positive aspect of polyphite meadows is that they can be grown both in dry conditions and through irrigation management. Thus, they can be a substitute of common grass. Apart of its environmental and ecological value it has a cultural meaning: to raise awareness of virtuous cultivation practices, to be favored in the agricultural sector; and educational for citizens, accustomed to conceiving the lawn as a monotonous, undifferentiated background, rather than as a fundamental ecosystem for soil health and biodiversity. Proper species need to be selected so it can grow optimally without the need for permanent management.	Appropriate option for a greater shading of the most uncovered areas of public spaces, exposed to greater quantities of direct solar radiation (play areas and the like) and cycle-pedestrian paths Their more or less straight course should be defined on the basis of the need to clearly identify formally perceptible spaces, while guaranteeing visual permeability with respect to the other elements of the context.	Another option is to design specific reforestation projects taking into account the characteristics of the park, the population and environmental needs and the requirements of the species. Species of different sizes and morphological, physiological and aesthetic characteristics should be incorporated, with the aim of generating a design as similar as possible to the natural ecosystem of the area.

professional.				
Soil Permeability				
Permeable pavement	Vegetated gutter	Infiltration trenches	Infiltration wells	Infiltration basins
Permeable pavements allow rainwater to pass through them and percolate to the underlying natural soil. Permeable concrete and porous concrete with high drainage capacity can be proposed. However, the geological composition of the soil must be considered before installing this type of solution. Instable terrains make necessary to carefully evaluate the materials to be used, taking into account three factors: permeability, flexibility and the load they place on the soil.	It is a type of sustainable drainage conveyance systems, which are devices whose mission is to convey stormwater to other larger transport rainwater to other major treatment systems or to appropriate discharge sites, providing a number of benefits along the way. Vegetated gutters are linear conveyance systems and as such are usually placed on the sides of roads, in some cases being themselves the collection points for runoff water to be conveyed to the next management system.	They are a type of storage and filtration system and are used as a strategy to control the amount of runoff flow in medium to high density residential areas. They collect and store runoff water until it infiltrates into the natural ground and can incorporate vegetation, offering an important aesthetic view in the city. The minimum distance to the water table 1.2 meters to allow exfiltration to take place. Geotextiles has been used for and separation geotextiles will be used to wrap the granular material.	Also fall under the typology of storage and filtration systems. A specific element for capturing surface water for storage and infiltration. They can be installed in the urban environment in tree surrounds, roundabouts or green areas, or as a complement to infiltration ditches, thus allowing the infiltration of a greater volume of water and avoiding the possible overflow of the ditch. The infiltration pit must be filled with granular drainage material to filter runoff water before infiltration into the ground. Filter and separation geotextiles are often used to wrap the	Are another type of storage and filtration system. They are elements for vegetation that allow the infiltration of rainwater. It is advisable that they are connected to each other to amplify the infiltration capacity.

			granular material, and emergency drains are used to send the excess to the sewerage system in the event that the design capacity is exceeded.	

Land stabilization

Concrete walls	Gunits	Geogrids
They offer high stability and strength. In addition, they are relatively easy to construct and can be customized to suit specific ground conditions. However, concrete walls can be expensive and can be unsightly. In addition, they are rigid and rather impermeable (which, if not properly drained from behind), can lead to the accumulation of groundwater and rainwater seepage.	Involves the application of a shotcrete layer on the slope to be stabilised. The advantages of concrete gunning include its high strength and durability, which makes it suitable for very steep slopes or conditions of high exposure to weathering. However, concrete gunite can be expensive and requires specialised equipment for its application. It would be a rigid solution with little or no permeability (depending on what solution is sought for drainage).	Geogrids are flexible mesh structures designed to be placed on the slope surface and anchored to the ground with nails or staples. Geogrids are an effective solution for slope stabilisation with moderate slope steepness, and are relatively easy to install. However, geogrids may be less effective in conditions of high exposure to weathering or on very steep slopes.
Geocells	**Biodegradable blankets**	**Gabion walls**
Three-dimensional structures made of materials such as plastic or geotextile, which are filled with soil, stone or other fill	It is a more environmentally friendly solution for slope stabilisation as they are made of	Flexible mesh structures designed to be placed on the slope surface and anchored to the ground with nails or staples. Geogrids are an effective solution for slope stabilisation with

material. Geocells are effective for stabilising moderately steep slopes, and can be less expensive than other solutions such as concrete walls. However, geocells may require more long-term maintenance than other solutions.	biodegradable materials such as straw or coconut fibre. Biodegradable blankets are a suitable solution for moderately steep slopes and can be less expensive than other solutions such as concrete walls. However, biodegradable blankets may require more long-term maintenance and may not be suitable for high weathering conditions.	moderate slope steepness, and are relatively easy to install. However, geogrids may be less effective in conditions of high exposure to weathering or on very steep slopes.

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