Deliverable 1.5 Intervention Conclusions:

Valencia

Project Number: 730283

Project Acronym: GrowGreen

Project Title: Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environments

Deliverable No.	D1.5
Work Package	WP1 Demonstration projects
Dissemination Level	Public
Author(s)	Francisca Hipolito
Contributor(s)	Martine Tommis - MCC
Delivery Date	25/211/2022
File Name	D1.5 Intervention Conclusions Valencia
Status	Final

This document has been prepared in the framework of the European Project GROWGREEN – Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environments (Grant Agreement No. 730283). This project has received funding from the European Commission's Horizon 2020 research and innovation programme.

CONTACT: Grainne Bradley Email: grainne.bradley@manchester.gov.uk

Contents

List of Figures

List of Tables

1. Executive Summary

Funded by the European Commission, GrowGreen explores the ways investing in nature based solutions (NbS) can help cities adapt a changing climate. Led by Manchester City Council (MCC), GrowGreen includes developments in Manchester (UK), Valencia (ESP) and Wroclaw (PL). This report presents the challenges and results from the work in Valencia, focused on Benicalap, an area located in the north west of the city, chosen for the need for regeneration and investment.

The baseline diagnostics for the area explored climate, air and water quality, health indicators, water management, noise, green space, soil contamination along with social and economic indicators. The aim of the project was to demonstrate how NbS can help Valencia to adapt to climate change. The key threats to Valencia are increasing temperatures and extreme weather events, often in the form of intense rainfall. The project also looks at the potential to deliver co-benefits. For example, how green space can improve biodiversity and impact on the social health and wellbeing of local people.

An number of demonstrators were developed across the Benicalap district.

- A sustainable forest – an area previously used for car parking
- A blue green corridor - with sustainable drainable, biocells and shaded space.
- A vertical ecosystem - on the façade of the local school to purify grey water.
- A green roof - on an activity centre for the elderly
- Open calls – increasing citizen participation and engagement, building structures, a biodiversity project and a community video.
- Biodiversity app - to educate.
- A local food distribution service.

Drawing on a three phase methodology of “Listen and Transform”, the project worked with local residents and stakeholders from a diverse range of organisations. Recognising that engagement of the local community was vital with participatory planning as a key element.

Post construction, monitoring and evaluation was led by the Polytechnic University of Valencia (UPV). This assessed the impact and effectiveness of the NbS interventions. Data was gathered through: remote sensing sensors, surveys, observations, interviews and focus groups.

The main results to be highlighted are:

- Biodiversity is significantly improved in the NbS applied in the various pilots of the project.
- The proportion of the five canopy types of the NbS (tree cover, bare soil, etc.) is balanced.
- Improved resilience of the introduced vegetation in relation to diseases and adaptation to the local climate.
- Increased environmental services, especially surface runoff management through increased soil permeability, improved climatic comfort, air quality and increased CO_2 absorption.
- The Mohawk method makes it possible to analyse the use of space and user behaviour. The following positive aspects are detected:
- Increased interest has been generated by the changes made in the neighbourhood where the pilots have been installed.
- NbS has contributed to meeting people's growing need to spend more time outdoors after the pandemic by improving the conditions of the district's open spaces.

- Thermal stress changes are very gradual. It is difficult and very slow to change the heat stress response in a whole action area but more feasible for immediate changes limited to the immediate vicinity of the vegetation.
- Air temperature is a key parameter but is not sufficient for the assessment of heat stress.
- In trees, slow and gradual changes are detected, for which it is important to take actions to maintain the carbon stock (debris from tree pruning and dead, diseased trees). This monitoring can be carried out on the basis of annual measurements.
- On water resilience SuDs delayed the impact of water flow by up to 4 - 5 hours. In addition to delaying the inflow of water into the collectors, they reduce the amount of water reaching the collectors by between 66 - 100 % (volumetric efficiency).
- Sediment can potentially clog features such as permeable pavement, however despite this it can still function.
- The SuDS at the Sustainable Forest retained all the runoff water generated in the park. This is 100% improvement in comparison to pre- construction.
- On water quality the SuDs can reduce the concentrations of a range of pollutants.
- There have been price increases due to inflation and global markets and whilst the impact on real estate costs cannot be totally evaluated at this stage, there is as view that the implementations may have impacted accelerated the rise of the Benicalap real estate market.

2. Introduction

Nature based solution (NbS) demonstration projects have been completed in each of the three GrowGreen cities, Manchester, Valencia and Wroclaw. This deliverable describes the interventions co-designed and implemented in Valencia, along with the outcomes, key messages and lessons learned. Following further data collection in spring/summer 2022, this report will be updated in November 2022.

The Grow Green project is located in the neighbourhood of Benicalap. The district is in the northwest of the historic centre of Valencia and was connected to the city of Valencia in the 19th century as a result of the growing city (Figure 1.1). With 2221 m2 it is only a small part of it, but with a high population density. There are on average 20 people per m2 living in Benicalap, resulting in a total of 48000 people. Compared to Valencia it covers only 1.5 % of the city area but contains 6% of the people [Ajuntament de Valencia, 2022].

Valencia covers an area of 124,65km2 and a population of 801,545 inhabitants (2020) and taking in to account the wider area it is the third most populous city and metropolitan area in Spain (after Madrid and Barcelona).

The city is mainly a service area with 84% employed in this sector – the retail and wholesale trade, and professional services. The city does retain an important industrial base, with 11% working in small and medium-sized companies - paper and graphic arts, wood and furniture, metal products and footwear sectors. Its dynamism as an economic centre and as a place of reference for multiple economic activities is reflected in the strength of key institutions for economic development such as Feria Valencia, the Autonomous Port, the Stock Exchange, the Palacio de Congresos and the universities. Valencia also has important cultural institutions: the Palau de les Arts, the IVAM, the Palau de la Música or the City of Arts and Sciences. Agricultural activities have minor importance with 3,001 hectares, mostly for horticultural crops.

Benicalap (Figure 1) was chosen as the demonstration site due to the need for regeneration and improvement. The area has lack of resources and services and has suffered a lack of investment.Compared with other areas in the city, the local population has lower incomes and education levels with higher levels of unemployment.

There are also urban development challenges. The housing is older and whilst there is a growing demand, there is a lack of new homes. The public infrastructure has suffered deteroration due vandalism and insufficent investment with numerous incidences of private housing being illegally occupied. There are also issues with street markets, insufficient street cleaning and illegal sales.

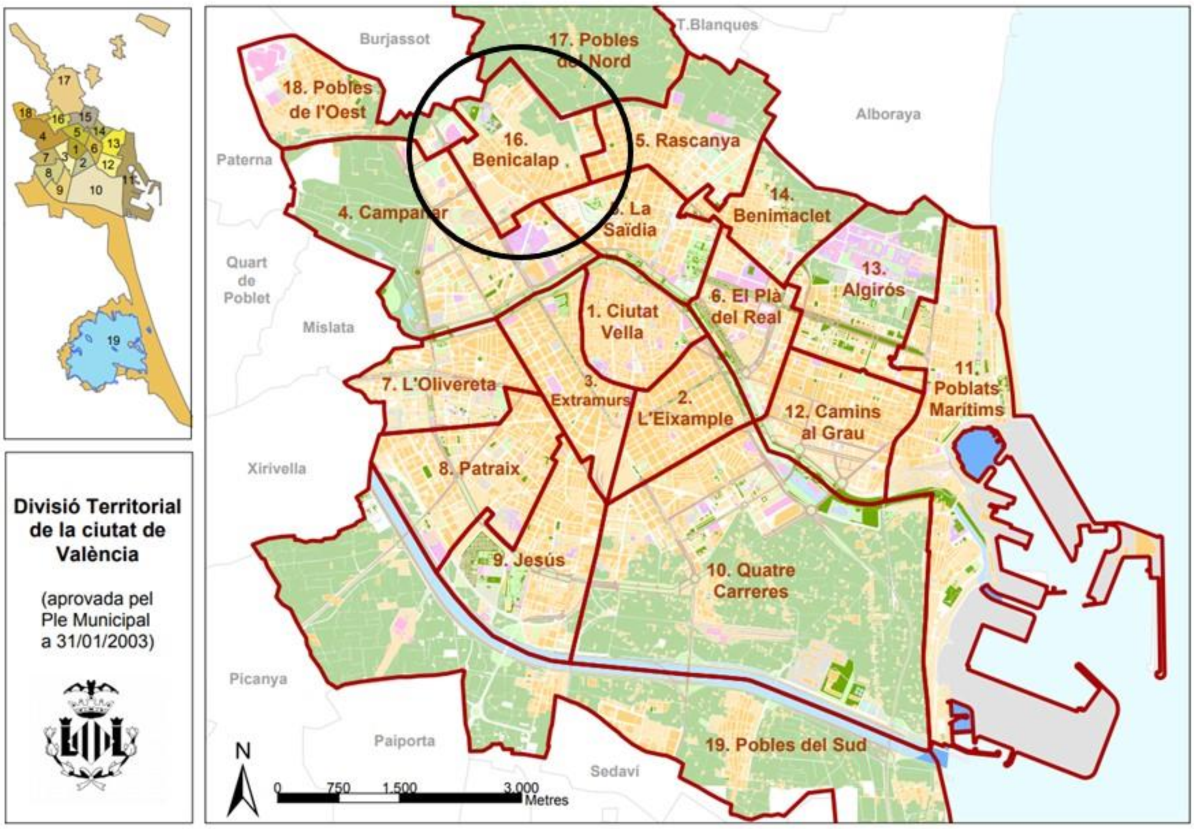


Figure 1 Map of Valencia and districts

Figure 2 Open plot with the skyscrapers of Avenida de les Corts Valencia in the background.(Image: Valencia Plaza).

Benicalap has three different areas (Figure 3):

1. **Benicalap** – to the south of the area.
2. **Nou Benicalap** - is the newest area of the district which seen in the structure of the area and the buildings.

3. **Ciutat Fallera - NbS was implemented in this area.** The area was chosen due to its socio-demographics. It was originally built as a community for the Fallas (monuments of wood and board). There is still artisan activity and a museum showing the history of the Fallas building process. An important part of Ciutat Fallera is the Benicalap Park, opened in 1983. This is a fenced area in the south of Ciutat Fallera and is the second most visited park in Valencia. Figure 3 shows the location of the green areas.

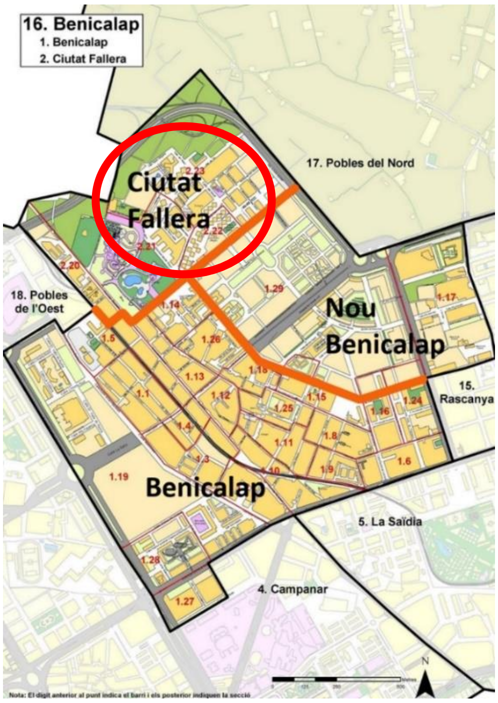


Figure 3 Map of Benicalap [ushuaialiving, 2022]

A visit to Benicalap shows the difference from other districts in Valencia. There are fewer people on the streets and most buildings are older than in the city centre and other areas. There is a difference between the new and old sections of the same district. Several new developments and restored buildings in Nou Benicalap including green spaces but overall is still a lack of public places such as playgrounds and a lack of greenery.

Benicalap is connected with the city centre by tram and underground. However, this does not include Ciutat Fallera. There are some tram stations in the Benicalap area plus metro and tram at the boundaries. The tram has a direct connection to the beach but to go to the city centre, there is the need to switch lines.

Benicalap is comparable to another community in Valencia, Rascanya (the reason it was selected as a control for the property betterment analysis).

The objectives for the demonstration project was to:

- Establish the evidence base that NbS in cities provide a cost-effective, sustainable, replicable means of increasing urban water and climate resilience and could also support co-benefits e.g., improvements in health and wellbeing, social cohesion, biodiversity, and improvement to socio-economic indicators.
- Provide NbS living labs to encourage investment and development across Valencia and beyond.

3 Diagnostic Report

The University Polytechnic of Valencia produced an initial diagnosis and baseline report for Benicalap in May 2018. This was structured on the Eklipse[1] framework (reference D1.1 Diagnosis and Baseline of Front Runner Cities). The report highlighted the following:

3.1 Climate

The average annual temperature is 23.0 °C during the day and 13.8 °C at night. In January (the coldest month), the temperature typically ranges from 14 to 20 °C during the day and 4 to 12 °C at night. In August (the warmest month), the temperature typically ranges from 28 to 34 °C during the day and about 22 °C at night. More than 50 tropical nights per year are assigned to Valencia (2002 – 2012). In the same period there are between 14 – 22 days per year with a combination of tropical night and maximum daily temperatures above 35°C.

3.2 Precipitation

Precipitation in the Valencia region tends to be concentrated in a relatively low number of days, with a large share of the total precipitation generated in a few rainfall episodes. Since the diagnosis report was published (May 2018) there have been two major flash flooding events, one in November 2020 and another in Oct 2021, both causing in Valencia and surrounding area severe damage to infrastructure and agriculture. The emergency services were mobilised to save lives due to the collapse of buildings and flooding road,.

3.3 Water Management

3.3.1 River network

The city is located at the Turia River mouth. The Turia River is an important fluvial system (catchment area 6394 km^2 and river length 280 km) which has historically impacted on the city's development in two ways: its irrigation system (the Turia system mean annual inflow is 416 hm^3/year) and periodic flooding. In 1957 rainfall flooded the city with significant casualties and economic impact. As a result, in the 1960's the river was diverted along the city's south bound and the old riverbed crossing Valencia was slowly transformed into the largest (11 km long. 250 m wide) green area of the city.

Two minor river systems run north and south of the city: the Carraixet river and the Poyo river. Both are typical ephemeral Mediterranean rivers.

[1] https://www.eklipse-mechanism.eu/

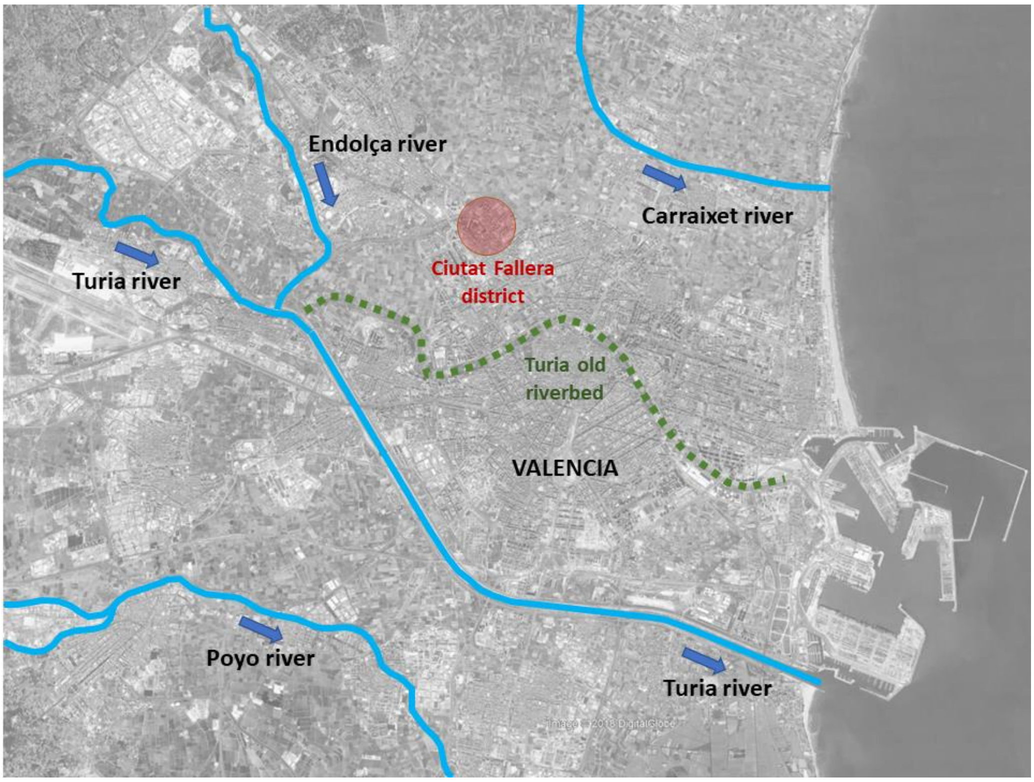


Figure 4 River systems within Valencia city area.

3.3.2 Drainage

Valencia is drained by a combined sewer network. The system is the result of more than 1000 years of evolution with the irrigation network developed during the Arab period. Today, the network is composed 1500 km conduits with of more than 65,000 manholes. The main sewers were planned and built during the 1970's - 80's as a result of the city planning derived from the above mentioned 1957 flood and the subsequent river diversion. upstream in the centre catchment. Due to the flat topography of the city, the network includes 61 pumping stations.

The irrigated agricultural land dates from the Romans, with even greater expansion in the Middle Ages, creating an important network of irrigation infrastructures including channels, diversions and small dam, mainly taking water from the Turia river. There are eight main irrigation channel systems all governed by the Water Court (Tribunal de las Aguas, http://www.tribunaldelasaguas.org/en/). This Court is the oldest existing justice institution in Europe; in 2009, the UNESCO inscribed it on the Representative List of the Intangible Cultural Heritage. Among the eight irrigation systems, the Tormos system influences the Ciutat Fallera district as some of its channels still cross the city in this area, from the Turia intakes in the west to the irrigated areas in the east.

3.4 Water quality

No specific water quality data was available for Benicalap but research in other parts of the city allows general conclusions to be drawn that suggests pollutant loads take place with rainfall volumes above 3 mm. Urban runoff from impervious areas under semi-arid climatic conditions present a significant level of pollution, with high event mean concentrations for suspended solids, organic matter, nutrients, and metals. The organic matter detected in the runoff has a low biodegradability and a slow biodegradation rate.

3.5 Air quality

The city has high levels of car ownership which makes traffic the main source of pollution, (approx. 90% of atmospheric pollutant emissions). The pollutants are oxides of sulphur, carbon and nitrogen, aromatic hydrocarbons, particles in suspension of variable size, ozone generated by solar radiation and noise as a contaminant of physical nature

The General Directorate of Environmental Quality of the Ministry of Infrastructure, Territory and Environment launched a project based on the implementation of Emissions Inventory of the Valencia n Community. The data in 2009 showed that traffic generates around 56% of total nitrogen oxides.

3.6 Noise

The main causes of noise pollution in the district are from road and rail traffic and industrial activities as seen in Figure 5.

Figure 5 Noise level map of Benicalap. 2012

3.7 Greenspace

Green space in Benicalap district represents almost 17% of the district and 8m2 per capita. In comparison with other districts in the city, the percentage of green areas in Benicalap is high because there is a large park, Benicalap Park, at the most northwestly point of the district, and two more formal gardens in the more affluent areas. For the rest of the area, public green spaces are scarce. In the lower income central neighbourhood green public space is totally different, mainly made up by squares and some small playgrounds without greenery.

The Sustainable Forest was a large disused plot of land adjacent to Benicalap Park. Built in 1983, at eight hectares, the park is the largest green space in the district. The plot was used as temporary car parking and was mostly barren except for 27 elm trees (*ulmus pumila*), 23 of which were removed due to disease and age. The best timber was retained for seating and aesthetic uses.

3.8 Social, Health and Economic

3.8.1 Participatory Planning and Governance

The most active groups in the neighbourhood in the district are Campanar Fallas Group (related to the local festivity Fallas) and the Neighbourhood Association Benicalap, Entre Caminos. There was not a strong resident participation in the engagement due to a lack of interest in public initiatives stemming from the sense of abandonment of the neighbourhood by the municipality.

Bordering the neighbourhood are the best group of ancient farmhouses in Valencia . Several have disappeared but others remain, such as the Alquería dels Moros, the Alquería de la Torre or the group of Alquerías de Lluna. Despite their heritage value some are derelict. Concerns from institutions such as the Consell Valenciá de Cultura and the Cercle Obert Benicalap Association have been raised. Different neighbourhood forums have insisted on the need to promote a real project of rehabilitation and reuse of these valuable and unique rural groups, integrating them in the Municipal Park of Benicalap, as noted in the 1988 General Urban Plan.

3.8.2 Social Cohesion

There is little social cohesion in the area. The lack of public investment, the high rates of unemployment, plus the feeling of distrust towards the public administration making this zone to be one of the most vulnerable of the city. There is a large number of immigrants and different nationalities (immigrant population 17.5%), but there is little coexistence as they form different groups by nationalities. There is also high presence of local ethnic minorities who form differentiated groups.

3.8.3 Health and Wellbeing

There is limited health data for the Benicalap district due to the lack of attention from institutions. Life expectancy for men is lower than the Valencia average but life expectancy for women is above the Valencia average.

3.8.4 Vulnerability to Climate Change

People living in Benicalap are particularly vulnerable to climate-related events, due to poverty, older infrastructure and the underfunded urban structure. The impact of heat stress is accentuated by energy poverty linked to low incomes.

3.8.5 Economic

Data from the City of Valencia shows 12.5K people from the Benicalap district - Ciutat Fallera, are in a state of "vulnerability", for reasons such as the lack of public facilities, means of transport, unemployment or demographic situation. The unemployment rate is 34%. Women in employment usually work in the service sector or retail, and men in industrial or manual roles. The area is occupied by working-class families and number of small local businesses. There is also an area with wide avenues with office blocks. Apartments cost €500 Euros per m2. The average price per square meter of social housing in Valencia is around 1205 Euros. The GDP per capita for residents of Benicalap is 13.8 % lower than the city average.

4 Determining Co-Benefits

4.1 Design Overview

The demonstration projects area:

- A **Sustainable Forest** as an addition of the local park in a space previously used for car parking
- A **Blue Green Corridor** along a main street incorporating sustainable drainages systems, bio-cells and shaded space.

- A **Vertical Ecosystem** on the façade of the local school to purify the grey water from the toilets.
- A **Green Roof** on an activity centre for the elderly
- A **Biodiversity App** to educate on biodiversity and NbS.
- A **Food Distribution Service** called Cistella Solidaria
- **Open Calls** to increase citizen participation and engagement resulting in building structures and workshops, a biodiversity project and a video. These resulted in five initiatives:
    - **A community garden for associations** on disused land.
    - **A civic centre** built in the community garden area using recycled materials with a paved area with a roof, electricity and lighting from renewable sources and planters.
    - **Workshops and wildlife monitoring** to promote the area's fauna, bats, and birds.
    - **A heat resilient devices in a school playground** to provide meeting areas, tables and benches for the school pupils.
    - **A media project** documenting the projects.

4.1 Sustainable Forest

This is an extension of the Benicalap Park using an area previously used for parking. Any wood, soil etc. were reused and young specimens of local species left for natural growth. It includes play area for children, areas to filter rainwater and prevent flooding as well as a separate biodiversity area simulating a Mediterranean forest.

The forest gives accessible passage and pedestrian connection to Andreu Alfaro Street and gives new access to Benicalap Park. Perimeter trees have been included to recover the historical perspective of the old Burjassot road, near historical farmhouses. The design concept is based on three elements: topography, vegetation, and water.

The topography was created to manage rainwater during rainfall events. It has been designed so that runoff is directed to the different Sustainable Urban Drainage Systems (SuDS). The SuDS typologies are mainly bio-retention systems such as the three infiltration basins connected in cascades; perimeter filter ditches and connection ditches between basins; and permeable pavements. The construction of the sustainable forest was created using existing soils, minimising environmental impact.

Biodiversity was improved by creating different strata's of vegetation (trees, shrubs, and terrestrial plants), encouraging the diversity of species and creating spaces for animal habitat. To improve thermal comfort in the area, tall vegetation has been installed to reduce exposure to direct solar radiation.

Figure 6 Sustainable Forest, Benicalap - Ciutat Fallera.

4.2 Green-Blue Corridor

The aim was to combat climate stress, increase biodiversity and improve the rainwater drainage systems. The solutions include the modification of the pavement allowing the retention and/or infiltration of water to the subsoil and the modification of the existing gardens into rainwater retention/infiltration areas. Several solutions were used:

- SUDs manage rainwater on the parking area. Two of the parking areas have been monitored, one in a park with a battery for electric cars, built with a grid slab and the other one in a curb parking area built with cobblestones.
- Bio-cells: the existing gardens in Calle del Foc (Foc Street) were converted into nodes of biodiversity and sustainable water management, different vegetation solutions have been installed and the kerb levels have been modified to allow the collection of water from the pavements.

- Linear bio-cells: the space for vegetation on the pavements has been enlarged, connecting the existing tree surrounds in a way that allows connectivity of biodiversity and also sustainable water management. Different vegetation and irrigation solutions have been installed.
- A shaded area has been created to adapt to thermal stress and to allow for furniture in Regino Mas Square: an urban living element with rainwater management.. A pergola has been installed to create a shaded space. The square contains an area with vegetation. Energy efficient lighting has been installed (Figure 7 and Figure 8).
- The existing trees in the area were retained as they were in good condition and provide a dense vegetation cover for the street. The lower vegetation was added to enrich the biodiversity. The number of trees in the Plaza de Regino Mas were increased.

Figure 7 Design of the green blue corridor, Benicalap

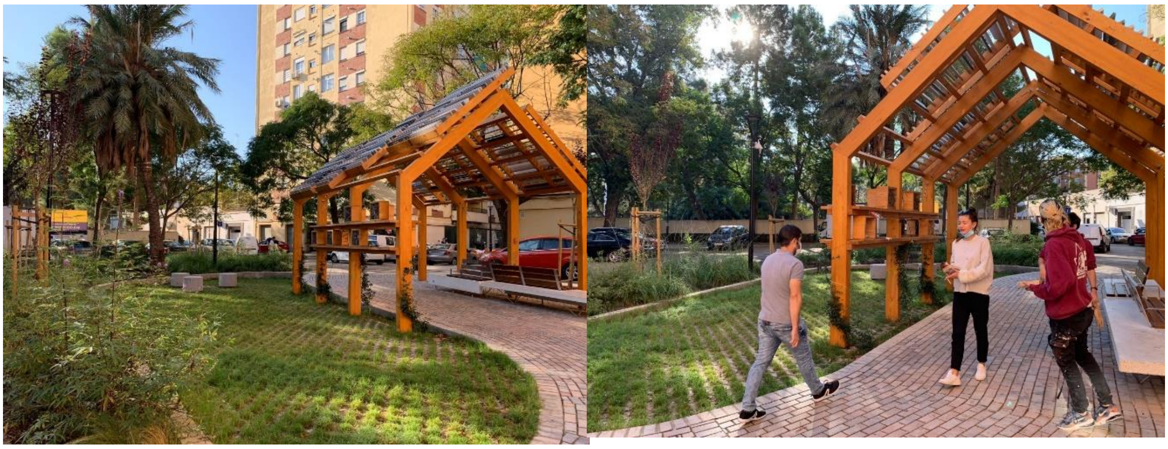


Figure 8 Regino Mas Square, Benicalap

4.3 Vertical Ecosystem

The vertical ecosystem (green wall) is located at the south-west façade of the public school "Ciutat Artista Faller" and was installed October 2019 (Figure 9). The main function is to purify the grey water from the school toilets. It is made up of plants, a series of buffer tanks to store the water as it passes through each process, a water softener, a reverse osmosis membrane. A ultraviolet lamp for disinfection was also installed in order to reuse the water to irrigate plants and the school garden.

The system has been in operation for two years. Maintenance has been by the subcontracted company (including the change of some elements of the system such as the UV lamp, new plants). Parameters such as turbidity, COD or suspended solids were analysed weekly and other parameters (*E.coli*, calcium, magnesium, BOD, nutrients) were also analysed as is required Spanish legislation of water reuse (Royal Decree 1620/2007).

In June 2021, modifications were made:

- Pipes, connections between them, filters and osmosis cartridges were replaced.
- An automatic system to monitor the efficiency of the process treatment precisely was installed.
- A bypass was installed in the reverse osmosis system as sometimes the water was not clean enough.
- A solenoid valve was installed in the outlet to keep the tank free of suspended solids.

Figure 9 Vertical ecosystem installed on the school façade

4.4 Green Roof

A green roof was installed on an activity centre for the elderly. The roof has an area of 345 m² and was originally a layer of gravel. The green roof project included both the technical elements for the drainage and waterproofing as well as the substrate and the plantations. It was planted with *Sedum sp*.

The aim was to provide a garden roof environmental reasons as well as health and wellbeing. The building is very hot during the summer as there is no infrastructure or trees to provide shade. Other benefits include drainage and runoff, energy efficiency (reductions of up to 84% in energy consumption can be achieved in buildings with green envelopes), acoustic insulation and biodiversity.

Figure 10 Green Roof

4.5 Biodiversity App

The app was developed by the Universidad Politécnica de Valencia . It is an interactive game-like tool to teach NbS plus the plant and bird biodiversity of the neighbourhood. The app has had around 700 downloads. The highest point of use has been shown in the late spring and early summer of 2021. The main objective was involve citizens in the monitoring of the pilot projects, as well as to improve knowledge about the benefits of elements of urban green infrastructure. The data shows that the app use is concentrated in Benicalap Park. This is to be expected as it is the most important biodiversity hotspot of the whole district.

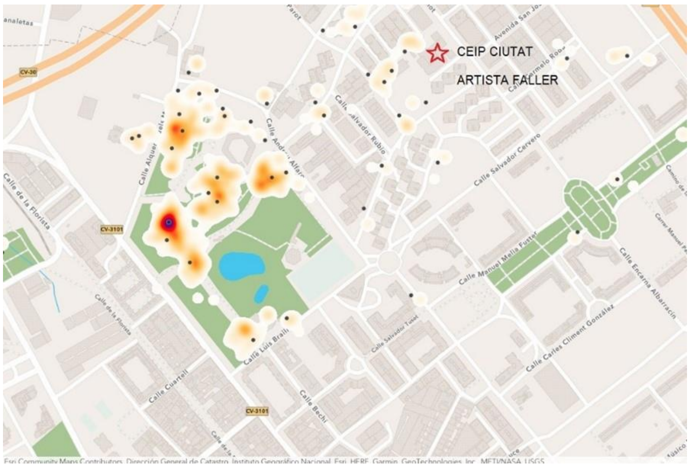


Figure 11 Distribution of the app use

Figure 12 Biodiversity App

The app contains three modules.. The 2D map indicates user's real-time location, the game mode introduces the user as an avatar in the 3D world and a module that promotes environmental awareness through bird watching. The user is guided to visit a series of points of interest (POIs) that appear on the 2D map. The POIs are the species of trees, shrubs, urban and peri-urban birds, previously selected to represent the most common flora and fauna species (birds) of Benicalap and Valencia , as well as architectural heritage (Alquerías and Casino of Americano).

4.6 Cistella Solidaria

This is a service distributing food cultivated in the vicinity. It was developed in conjunction with the La Fundación De La Comunitat Valenciana Para La Promoción Estratégica, el Desarrollo y La Innovación Urbana and with C.E.D.A.T. A.G, S.L. It is organized via focus groups to ensure representation of social groups and price regulation. Publicity materials and programs were developed.

4.7 Open Calls

The project implementation criteria included citizen participation. To promote this an open call was made for local businesses to involve the community. The call was designed via workshops with citizens and stakeholders and a focus on the participatory process, e.g., promoting the orchard, creating spaces and activities for neighbourhood meetings and promoting biodiversity.

The call generated five projects, all of which were implemented:

ESPAI VERD BENICALAP (Benicalap Green Space/Community Garden) - Self-build workshops repurposed disused land on Avenida Hermanos Machado. The space has three areas: a community garden, a forest of fruit trees and an area for socio-educational activities. Over 15 associations from Benicalap meet regularly to manage the orchard and forest as well as to programme activities linked to ecology, local culture, and social integration.

Figure 13 Construction and gardening workshops

CENTRE CÍVIC VERD (Green Civic Centre) A pergola was built using recycled materials. This pergola provides a paved area with a roof, electricity and lighting from renewable sources, storage and planters. The construction was coordinated by professionals from the Arrelaires association with the help over 50 volunteers, ranging from children to the elderly.

Figure 14 Self-built pergola and citizen assembly on the pergola

ALIATS ALATS (Winged Allies) – workshops and wildlife monitoring - The aim of was to promote the presence of the area's fauna, bats, and insectivorous birds i.e. species that protect against mosquitoes and other insects. Workshops were held with the local school. A monitoring station was installed. The project was managed by the company Càdec ambiental.

Figure 15 Bat nesting box and students showing their creations

URBAN RESILIENCE PROVISION – a shaded area was created to provide meeting areas, tables and benches for the pupils of IES Benicalap playground.

Figure 16 Creating structures in the playground

ECO-REMEI - a media project that followed the winning projects as well as the construction of the demonstration projects. The result has been the production of mini videos of each project where the authors tell the story of the work carried out. https://ecoremedi.es/proyectos/

5 Designing Key Indicator Impacts

The overall aim of the combined projects was to demonstrate how NbS can help Valencia to adapt to climate change. The location based interventions are shown on Figure 17 Map of Demonstrators.

5.1 Design Overview

Blue Markers	Black Markers
1. Sustainable Forest	1. Benicalap Green Space
2. Green-blue corridor	2. Green Civic Centre
3. Vertical Ecosystem	3. Aliats Alats / Winged Allies
4. Green Roof	4. Urban Resilience Provision

Figure 17 Map of Demonstrators

5.2 Sustainable Forest

Water retention and purification were the main objective with the aim to prevent flooding due to the lack of water resilience in the area. It includes a SuDs system consisting of three cascading infiltration basins; perimeter filter trenches with connection between basins; and permeable pavements. It has been monitored during/after heavy rains, using information from the sewerage services.

As a medium sized city with high population density, Valencia has typical CO^2 emission issues. This is especially highlighted in Benicalap neighbourhood and Ciutat Fallera due to the volumes of high traffic in the surrounding areas. CO^2 reduction is monitored via sensors near the Benicalap Park and at one entrance to the city by highway. This included the pedestrianisation of an adjacent road.

Biodiversity was also a driver, and the area only used native plants to create the small "wild" urban Mediterranean forest. The impacts on biodiversity were not directly monitored. This would require more longitudinal work.

5.3 Green-Blue Corridor

The lack of green areas was a main driver of the NbS, and the new green zones are expected to absorb CO^2 emissions. These are measured in the Regino Mas Square. Sensors were also installed to monitor the temperature by the pergola and the new green areas. Water retention and dispersal is also an objective of this action and includes SUDs in Regino Mas Square, and in street parking lots. These are monitored via observation.

The design included the use of native plants and the pergola in Regino Mas Square includes insect hotels.

5.4 Vertical Ecoystem

Water retention and re-use was the main objective. Water is reused in in the school's gardens and monitored by sensors.

5.5 Green Roof

Water retention was the main objective. The water capacity retention is monitored by measurement systems with sensors. The temperature regulation is monitored by sensors both on the roof and inside the building,

5.6 Biodiversity App

The aim was to raise awareness and enable data collection on biodiversity.

5.7 Green Civic Centre

Due to the harsh summers and the proximity traffic, the Green Civic Centre developed. It provides shelter and thermal comfort. Several trees have been planted with three aims: fruit, noise insulation inside the space and outside, trees for aesthetic and biodiversity purposes.

5.8 Winged Alies (Aliats Alats)

This action is specific for conservation of birds and especially bats. Bat biodiversity is monitored with sensors and nests and studied in the Park of Benicalap.

The KPIs developed in Work Package 2

Challenge Area	Benicalap KPIs
1. Climate Mitigation & Adaptation	• Humidity. • Air temperature. • Energy and carbon savings from reduced building energy consumption • Mean Radiant Temperature • Physiological Equivalent Temperature PET • Carbon storage and sequestration in vegetation and soil
2. Water Resilience	• Run-off coefficient in relation to precipitation quantities.
3. Water Management	• Reduction on runoff peak discharges. • Reduction on runoff volume rates. • Physical water quality indicators: turbidity, suspended solids, transparency • Chemical water quality indicators: pH value, nutrient levels (especially nitrogen and phosphorus), salinity, heavy metals levels, organic pollutants levels, dissolved • Biological water quality indicators: biochemical o1igen demand BOD, etc • Urban greywater reutilization • Reduction of wastewater organic matter pollution and pathogen content • Reduction of nutrient (N, P, K) content and salinity
4. Green Space Management	• Accessibility to greenspace • Diversity of trees and shrubs • Structural connectivity • Diversity of vegetation strata
5. Air Quality	• Pollution levels (PM10)
6. Noise	• Noise levels (LAFma1, Lday)
7. Participatory Planning and Governance	• Electoral participation rate (municipal and regional). • Rate of participation in calls for participation budgets.
8. Social Justice and Social Cohesion	• Percentage of individuals with access to at least 2 hectares of green space within 300 metres of home, percentage of individuals with access to at least one 20 hectare site within 5 kilometers of home, number of nature reserve/conservation areas per 1000 population • Percentage of households in full-time employment (Neighbourhood), percentage of households earning less than the national and regional average (City), percentage of households classified as deprived (Neighbourhood) • Singular elements (informative points, monuments or artistic interventions) in the public space • Adaptation of basic furniture (litter bins ...) • Adaptation of children, youth and elderly equipment.
9. Public Health and Wellbeing	• Mortality annual rate • Life annual expectancy • Reduced cardiovascular morbidity and mortality • Percentage of people taking notice of their environment • Percentage people who feel integrated into their community • Percentage of people with an attachment/sense of belonging to the neighbourhood • Percentage of people of who feel able to trust one another within the neighbourhood • Percentage of people who are happy in their daily lives. • Percentage of people undertaking forms of physical activity
10. Potential of Economic Opportunities, Green	• One-off construction costs • Recurring / maintenance costs

Jobs and Business Models	• Property betterment • Direct jobs & local economy • Indirect jobs & local economy

Table 1 KPIs and Challenge Areas

5.9 Co-Design Process

Stakeholder engagement used "Listen and Transform" methodology. This uses the tool "Doing Cities with People"[2] which classifies the actions into three channels: **Dissemination, Citizenry, Participatory**. The majority of the dissemination actions are shared with the communication tasks and the participatory actions are mostly part of co-design process.

The participation strategy was developed adapted to the different phases of the project during September to December 2018, with a second phase of monitoring in 2019 and a final phase in 2021.

Preparation: The objective was to develop the process and collect information from stakeholders and other NbS projects to create a starting point.

DCP tool	ACTIONS (* actions with continuity in next phase)
Diffusion, Transparency and Visibility	1. Contents design for Web and RRSS*. 2. Contents for brochures and dissemination materials*.
Citizenry, Sharing results and Education	3. Identification of stakeholders.

Listening phase - Promotion of participation, identification, and co-design of proposals: The objective was to promote the participation process to reach out through communication and awareness-raising tools. This was to the general population and those living in the neighbourhood. It achieved:

- Reinforcing and recognising the social vision of Benicalap.
- Raising the project profile and recognising the public space needs of the citizens.
- To recognise the initial proposals for co-design and co-management of the demonstration projects.

DCP	ACTIONS (* actions with continuity in next phase)	AGENTES
Diffusion, Transparency and Visibility	4. Web and RRSS, Informative brochures, Media & Articles in press. * 5. Informative panels and mailboxes in public facility buildings. *	Citizens. Facilities: Municipal Library Vicent Tortosa Biosca, Elder Center Benicalap, Popular University, Ciutat Artista Faller School and Artista Fallero Museum.

2 This methodological model structures the processes trough three channels (Diffusion, Citizenry strategy and Participative Project) of work which generate transparency, pedagogy, and execute projects of improvement achieving community implication and appropriation.

Citizenry, Sharing results and Education	6. Fifteen interviews with agents of interest. 7. Online and physical questionnaires and civic street agents. 8. Perceptive maps civic street agents. mental maps to recognize the image created by residents about the neighbourhood. 9. Green educational workshops at schools by ages.	Social, economic and cultural associative network. Neighbourhood collectives (women, elderly, young ...). Children of the neighbourhood, more than 300 pupils of the elementary school.
Participation, collaboration and co-management	10. Neighbourhood co-design workshop, first proposals for de demo-projects. 11. Co-design Workshop with elderly people. 12. Design criteria gender workshop to define a series of criterions that should integrate the demonstration projects	Associative network. Citizens. Elder Centre. Women's association.

Transformation phase. Accompaniment to the execution of the projects and make collectively visible the projects and initiatives developed: The main objective of the transformation phase was to respond to the proposals identified during the listening phase. In order maintain interest different participatory actions were developed, from painting of the spaces to events with the citizens. This phase integrated the development of participatory actions related to the open call.

DCP	ACTIONS (* actions with continuity in next phase)	
Diffusion, Transparency and Visibility	1. Information brochures on the demo-projects*. 2. Explanatory panels for pilot projects in equipment 3. Web and HR support for projects*. 4. Ephemeral intervention in public space	General citizens. Facilities: Municipal Library Vicent Tortosa Biosca, Elder Center Benicalap, Popular University, Ciutat Artista Faller School and Artista Fallero Museum.
Citizenry, Sharing results and Education	5. Public event in public space to share results of the Open Call and explain the future demo-projects.	Citizens. Social, economic and cultural associative network.
Participation, collaboration and co-management	6. Pilot Projects Validation Workshop. 7. Collaborative Green Initiatives Workshop. 8. Meetings with agents to follow up the pilot projects	Independent professionals. Associative network.

Tracking phase. Evaluation of results and facilitation of co-management with advice and training for citizen initiatives of collaboration associated with solutions based on nature : Once the participation process was completed, implementation of the demonstration projects and open call were monitored. The aim of this was to ensure continuity and ownership. Workshops were facilitated to help citizens understand how NbS works.

DCP	ACTIONS	AGENTS
Diffusion, Transparency and Visibility	1. Information brochures on the pilot projects* 2. Web and RRSS support for projects*	General citizens.
Citizenry, Sharing results and Education	3. Facilitation of workshops to involve children in the management of the PPP. 4. Walks to disseminate and explain the evolution of the pilot projects. 5. Facilitation of environmental workshops linked to the vertical garden. 6. Final Public event in public space to share results.	Citizens. Primary schools. Secondary schools. Professional Education, artista fallero. Espai Verd Associations.
Participation, collaboration and co-management	7. Co-construction of the slats of the green corridor pergola. 8. Accompanying the co-construction of the projects of the most important collaborative green initiatives Civic Centre and Espai Verd	Primary schools. Secondary schools. Professional Education, artista fallero. Espai Verd Associations.

Figure 18 Participation activities, Benicalap

6 Evidence Based Outcomes

The monitoring and evaluation of the demonstration projects focused on the effectiveness of the NbS interventions and the ability to engage local stakeholders, particularly citizens.

6.1 Climate Mitigation and Adaptation (Challenge 1)

6.1.1 CO_2 Sequestration / Storage

The pilot areas all had existing vegetation. This was evaluated, including the annual monitoring of trees (number, species and physical measurements e.g. trunk diameter and height).

In the Sustainable Forest location most of the existing trees (85%) were in a poor condition and it was not possible to retain them. In order to maintain carbon storage, the majority of the carbon was maintained in the small forest area in the form of roots and by converting the trunks into furniture/decoration/games. This is an innovative strategy to maintain carbon stock in green areas when performing management or re-designing activities.

	Co2 sequestration & storage					
	Pre-greening (2019-2020)			Post-greening (2021-2022)		
ACTION	CO2 SEQUESTRATION VEGETATION (TREES), ANNUAL	CO2 STORAGE TREES	CO2 STORAGE SOIL	CO2 SEQUESTRATION VEGETATION (TREES), ANNUAL	CO2 STORAGE TREES	CO2 STORAGE SOIL
	ton CO2/year	ton CO2	ton CO2	ton CO2/year	ton CO2	ton CO2
ACTION 2: SUSTAINABLE FOREST	0.74	26.42	TBC	0.34	35.27	TBC
ACTION 3: GREEN – BLUE CORRIDOR	3.18	69.74	TBC	4.07	74.76	TBC

Table 2 CO2 sequestration & storage

6.1.2 Heat Stress

A number of indicators were used to evaluate heat stress. For the evaluation of Physiologically Equivalent Temperature (PET) and Mean Radiant Temperature (MRT), air temperature, wind, relative humidity and "undisturbed" solar radiation were monitored. To fully evaluate heat stress, information must also take the infrastructure into account e.g., trees and buildings. Software was used to calculate the KPI is known as the "Rayman Model". For the evaluation, the location was divided in four or five sectors and hourly simulations were performed. The final KPIs were obtained as the average. Based on PET values, it was calculated the percentage of time (every month) with heat stress (it has been considered heat stress for PET>29°C). Air temperature, wind, relative humidity was obtained from local monitoring stations. The solar radiation is the Global Horizontal Radiation from weather station 8414A in Valencia Airport. Based on hourly PET values thermal comfort will be assessed according to the following reference table.

Thermal perception PET ranges.

Max.	Min.	Thermal perception	
	>41	**Extreme heat stress**	**HEAT STRESS**
41	**35**	**Strong heat stress**	
35	**29**	**Moderate heat stress**	
29	23	Slight heat stress	
23	18	No thermal stress	
18	13	Slight cold stress	
13	8	Moderate cold stress	
8	4	Strong cold stress	
	<4	Extreme cold stress	

Table 3 Thermal perception PET ranges.

Figure 19, Figure 20, Figure 21 and Figure 22 show PET and MRT (maximum, minimum and average) from February 2019 to October 2020. The values were calculated from average hourly data. The maximum and the minimum are not the absolute maximum and minimum values of the month (due to being extreme and hence not representative). The maximum and minimum value was identified each day and then the monthly average of the daily maximum and minimum values were calculated.

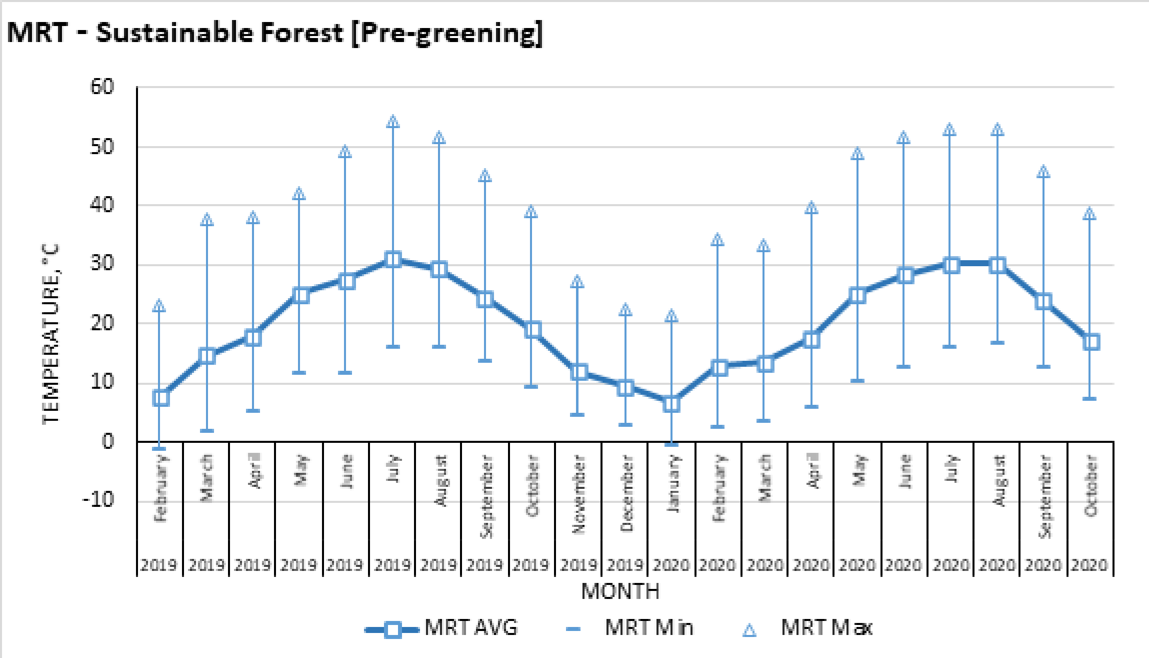


Figure 19 MRT Sustainable Forest Pre Greening

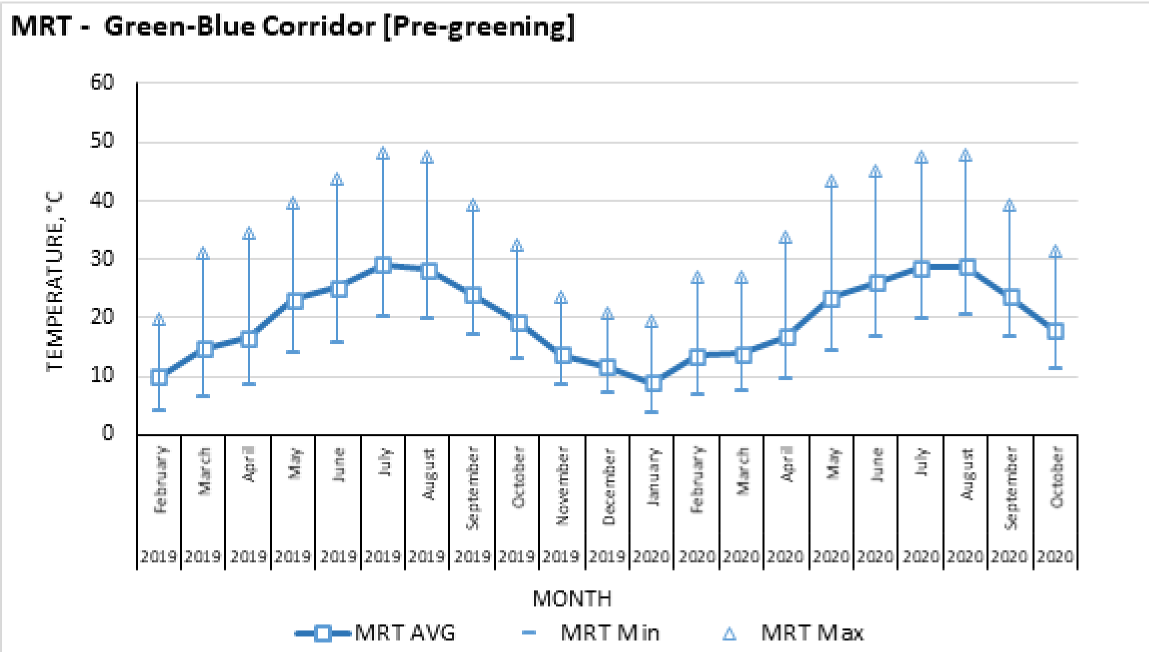


Figure 20 MRT Sustainable Forest Post Greening

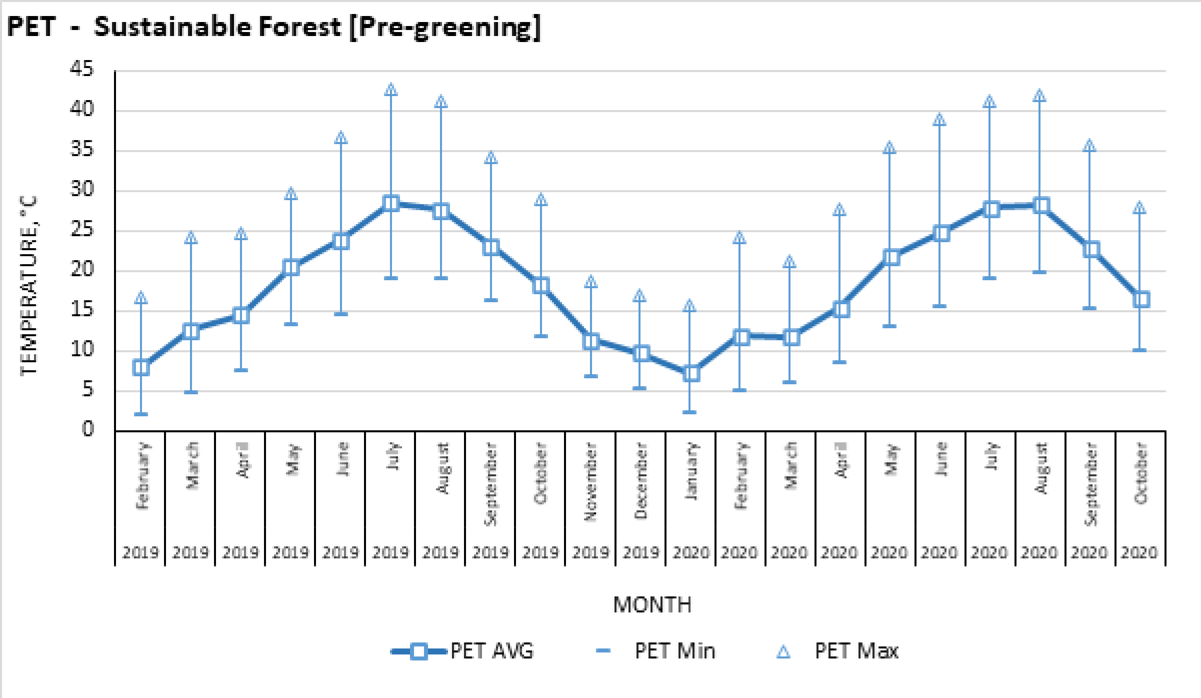


Figure 21 PET Sustainable Forest Post Greening

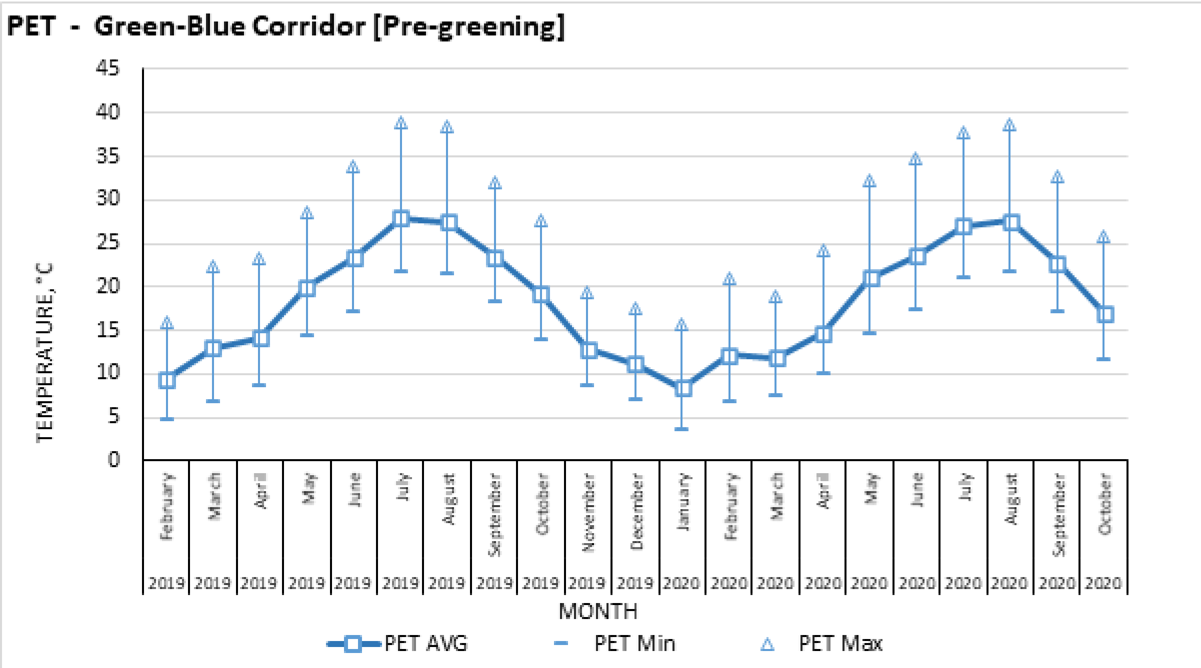


Figure 22 PET Green Blue Corridor Pre Greening

The heat stress hours have been calculated with PET ranges. For the Green Corridor in July and August 30-33% of the time (210 -220 hours in a month) and for the Sustainable Forest 38-42% time in July and August (280 -290 hours in a month). This simulation is before the pilots.

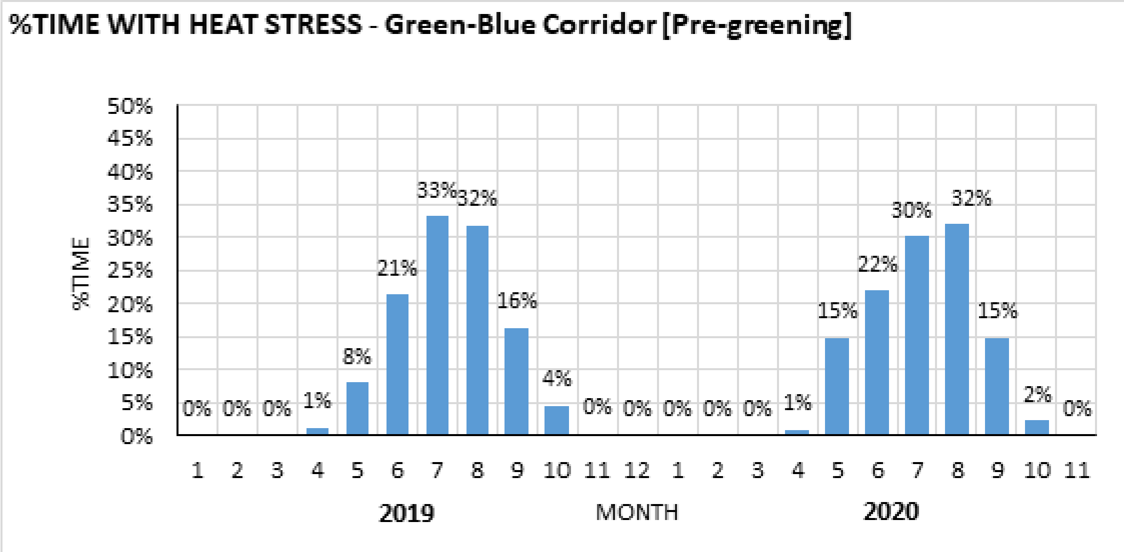


Figure 23 Heat stress – Green-Blue Corridor (pre-greening)

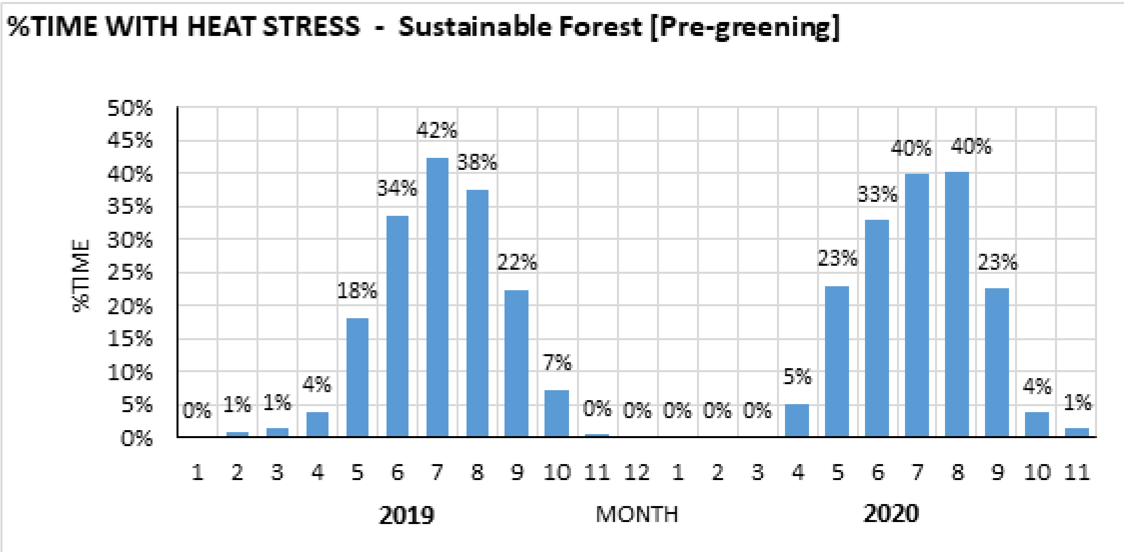


Figure 24 Heat stress – Sustainable Forest (pre-greening)

Prior to the pilot, approximately. 75-80% of the total area had no trees pre-greening. Heat stress presents about 34-42% of the time in summer months. In the Green-Blue Corridor pilot there are tall buildings in the surroundings along with trees, hence heat stress was lower in the pre-greening.

6.1.3 Thermal Walks - Valencia

Dynamic monitoring was used to gather heat stress data. This was collected using a heat stress sensor and a GPS tracker. An identical route was followed at a similar pace and at the same time of the day to create a record of temperature, relative humidity, air quality, wind speed, heat index etc. This was carried out throughout the seven months of the post-green monitoring. GIS was used to create visual the representations of the data.

Predicted Mean Vote (PMV) reflects the influence of the physical and physiological variables. It is derived from the equation of thermal balance from a psycho-physical well-being scale and expresses the mean vote PMV) on the thermal sensations of a sample of individuals in the same environment.

Predicted Percentage of Dissatisfied (PPD) is derived from the PMV index and quantifies in percentage the "dissatisfied" individuals in relation to certain microclimatic conditions. PDD also takes into account:

- Va - air speed
- Tg - globe thermometer temperature
- Ta - ambient temperature
- RH - relative humidity

Heat Index (HI) is calculated from environmental temperature and relative humidity. It estimates the physiological discomfort resulting from high temperatures in the presence of high humidity. The sultry heat condition limits the dispersion of heat from the human body, hindering the thermoregulation process with possible consequences for health e.g., heat stroke.

The route used was selected to be representative of the Benicalap neighbourhood and the pilot projects, including the Benicalap Park, Sustainable forest, Blue Green corridor and Salvador Rubio Street. This took in urban spaces with and without vegetation, and urban fabric. It also went via existing UPV sensors so as to correlate with this data. The pace was constant and at a similar time of the day i.e. midday when the sun is highest. The main indicators were HI and PDD.

Figure 25 Benicalap map with the route (clockwise) and UPV sensor locations.

6.1.3.1 Heat Index Evaluation

Figure 26 and Figure 27 show the HI for April and July. In April, HI values oscillate between 25.0ºC and 27.4ºC and in July the HI map shows 33.8ºC and 43.2ºC. The highest values are in the areas where there is direct exposure to sunlight. April is usually a month with more cloudy days and hence the variation between values is small in contrast temperatures in July.

Figure 26 visualises the contrast along the route with the HI value difference (also shown as a percentage) and illustrates differences between areas with dense-light shadow and direct sun radiation.

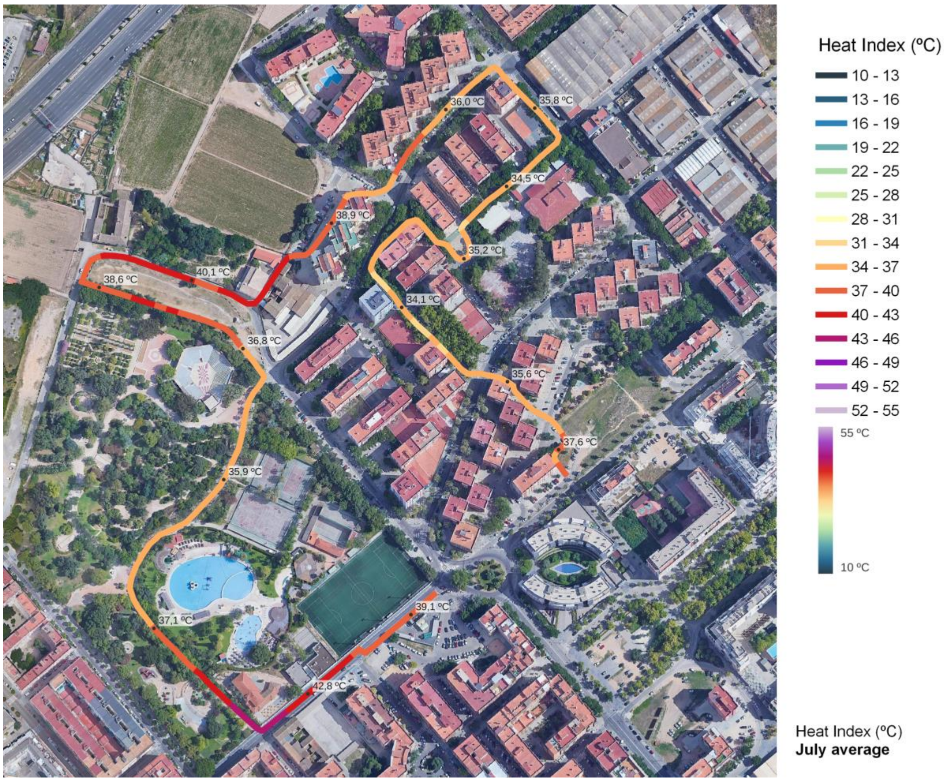


Figure 26 July Average Comparison Heat Index

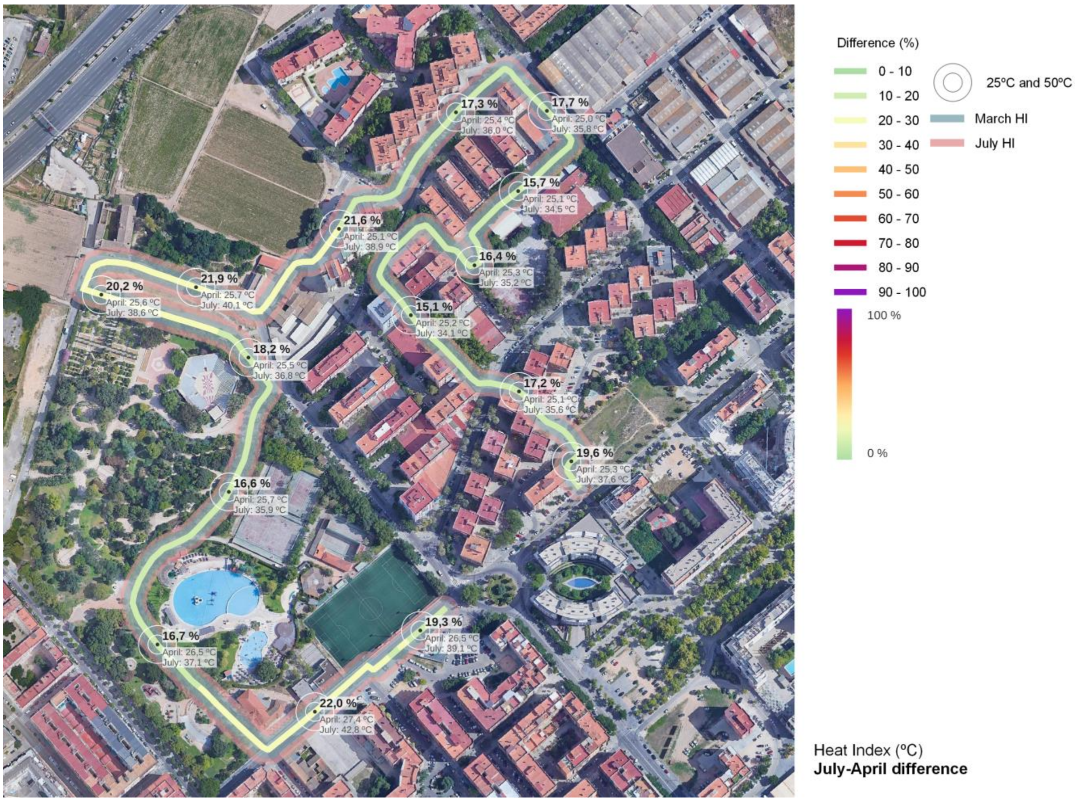


Figure 27 July - April Difference Heat Index

6.1.3.2 Predicted Percentage of Dissatisfied People Evaluation

Figure 28, Figure 29 and Figure 30 are representations of April and July's PPD. In April, PPD values oscillate between 14.2% and 62%. One of the points where it is nearest to comfort (0%) is in the plot of the Sustainable Forest. In July's PPD map, the values vary from 69% to 100% of dissatisfied people. This discomfort value is usual throughout the track due to summer conditions in Valencia. It is lower in areas with fully grown vegetation.

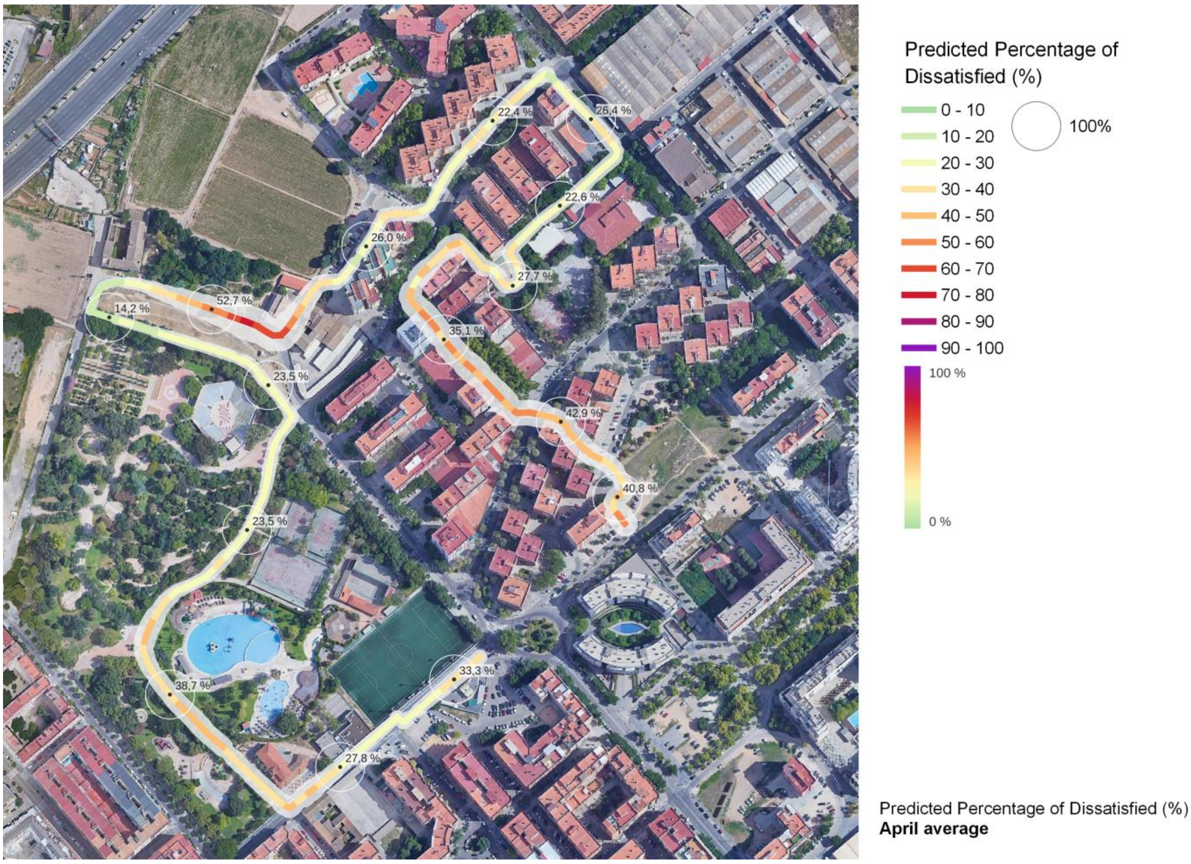


Figure 28 Predicted Percentage of Dissatisfaction - April Average

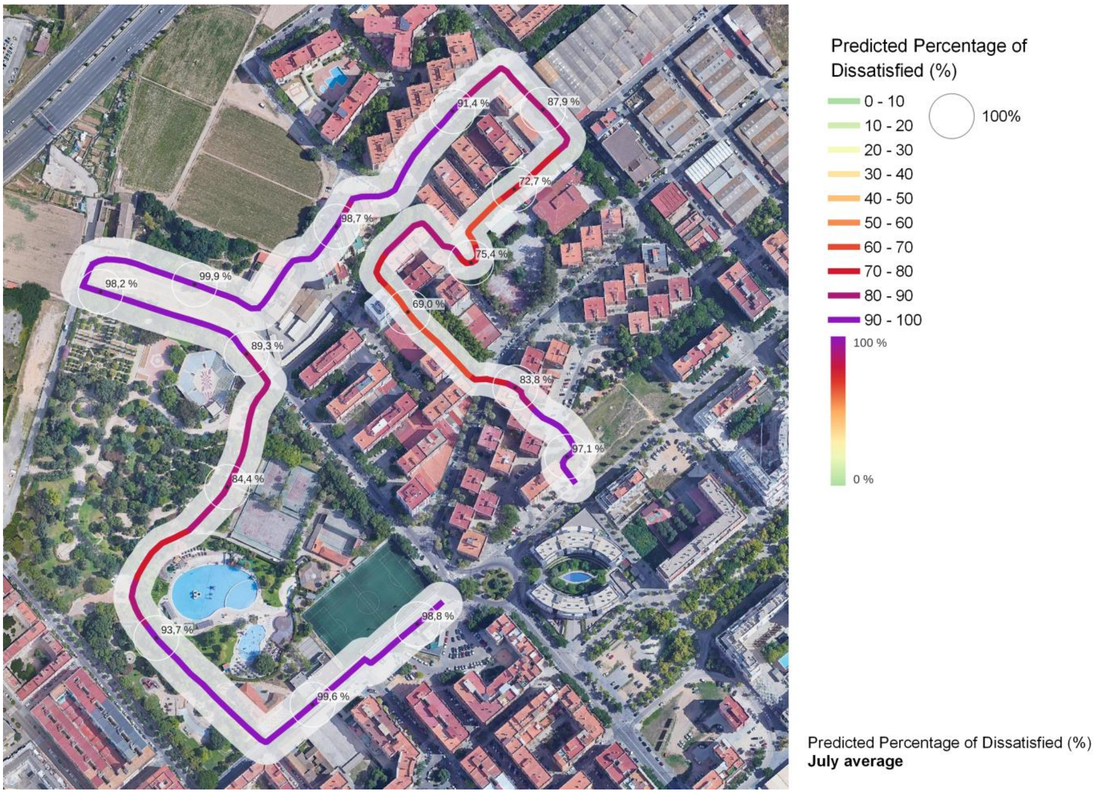


Figure 29 Predicted Percentage of Dissatisfaction - July Average

The April-July comparison shows a dramatic the increase in thermal dissatisfaction. The percentages show the increase in PPD and with visualisation showing the values along the route.

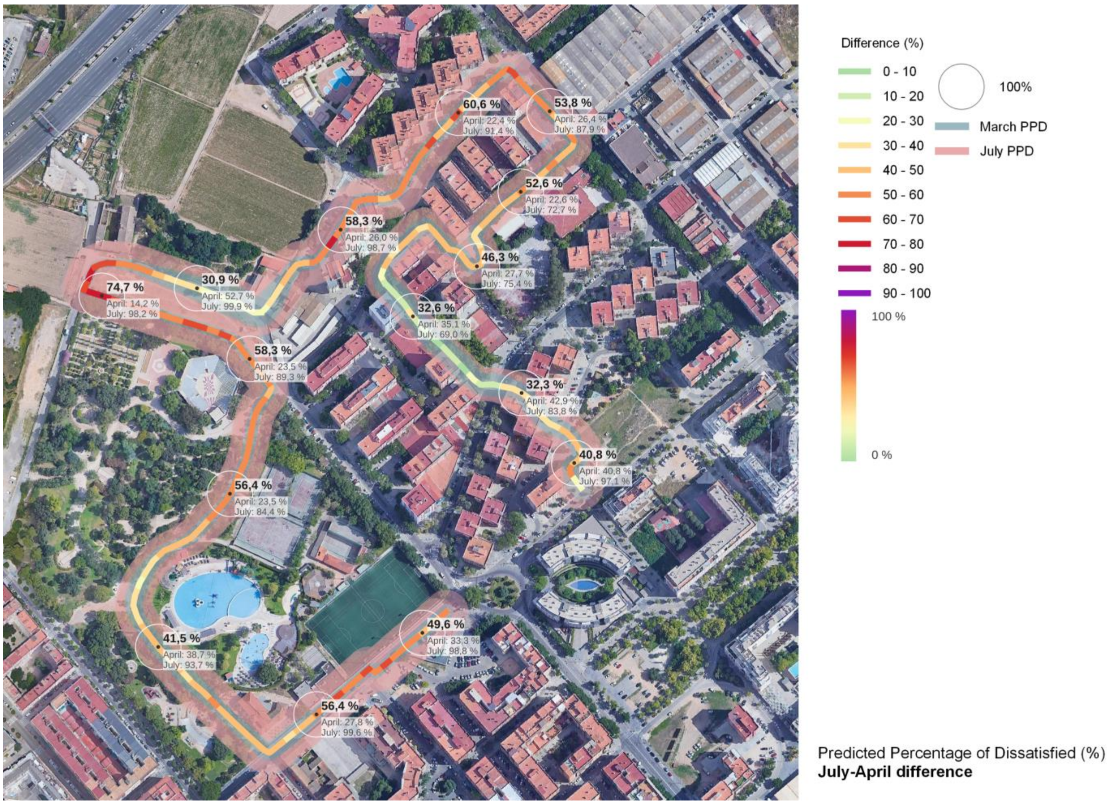


Figure 30 Predicted Percentage of Dissatisfaction - July - April Difference

6.1.4 Energy and Carbon Savings From Reduced Building Energy Consumption

For the Vertical Ecosystem and Green Roof the objective is to evaluate energy and CO^2 savings. The evaluation is based on:

- Building energy modelling and monitoring of air temperature (internal) and wall / roof temperature
- A simulation using ENERGY+ software (before and after NbS installation).
- Information on specification, materials, HVAC system, operation schedules/occupation and temperature setpoint for modelling.
- Indoor temperatures, operating set point and operation schedules.
- Meteorological data measured in Benicalap in 2019/2020.

The results for building and the room where the Vertical Ecosystem is installed are:

Electricity Consumption 2020 (kWh)				
Months	Building Pre-greening		Building with Vertical Ecosystem (Post-greening)	
	Building	Room 13	Building	Room 13
January	2073.4	277.3	2049.4	256.9
February	773.1	111.9	759.0	99.6
March	705.6	96.0	692.5	84.8
April	70.8	6.0	72.6	7.3
May	642.3	71.4	646.8	75.1
June	881.8	97.8	883.7	99.4
July	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0
September	752.5	82.5	753.7	83.6
October	94.6	12.9	91.2	10.0
November	271.4	35.8	265.8	30.7
December	241.3	33.7	236.4	28.9

Table 4 Annual electricity use pre and post greening – Vertical ecosystem

The Vertical Ecosystem was initially simulated as a shadowing element, but the data evaluation showed it was best as an insulation layer. The energy savings in the classroom are ~10% for heating in winter months. In summer, the vertical ecosystem blocks solar radiation and provides lower heat flux through the wall in the morning. However, due to the extra insulation preventing night-time cooling and the shadowing trees, the consumption in cooling is similar. The net electricity savings are 49 kWh per year, an equivalent of 7.35 kg CO2/year.

The results for the Green Roof building:

Electric Consumption 2021 (kWh)		
Months	Building	Building with GreenRoof
January	814.11	1108.36
February	500.55	358.36
March	122.98	419.27
April	104.00	81.34
May	174.03	421.51
June	1022.99	1213.88
July	2780.23	2410.46
August	0.00	0.00
September	1625.43	1391.25
October	2.95	TBC
November	112.27	TBC
December	484.43	TBC

Table 5 Annual electricity use pre and post greening – Green Roof

Some of the data not wholly reliable due to COVID-19. This explains the reason the spring 2020 data is so low i.e. the population was quarantined. In summer, the service reopened but in autumn and winter closed again. In 2021 it again reopened, but the energy consumption is variable and much higher than normal because the windows were left open to ventilate. Energy consumption did not increase even so the situation was so different. From this it can be concluded that the Green Roof successfully regulated the building temperature.

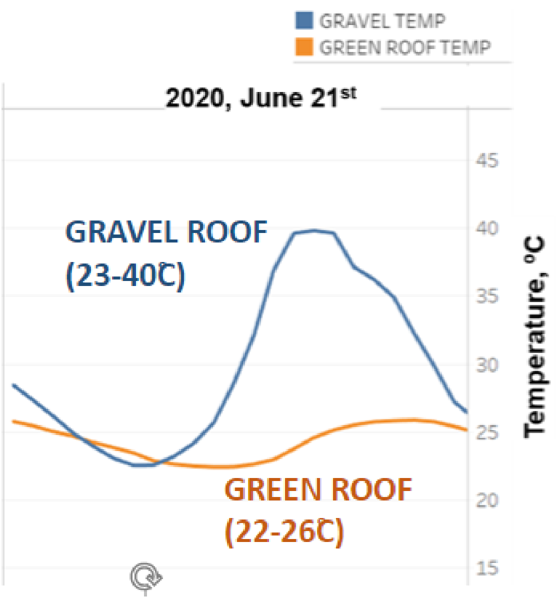


Figure 31 Temperature Green vs. Gravel Roof

6.2 Green Space Management - Biodiversity (Challenge 4)

See D2.3 Monitoring and Evaluation of Environmental Objectives.

The biodiversity indices were calculated for the Demonstration Area before and after the interventions. To express the measure of biodiversity, the Shannon (Shannon-Wiener) Diversity Index (H') is used. The Shannon Diveristy Index takes into account the number of species present within a given area or habitat - i.e. the richness, and their relative abundance with that area or habitat - i.e. the eveness. This equation was used:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where: *H'* - Shannon diversity index; *S* - number of species
p_i - Proportion of individuals of i-th species within the dataset

6.2.1 Green Space Management: Diversity of Trees, Shrubs and Vegetation

Measurements were taken in July 2021 for Sustainable Forest and Green-Blue Corridor pilots. Vegetation data from the greenhouses and vegetation data assessed in the field were used to calculate the green space management KPI for the post-greening stage.

The estimation of the values of post-greening vegetation diversity shows a significant rise. In the case of the Green-Blue Corridor, the Shannon Index increases from 1.28 to 2.74, which means from an initial poor biodiversity level (0.5 < H' < 1.5) it moves to a good level of biodiversity (2 < H' < 3) and the evenness raises in 40%. For the forest, which in pre-greening stage contains just one species (*Ulmus pumila*), in the post greening stage i reaches a good level of biodiversity (2 < H' < 3) and a more equal species distribution (closer to value 1).

NbS	Diversity Index	**Trees, shrubs, bushes and creeper diversity**		**Strata diversity**	
		Pre-greening	Post greening	Pre-greening	Post greening
Green-blue corridor	Shannon-Wiener Index	1.28	2.74	0.86	1.10
	Maximum diversity	3.66	3.66	1.61	1.61
	Evenness	0.35	0.75	0.55	0.68
	Number of species	15	39		
	Difference between pre-greening and post greening	**113.91 %**		**28.24 %**	
Sustainable small forest	Shannon-Wiener Index	0*	2.59	0.57	1.32
	Maximum diversity	0	3.78	1.61	1.61
	Evenness	-	0.68	0.35	0.82
	Number of species	1	44		
	Difference between pre-greening and post greening	**159.46%**		**132.43%**	

*There was only one species (*Ulmus pumila*) and ruderal vegetation

Table 6 Diversity Index values in corridor & sustainable small forest before & after NbS

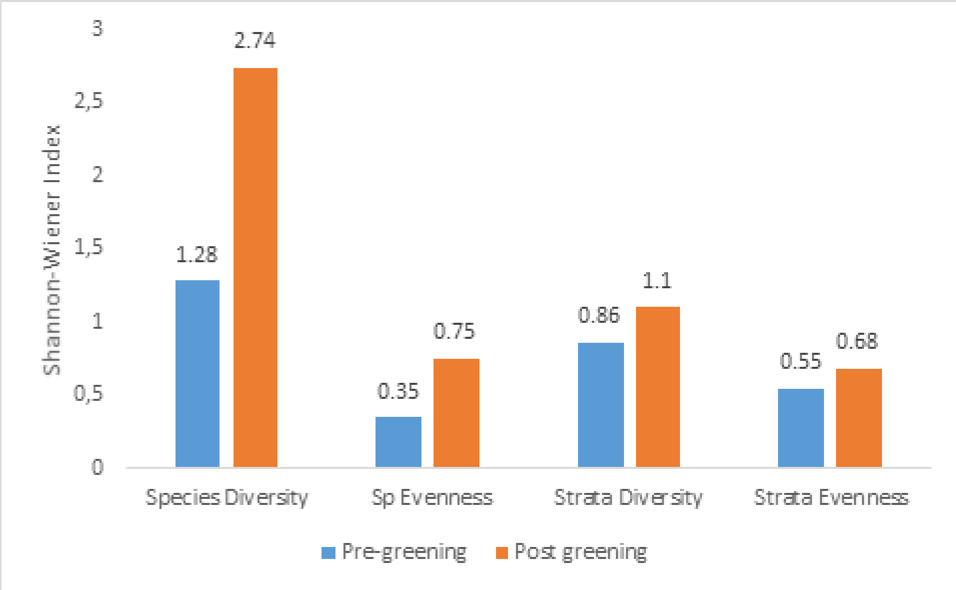


Figure 32 Diversity KPIs in Green-blue corridor

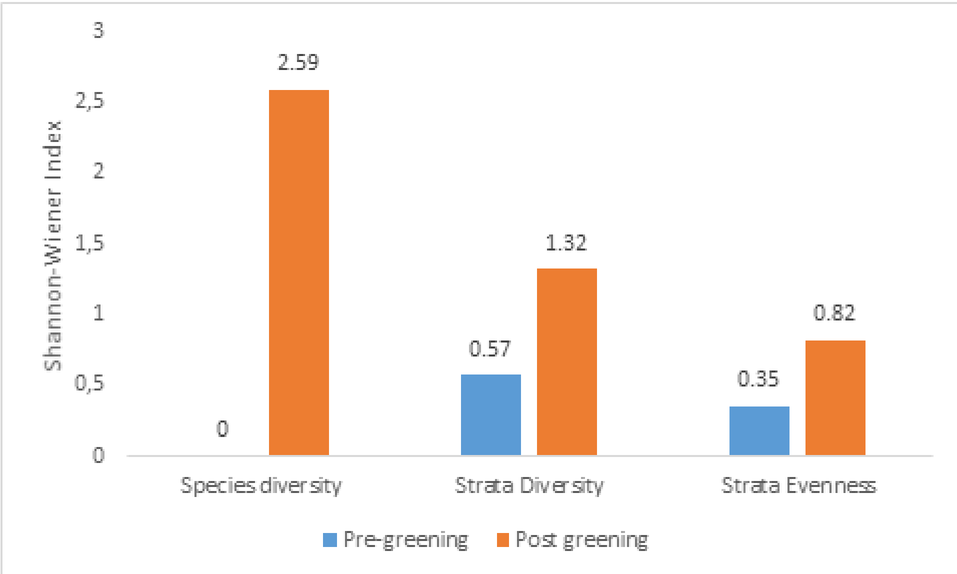


Figure 33 Diversity KPIs in Sustainable small forest

When comparing the diversity of vegetation strata for pre and post greening stages, the increase in Shannon Index for the Green Corridor (from 0.86 to 1.10) and evenness (from 0.55 to 0.68) is small. For the Sustainable Forest, the changes are more obvious with all five types of habitats presenting a very good distribution (evenness is 0.82), species richness is 44 and the biodiversity value doubles (from 0.57 to 1.32).

Sustainable forest	Bare ground and turf grass	Rough grassland and herbs	Shrubs, bushes and creeper species	Tree cover	Built environment
Pre-greening	74.6 %	0%	0%	25.4%	0%
Post greening	0%	31.60%	35.04%	19.28%	14.08%

Table 7 Diversity KPIs in Sustainable Forest

Green-blue corridor	Bare ground and turf grass	Rough grassland and herbs	Shrubs, bushes and creeper species	Tree cover	Built environment
Pre-greening	3.18%	0.04%	1.09%	40.90%	54.79%
Post greening	0%	3.61%	12.72%	34.80%	48.87%

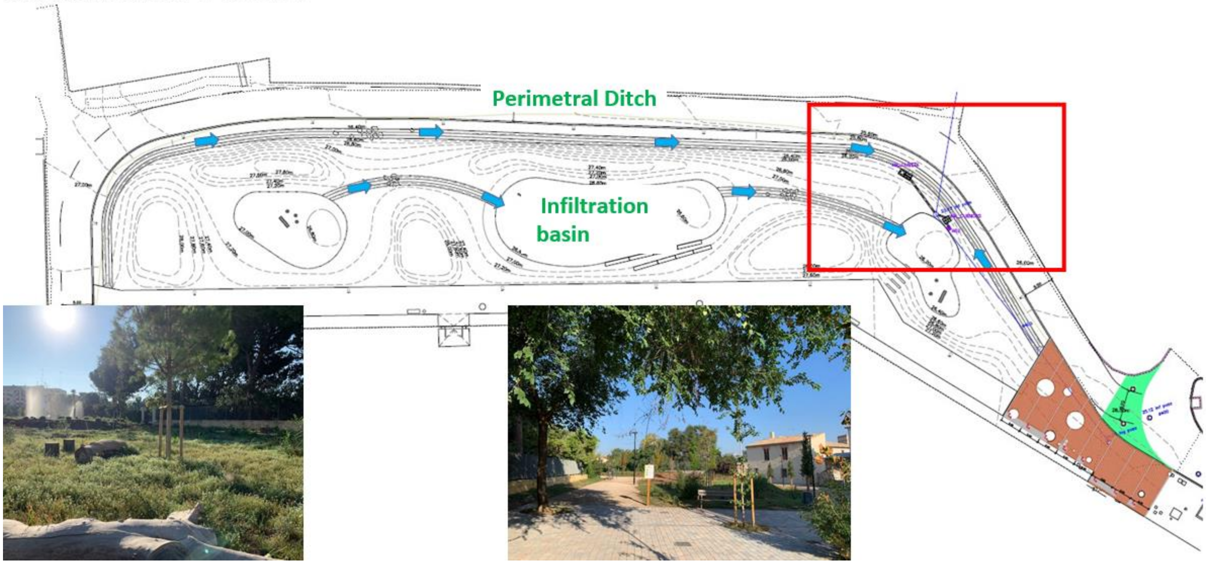
Table 8 Diversity KPIs in Green-blue corridor

The diversity results in the Sustainable Forest are explained by the fact that in the pre-greening stage only two out of five types of habitats were identified (trees, 25.4% and bare ground/turf grass, 74.6%). After the implementation of NbS, the rough grassland and herbs and shrubs, bushes and creeper plants increased 67%. In the Green Corridor, the percentage of built environment decreased 6% due to the use of the permeable pavement. The rough grassland and herbs, and shrubs, bushes and creeper species increased between 4% and 12% after the implementation of the biocells and new vegetation species. These results are the first-year post greening. When trees reach their maturity, crown coverage is expected to be > 70%.

6.3 Water Resilience (Challenge 2)

The Sustainable Forest and the Green Blue Corridor (Calle del Foc / Foc Street) used NbS and SuDs to manage local stormwater runoff. They were designed to manage urban runoff by encouraging infiltration and attenuating water originating from hard surfaces, including adjacent highways and paved areas. Figure 34 to Figure 39 show the location of the SuDS.

Sustainable Forest



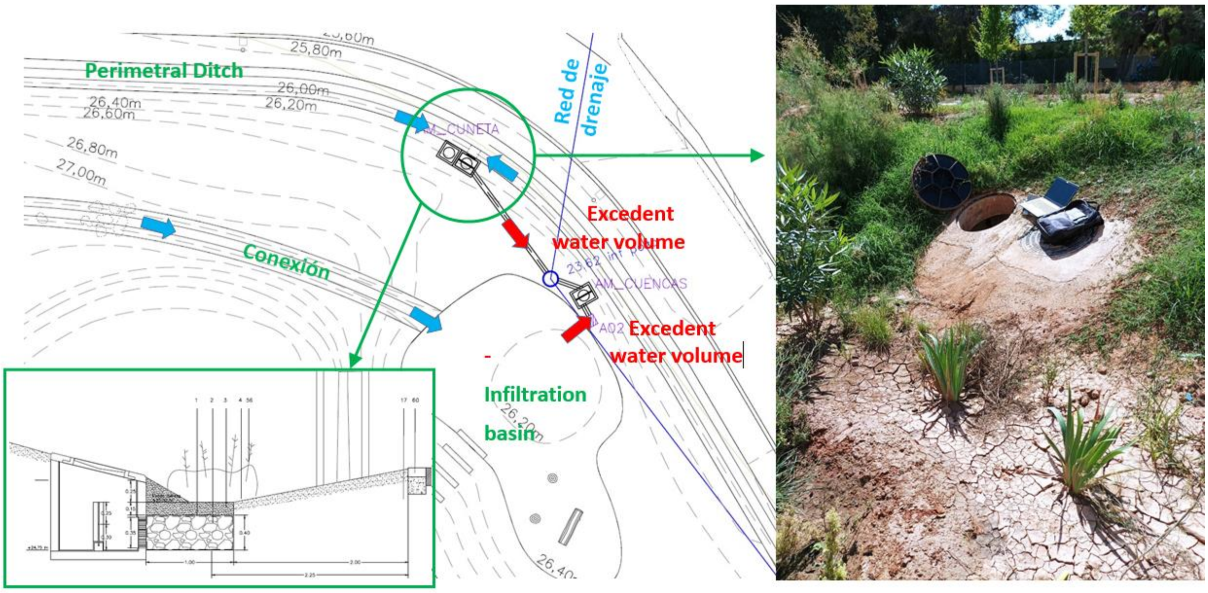


Figure 34 Sustainable Forest Monitoring I

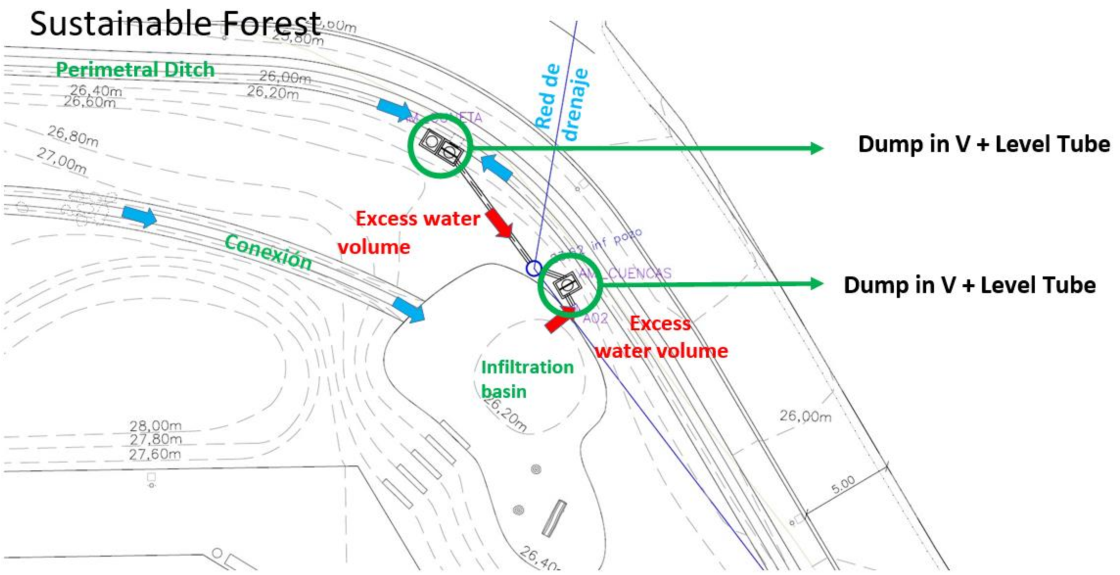


Figure 35 Sustainable Forest Monitoring II

Figure 36 Blue Green Corridor - Foc Street Monitoring

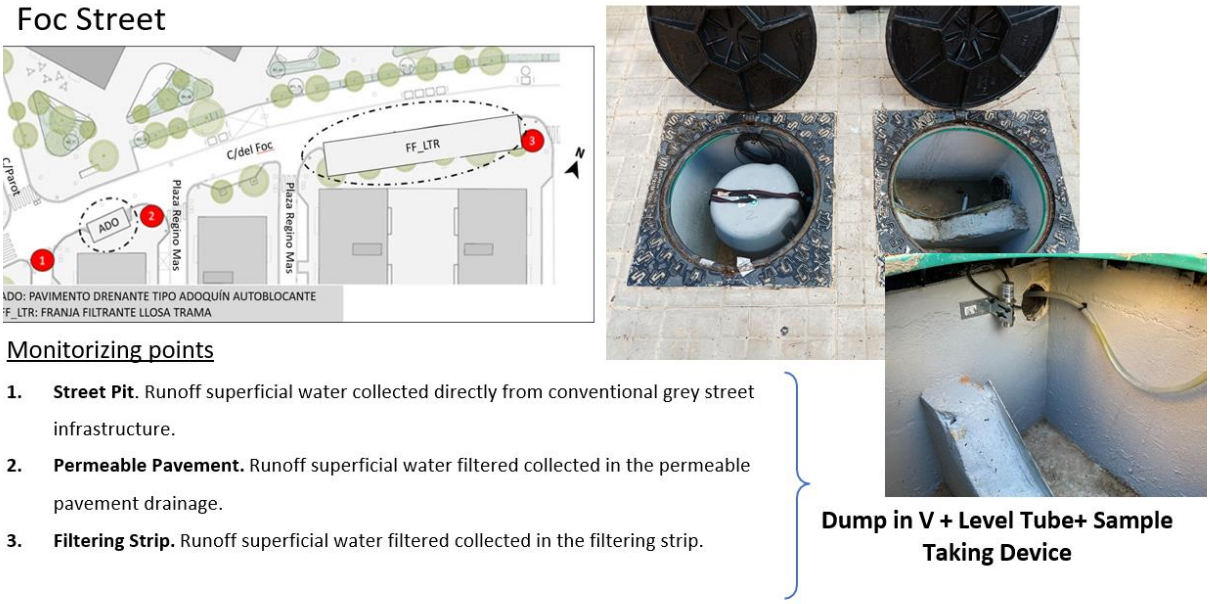


Figure 37 Blue Green Corridor – Calle del Foc - Foc Street Monitoring II

The SuDS in Foc Street presented problems due to the particle size of the joint filler was being as initially agreed i.e. it was too small. In November 2021 remedial works were required

Figure 38 Blue Green Corridor - Foc Street SUDS Remedial Works

There were also issues with large amounts of sediment in and around the street and plant material from the trees being deposited on the surface of the filter strip. This formed an impermeable crust that clogged the joints of the permeable pavement and had to be addressed via remedial works to the adjoining garden by the maintenance services in November 2021.

Figure 39 Blue Green Corridor - Foc Street SUDS showing sediment deposits

6.3.1 Water Resilence Outcomes

This section shows the results of the water quantity for the most representative events collected from July 2021 to May 2022. The results are presented as hydrographs, i.e. a series of graphs representing the evolution of the flows generated by each rainfall event as a function of time at each of the points sampled.

Key terms:

- **i (mm/h):** rainfall intensity with a five-minute time discretisation.
- **Excess volume (litres):** Volume of water that arrives at each collection chamber and is discharged to the collector through the V-spillways installed in them. This is the volume of water leaving each SuDS pilot.
- **Q/A (mm/h):** Excess flow with respect to the runoff area with a five-minute time discretisation.
- **Total runoff (litres):** Volume of water generated over each of the drainage surfaces.
- **Volumetric efficiency (%):** Ratio between the volume of precipitated water and the volume of water retained by the SuDS pilot.
- **Infiltration rate (cm/s):** The rate at which water penetrates the porous medium through its surface. The infiltration velocity test is carried out using the LCS permeameter and is performed every 1.5 - 2 months to check the filtering capacity of the surfaces of the SuDS structures.

Precipitation

Events monitored	Precipitation Volume (mm)
26/07/2021	10,3
01/09/2021	45,1
20/09/2021	**5,4**
23/09/2021	2,3
19/11/2021	**54,4**
25/01/2022	**9,8**
25/02/2022	5,5
04/03/2022	**30**
07/03/2022	**33,3**
21/03/2022	**76,1**
20/04/2022	**37,4**

Table 9 Precipitation Events (mm)

The key events in bold are shown in Table 10 Precipitation Events Table 10 and are examined in detail in the following graphs. Rainfall intensity is shown in yellow.

Event Date	Rainfall in mm	Volumetric Efficiency %		
		Street Pit	Permeable Pavement	Filtering Strip
20/09/2021	5.4	-	100	100
19/11/2021	54.4	-	79	70
25/01/2021	9.8	-	100	100
04/03/2022	30		97	100
06/03/2022	33.3	-	97	99
22/03/2022	76.1	-	clogged	80
20/04/2022	37.4	-	--	66

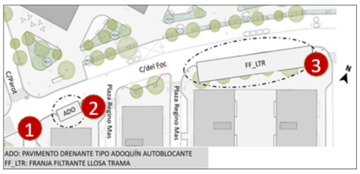
Table 10 Precipitation Events % Efficiency

The key to the locations is:

1: Flow rate **street pit** exit
2: Flow rate **permeable pavement** exit
3: Flow rate **filter strip** exit

Precipitation = 5.4 mm **Hydrograph. Event: 20 of September of 2021**

Event 20.09.21	Total Runoff (litres)	Excess Volume (litres)	Volumetric Efficency (%)
Street Pit	2044	2017	-
Permeable Pavement	1559	0	100
Filtering Strip	3386	0	100



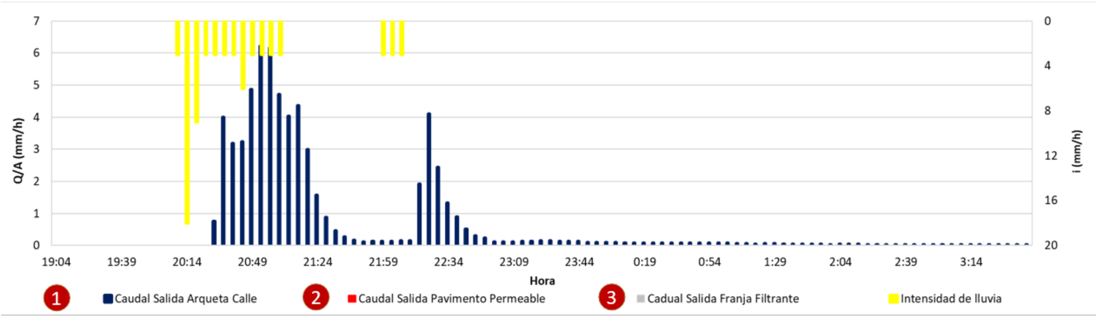


Figure 40 Rainfall intensity 20 September 2021

Precipitation = 54.4 mm **Hydrograph. Event: 19 of November of 2021**

Event 19.11.21	Total Runoff (litres)	Excess Volume (litres)	Volumetric Efficency (%)
Street Pit	20681	13859	-
Permeable Pavement	15783	3282	79
Filtering Strip	34288	10305	70

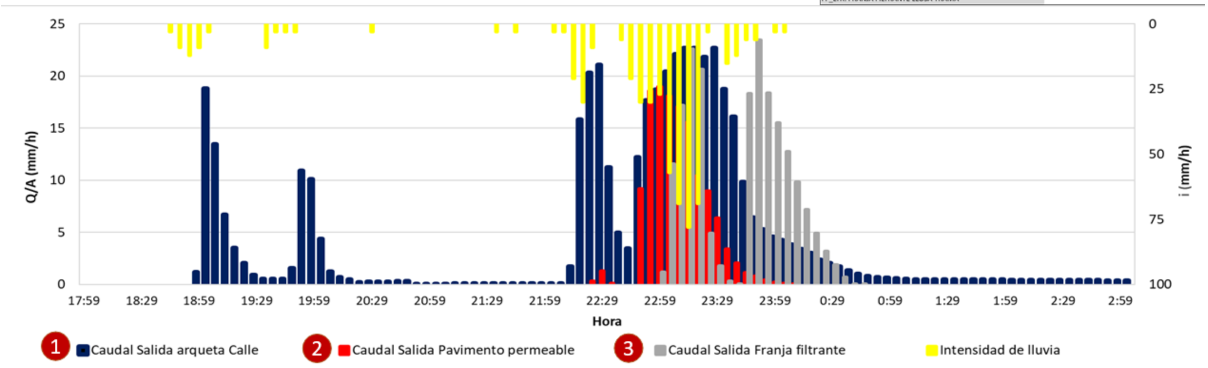
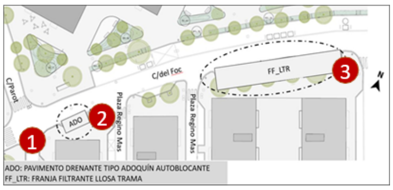


Figure 41 Rainfall intensity 19 November 2021

Precipitation = 9.8 mm **Hydrograph. Event: 25 of January of 2021**

Event 25.01.22	Total Runoff (litres)	Excess Volume (litres)	Volumetric Efficency (%)
Street Pit	3733	3699	-
Permeable Pavement	2849	0	100
Filtering Strip	6190	0	100



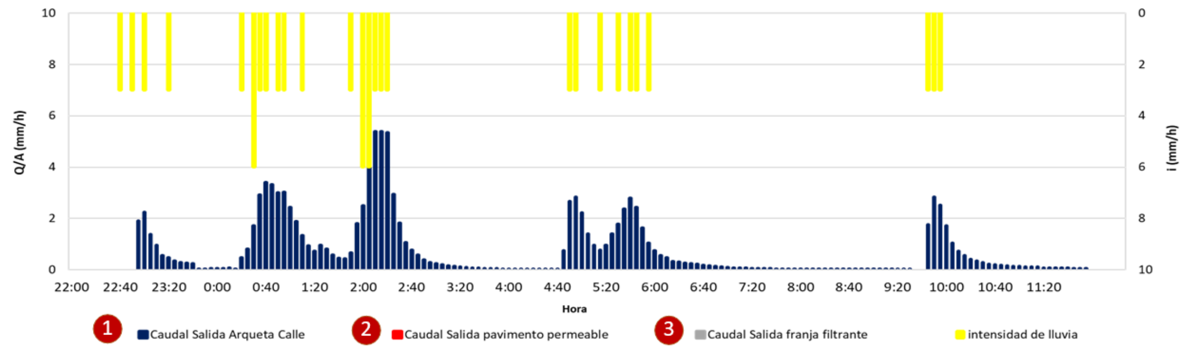
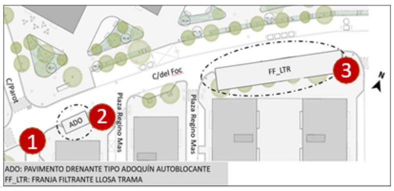


Figure 42 Rainfall intensity 25 January 2022

Precipitation = 30 mm **Hydrograph. Event: 04 of March of 2021**

Event 04.03.22	Total Runoff (litres)	Excess Volume (litres)	Volumetric Efficency (%)
Street Pit	11400	11031	-
Permeable Pavement	8693	234	97
Filtering Strip	18884	0	100



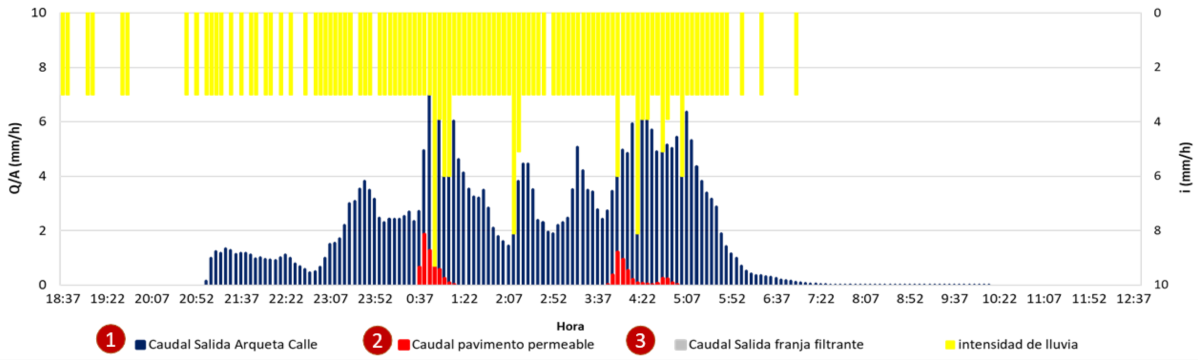
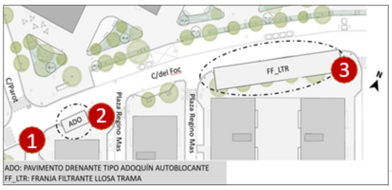


Figure 43 Rainfall intensity 4 March 2021

Precipitation = 33,3 mm **Hydrograph. Event: 06 of March of 2021**

Event 06.03.22	Total Runoff (litres)	Excess Volume (litres)	Volumetric Efficency (%)
Street Pit	11400	11031	-
Permeable Pavement	9657	234	97
Filtering Strip	20979	153	99



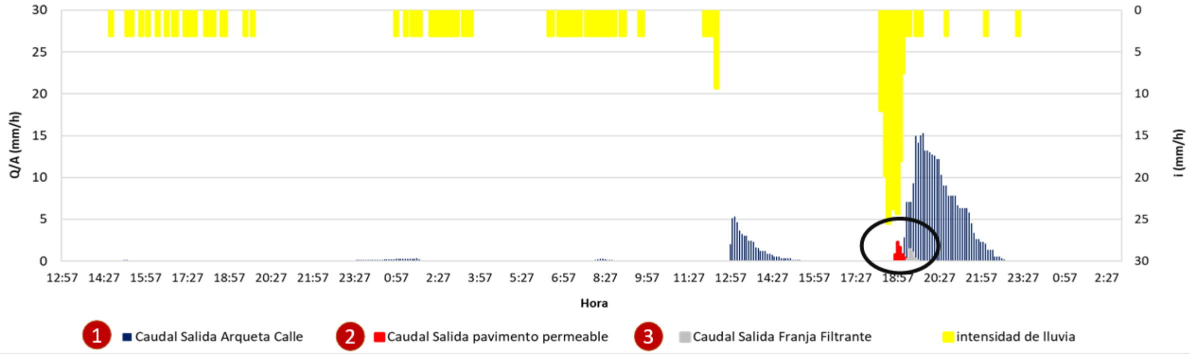


Figure 44 Rainfall intensity 6 March 2021

Precipitation = 76,1 mm **Hydrograph. Event: 22 of March of 2021**

Event 22.03.22	Total Runoff (litres)	Excess Volume (litres)	Volumetric Efficency (%)
Street Pit	27396	27103	-
Permeable Pavement	22069	-* Clogged	-
Filtering Strip	47943	9540	80

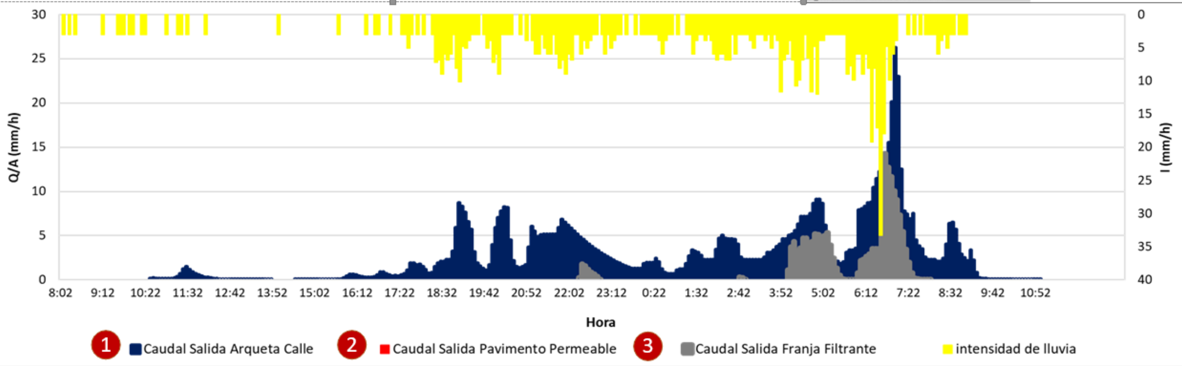


Figure 45 Rainfall intensity 22 March 2021

Precipitation = 37,4 mm **Hydrograph. Event: 20 of April of 2021**

Event 20.04.22	Total Runoff (litres)	Excess Volume (litres)	Volumetric Efficency (%)
Street Pit	14212	14193	-
Permeable Pavement	10832	-* Clogged	-
Filtering Strip	23531	7966	66

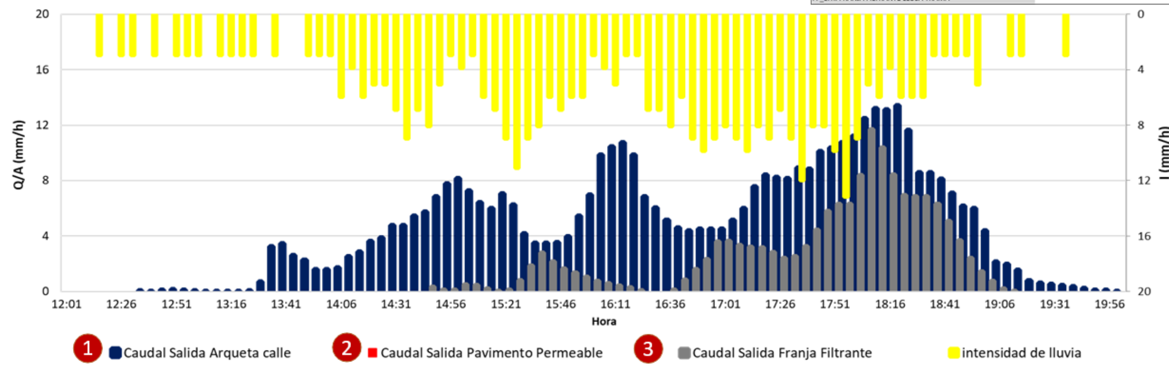


Figure 46 Rainfall intensity 20 April 2021

Test day	Filtering Strip		Permeable Pavement	
14/09/2021	0		0	
09/11/2021	**1,00***		**1,00***	
23/12/2021	0,88	-12 %	0,25	-75 %
18/02/2022	0,68	-20 %	0,15	-10 %
12/04/2022	0,51	-17 %	0	

Figure 47 Infiltration rate in relative terms (Vinfil/Vinfil_max) and percentage loss from the time the SuDS were regenerated to the last infiltration test performed.*

Figure 48 SuDS pavement

Five months after the reconstruction of the permeable pavement it was clogged on the surface due to sedimentation. It was verified that if the material between the joints was removed, there was still filtration capacity.

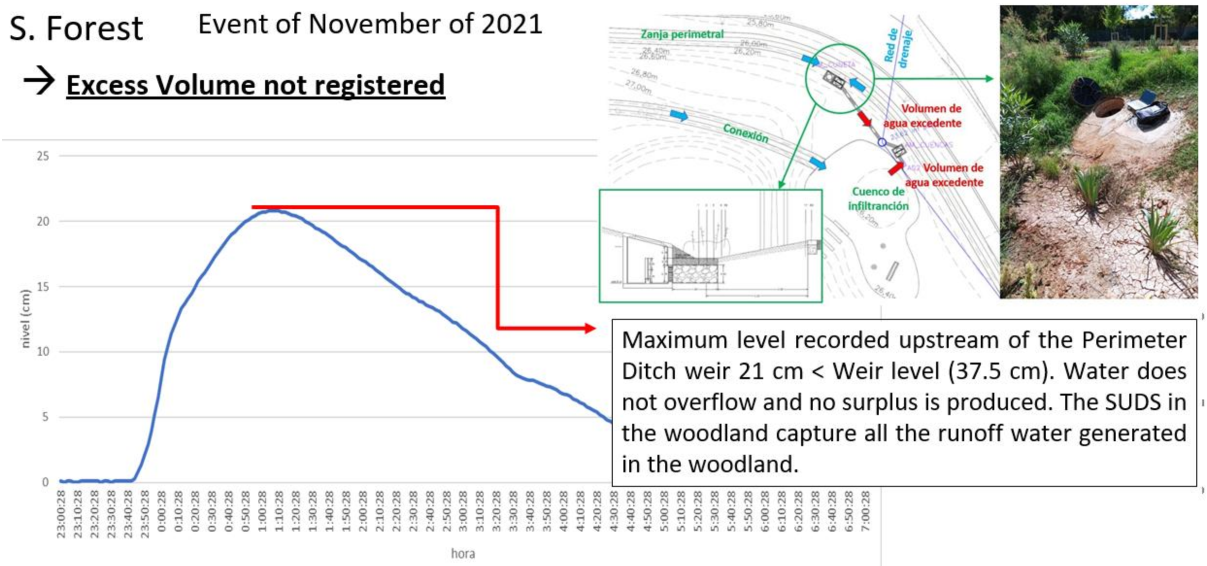


Figure 49 Sustainable Forest - Excess volume not registered Nov 21

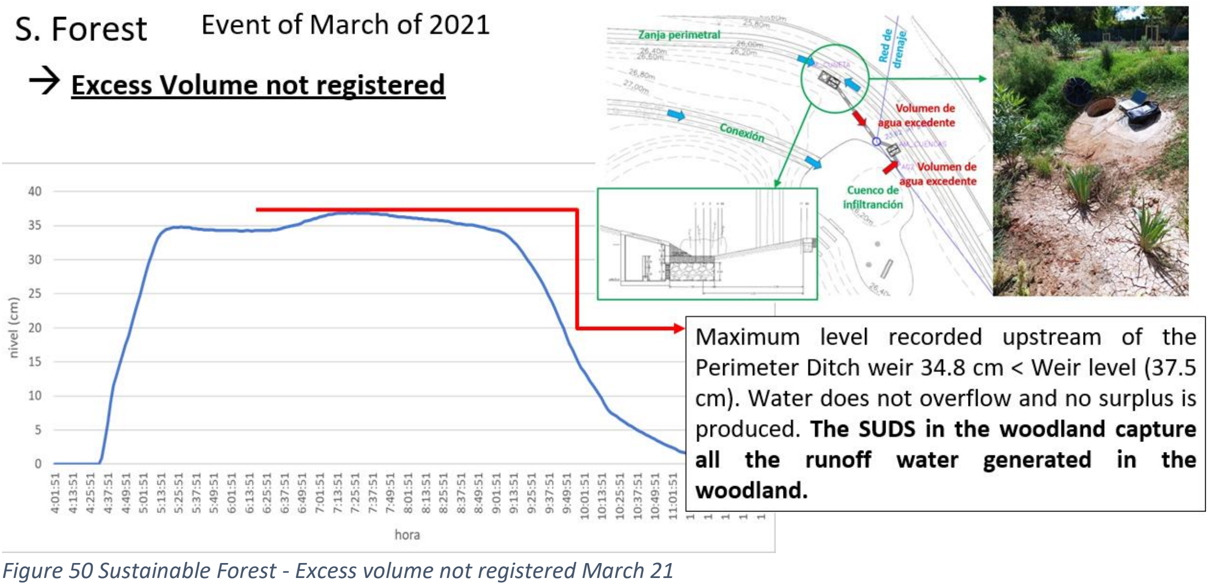


Figure 50 Sustainable Forest - Excess volume not registered March 21

6.3.2 Water Resilience Conclusions

The outcomes are as follows:

- Through conventional flows are generated 10 - 20 minutes after the onset of rainfall (Point 1. Street Gutters), in the SuDS (Point 2 Permeable Pavement and 3. Filter Strip), they are delayed by up to 4 - 5 hours.
- In addition to delaying the inflow of water into the collectors, they reduce the amount of water reaching the collectors by between 66 - 100 % (volumetric efficiency).
- The Filter Strip can withstand a 20 mm rainfall without generating flow.
- The biggest issue has been the large amount of sediment that clogging the permeable pavement.

- Despite a 49% reduction in the infiltration rate in the Filter Strip it continued to function correctly.
- The SuDS at the Sustainable Forest retained all the runoff water generated in the park. This is 100% improvement in comparison to pre- construction.

6.4 Water Quality (Challenge 3)

This section gives the water quality results of some of the most representative rainfall events from July 2021 to May 2022. Table 11 lists the pollutants measured.

Physicochemical Parameters	Specific Pollutants
COD - Chemical Oxygen Demand	HT Total Hydrocarbons
BOD - Biological Oxygen Demand	PAH - Polycyclic Aromatic Hydrocarbons
TSS - Total Suspended Solids	Heavy metals
TP - Total Phosphorus	

Table 11 Pollutants present and measured after key precipitation events

Key terms:

- **Total mass removed**: amount of mass captured in the SuDS. It is estimated as the difference between the product of the inlet and outlet TSS concentrations (mg/l) and the inlet and surplus water volumes (litres) generated during each rainfall event. For the estimation of the total mass removed from the system, the concentrations of solids are used since most of the pollutants are transported attached to the surface of the pollutants.
- **ARU**: Urban Wastewater. Tables of typical concentrations of typical medium-weak wastewater are shown for comparison with the concentrations recorded in the STREET RACK.
- **EDAR Outlet**: Concentrations at the outlet of a EDAR according to Directive 91/271 to compare with the concentrations recorded at the outlet of the PERMEABLE PAVEMENT and the FILTERING STREET.
- **RD 817/2015 ANNEX IV Environmental** quality standards for priority substances and other pollutants, as well as in DIRECTIVE (EU) 2020/2184 ANNEX I Part B on the quality of water intended for human consumption, to compare concentrations of Total Hydrocarbons, PAHs and Heavy Metals.

Water samples were collected at each event (2 litres):

- Time intervals: 3 (10 min); 3 (30 min) July – March
- Time intervals: 3 (15 min); 3 (60 min) March – May Parameters analysed

Event	Street Pit	Permeable Pavement	Filtering Split
26/07/2021	X	Not Collected	Not Collected
01/09/2021	X	X	X
20/09/2021	X	Not Collected	Not Collected
23/09/2021	X	Not Collected	Not Collected
19/11/2021	**X**	**X**	**X**
25/01/2022	X	Not Collected	Not Collected

Event	Street Pit	Permeable Pavement	Filtering Split
25/02/2022	X	Not Collected	Not Collected
04/03/2022	**X**	**X**	Not Collected
07/03/2022	**X**	Not Collected	Not Collected
21/03/2022	**X**	Not Collected	**X**
20/04/2022	**X**	Not Collected	**X**

Table 12 Events collected:

Permeable Pavement **Filtering Split**

Table 13 Street Pit samples collected: darker colour in the first samples, indicated a higher concentration of solids, decreasing as the event is prolonged.

6.4.1 TSS (Total Suspended Solids)

Parameter	Street Pit P1	Permeable Pavement P2	Filtering Split P3
DQO (mg/L)	238 ± 135; (410 - 97)	124 ± 46; (210 - 85)	116 ± 13; (132 - 100)
DBO_{20} (mg/L)	67 ± 70; (208 - 25)	24 ± 11; (39 - 11)	33 ± 11; (47 - 22)
SST (mg/L)	201 ± 282; (772 - 52)	214 ± 219; (276 - 133)	158 ± 102; (303 - 64)
NT (mg/L)	2,3 ± 0,8; (3,4 – 1,4)	1,5 ± 0,5; (2,2 - 0,6)	5,6 ± 1,5; (8,6 - 4,2)
FT (mg/L)	1,0 ± 1,2; (3,3 - 0,2)	0,7 ± 0,4; (1,3 - 0,4)	0,7 ± 0,4; (1,1 - 0,5)

Table 14 Mean values ± standard deviation; (maximum and minimum) Event: 19/11/2021

Total mass eliminated:

- Permeable Pavement: 2,5 kg
- Filtering Pit: 5,3 kg

Parameter	ARU	EDAR Exit. Directive 91/271
DQO (mg/L)	500 - 250	125
DBO$_5$ (mg/L)	220 - 110	25
SST (mg/L)	720 - 350	35
NT (mg/L)	40 - 20	10
FT (mg/L)	8 - 4	2

The concentrations at the outlet of the Permeable Pavement and the Filter Strip are lower (except for TSS) than those set by Directive 91/271 at the outlet of a EDAR. However, important reductions are achieved.

Parameter	Street Pit P1	Permeable Pavement P2	Filtering Split P3
DQO (mg/L)	181 ± 172; (442 - 10)	18,5 ± 6,8; (28 - 7)	Not collected
DBO$_{20}$ (mg/L)	114 ± 87; (250 - 31)	14 ± 8; (27 - 3)	Not collected
SST (mg/L)	102 ± 49; (164 - 20)	87 ± 52; (181 - 48)	Not collected
NT (mg/L)	4,8 ± 2,6; (8,6 – 2,0)	1,9 ± 0,5; (2,8 - 1,2)	Not collected
FT (mg/L)	1,2 ± 0,5; (1,7 - 0,4)	0,4 ± 0,1; (0,6 - 0,3)	Not collected

Table 15 Mean values ± standard deviation; (maximum and minimum) Event: 04/03/2022

Total mass eliminated:

- Permeable Pavement: 0.9 kg
- Filtering Pit: 0 kg

Parameter	ARU	EDAR Exit. Directive 91/271
DQO (mg/L)	500 - 250	125
DBO$_5$ (mg/L)	220 - 110	25
SST (mg/L)	720 - 350	35
NT (mg/L)	40 - 20	10
FT (mg/L)	8 - 4	2

Table 16 The concentrations at the outlet of the Permeable Pavement and Filter Strip vs. EDAR

The concentrations at the outlet of the Permeable Pavement and Filter Strip are lower (except for TSS) than those set by Directive 91/271 and reductions are achieved.

Parameter	Street Pit P1	Permeable Pavement P2	Filtering Split P3
DQO (mg/L)	240 ± 118; (366 - 81)	80*	77 ± 11; (87 - 63)
DBO_{20} (mg/L)	179 ± 89; (258 - 52)	56*	30 ± 9; (36 – 14)
SST (mg/L)	118 ± 15; (139 - 103)	86*	93 ± 26; (121 - 55)
NT (mg/L)	$9{,}8 \pm 5{,}4$; (15,2 – 3,4)	1,2*	$3{,}6 \pm 1{,}1$; (5,4 – 2,2)
FT (mg/L)	$1{,}4 \pm 0{,}4$; (1,8 - 0,8)	0,4*	$0{,}6 \pm 0{,}2$; (0,7 - 0,3)

Table 17 Mean values ± standard deviation; (maximum and minimum) Event: 07/03/2022

Total mass eliminated:

- Permeable Pavement: 1,1 kg
- Filtering Pit: 2,5 kg

Parameter	ARU	EDAR Exit. Directivve 91/271
DQO (mg/L)	500 - 250	125
DBO_5 (mg/L)	220 - 110	25
SST (mg/L)	720 - 350	35
NT (mg/L)	40 - 20	10
FT (mg/L)	8 - 4	2

Table 18 The concentrations at the outlet of the Permeable Pavement and Filter Strip vs. EDAR

The concentrations at the outlet of the Permeable Pavement and Filter Strip are lower (except for TSS) than those set by Directive 91/271 at the outlet of a EDAR and reductions are achieved.

Parameter	Street Pit P1	Permeable Pavement P2	Filtering Split P3
DQO (mg/L)	104 ± 19; (131 - 75)	Not collected	32 ± 13; (44 - 7)
DBO_{20} (mg/L)	76 ± 33; (113 - 53)	Not collected	$27{,}5 \pm 0{,}3$; (27,1 – 27,7)
SST (mg/L)	121 ± 13; (164 - 20)	Not collected	34 ± 7; (45 - 23)
NT (mg/L)	$4{,}7 \pm 0{,}7$; (5,6 – 3,8)	Not collected	$1{,}6 \pm 0{,}5$; (2 - 0,8)
FT (mg/L)	$1 \pm 0{,}5$; (1,9 - 0,7)	Not collected	$0{,}3 \pm 0{,}2$; (0,6 - 0,2)

Table 19 Mean values ± standard deviation; (maximum and minimum) Event: 21/03/2022

Total mass eliminated:

- Permeable Pavement: 0kg
- Filtering Pit: 5,5 kg

Parameter	ARU	EDAR Exit. Directive 91/271
DQO (mg/L)	500 - 250	125
DBO_5 (mg/L)	220 - 110	25
SST (mg/L)	720 - 350	35
NT (mg/L)	40 - 20	10
FT (mg/L)	8 - 4	2

Table 20 The concentrations at the outlet of the Permeable Pavement and Filter Strip vs. EDAR

The concentrations at the outlet of the Permeable Pavement and the Filter Strip are lower than those set by Directive 91/271 at the outlet of EDAR.

Valores medios ± desviación típica; (máximos y minimos)   Evento: 20/04/2022

Parameter	Street Pit P1	Permeable Pavement P2	Filtering Strip P3
DQO (mg/L)	391 ± 93; (507 - 289)	Not collected	13 ± 6; (25 - 10)
DBO_{20} (mg/L)	196 ± 31; (235 – 160)	Not collected	< 10
SST (mg/L)	265 ± 82; (382 - 204)	Not collected	16 ± 0,2; (19 - 13)
NT (mg/L)	5,9 ± 1,4; (7,6 – 4,5)	Not collected	1,5 ± 0,4; (2 - 1)
FT (mg/L)	1,2 ± 0,2; (1,4 - 0,9)	Not collected	0,3 ± 0,03; (0,4 - 0,3)

Table 21 Mean values ± standard deviation; (maximum and minimum) Event: 20/04/2022

Total mass eliminated:

- Permeable Pavement: 0 kg
- Filtering Pit: 6.1 kg

Parameter	ARU	EDAR Exit. Directive 91/271
DQO (mg/L)	500 - 250	125
DBO_5 (mg/L)	220 - 110	25
SST (mg/L)	720 - 350	35
NT (mg/L)	40 - 20	10-15
FT (mg/L)	8 - 4	1- 2

Table 22 The concentrations at the outlet of the Permeable Pavement and Filter Strip vs. EDAR

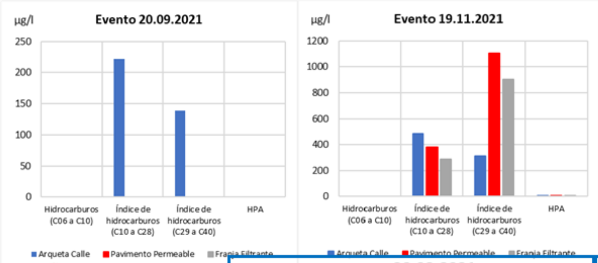
The concentrations at the outlet of the Permeable Pavement and the Filter Strip are lower than those set by Directive 91/271 and reductions are achieved.

6.4.2 Hydrocarbons and PAH

Hydrocarbons (PHA[3]) were detected following key precipitation events, with gasoline, diesel and oil. These are would not normally be found in run off and hence have an implication for wastewater.

Total hydrocarbons and PAH

The use of SUDS reduces the concentration of HPA (µg/l) and decreases the amount of hydrocarbon mass reaching the collectors.



The following PAHs have been detected:

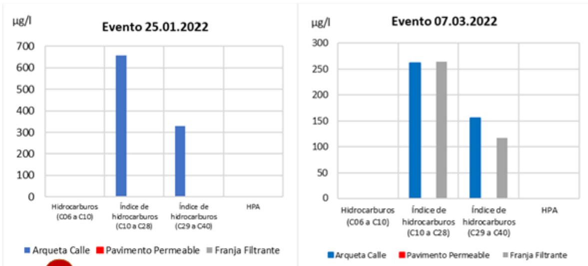
- Phenanthrene, Naphthalene, Chrysene
- Pyrene

Element	Limits RD 817/2015	DIRECTIVE (UE) 2020/2184	20.09.2021			19.11.2021		
			Street Pit	Permeable Pavement	Filtering Split	Street Pit	Permeable Pavement	Filtering Split
Fracción C06 – C10(µg/l) (gasolina)	-	-	<0,1	-	-	<0,1	<0,1	<0,1
Fracción C010 – C28 (µg/l) (diésel)	-	-	222,33	-	-	482,33	380,33	287
Fracción C29 – C40 (µg/l) (Aceite de motor)	-	-	139,03	-	-	312,42	1104	901,33
HPA	0,10*	0,10*	0,16	-	-	0,14	0,11	0,02

Figure 51 Suds and hydrocarbon reduction

Total Hydrocarbons and HPA

The use of SUDS reduces the concentration of HPA (µg/l) and decreases the amount of hydrocarbon mass reaching the collectors.



The following PAHs have been detected:

- Chrysene, Phenanthrene, Fluoranthene and Pyrene.

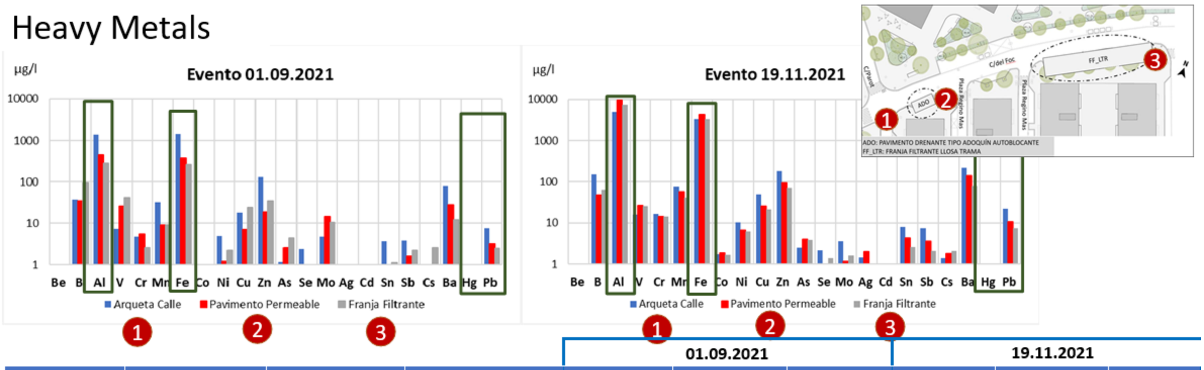
Element	Limits RD 817/2015	DIRECTIVE (UE) 2020/2184	25.01.2022			07.03.2022		
			Street Pit	Permeable Pavement	Filtering Split	Street Pit	Permeable Pavement	Filtering Split
Fracción C06 – C10(µg/l) (gasolina)	-	-	<0,1	-	-	<0,1	0,0	0,00
Fracción C010 – C28 (µg/l) (diésel)	-	-	657	-	-	263	0,0	265
Fracción C29 – C40 (µg/l) (Aceite de motor)	-	-	328	-	-	156,5	0,0	117
HPA	0,10*	0,10*	0,30	-	-	0,00	0,0	0,0

Figure 52 Suds and hydrocarbon reduction

6.4.3 Heavy Metals

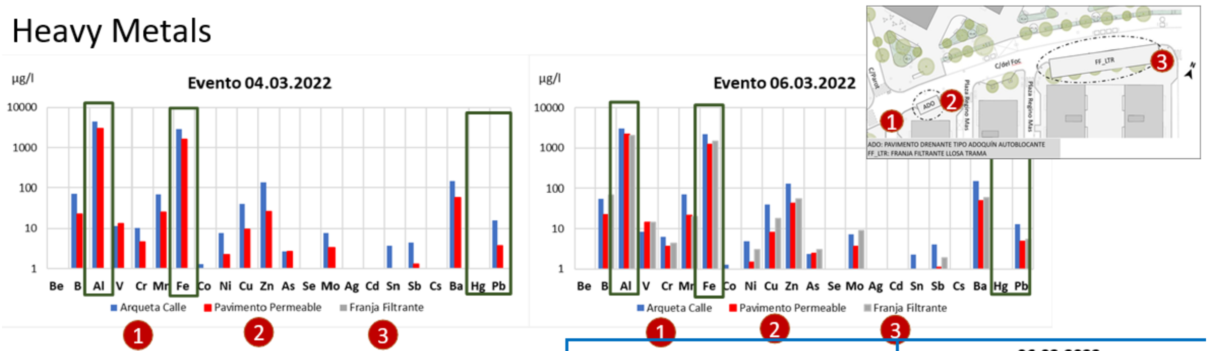
Heavy metals were detected following key precipitation events, particularly aluminum, iron, mercury and lead. These are would not normally be found in run off and hence have an implication for wastewater.

[3] Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They result from burning coal, oil, gas, wood, garbage, and tobacco.



Element	Limits OMS	Limits RD 817/2015	DIRECTIVE (UE) 2020/2184	01.09.2021			19.11.2021		
				Street Pit	Permeable Pavement	Filtering Slplit	Street Pit	Permeable Pavement	Filtering Slplit
Aluminio (µg/l)	200	-	200	1390	447	283	4927	9511	7398
Hierro (µg/l)	-	-	200	1417	373	260	3336	4297	3340
Mercurio (µg/l)	6	0,07	1	0,09	0,03	0,19	0,45	0,49	0,05
Plomo (µg/l)	10	14	10	7,65	3,09	2,47	21,93	10,85	7,48

Figure 53 Heavy metals



Element	Limits OMS	Limits RD 817/2015	DIRECTIVE (UE) 2020/2184	04.03.2022			06.03.2022		
				Street Pit	Permeable Pavement	Filtering Slplit	Street Pit	Permeable Pavement	Filtering Slplit
Aluminio (µg/l)	200	-	200	4455,5	3027,7	-	2986,3	2195,0	2052,0
Hierro (µg/l)	-	-	200	2869,3	1587,3		2210,8	1236,0	1483,0
Mercurio (µg/l)	6	0,07	1	0,8	0,1	-	0,00	0,00	0,07
Plomo (µg/l)	10	14	10	16,1	3,7	-	13,13	4,94	5,44

Figure 54 Heavy metals

6.4.4 Water Quality Conclusions

The impact of SuDs on water quality is as follows:

- The use of SuDS reduces the concentrations of COD, BOD, total nitrogen and total phosphorus to values below those set by Directive 91/271 at the outlet of a WWTP. In some events, Suspended Solids concentrations are also below this limit (35 mg/l).
- The use of SuDS reduces the concentrations of PAH (µg/l) and reduces the amount of Total Hydrocarbons and PAH reaching the sewers.
- The use of SuDS reduces the concentrations of heavy metals (µg/l) and decreases the amount reaching the collectors. Aluminium and iron have been detected at all monitoring points with high concentrations.

- In the event of 19.11.2021 there is no clear decrease in some pollutants, suspended solids, for example, reach higher concentrations in the Permeable Pavement. This is mainly due to the washing of the material (gravel) in what was the first rainfall event after the reconstruction of the SuDS.

6.5 Participatory Planning and Governance (Challenge 9)

Post greening observations using the MOHAWK[4] methodology were carried out in November 2021. A significant difference can be seen in the Sustainable Forest with the percentage of people who became aware of their natural environment over five times than in pre-greening stage. The vertical garden and the new pergola in the square contribute to this. The social interactions in all pilot projects increased ~15%, with local people taking advantage of the green areas, pergola and seating.

The percentage of people walking or passing through the area increased for both areas. On the streets there were more sedentary people than previously mainly due to the opportunity provided by seating and restaurant terraces. During COVID-19 the open space saw more use. Following the NbS implementation more sedentary females were observed in the Corridor square, using the new benches under the pergola and more children were running and riding their bikes or skateboards in the forest and square. This goes someway to explaining the high increase of KPI values (between 10% and 17%).

KPI (%)	Forest	Corridor Street	Corridor Square	Forest	Corridor Street	Corridor Square
percentage of people taking notice of their environment	14.1	0.6	1.1	35.01	3.26	4.21
people who are connecting	29.93	34.77	28.89	44.66	52.48	40.59
people who are sedentary	17.67	16.25	8.15	16.02	31.15	12.54
people undertaking forms of physical activity (walking)	71.81	81.10	79.56	80.71	81.02	86.26
people undertaking forms of physical activity (vigorous)	10.51	2.65	12.28	6.97	3.63	2.54
children who are sedentary	7.35	4.83	4.76	13.08	5.26	12.25
teens who are sedentary	8.82	4.29	21.90	18.69	8.89	11.07
adults who are sedentary	77.94	71.38	37.62	54.21	69.54	62.45
older adults who are sedentary	5.88	19.50	35.71	14.02	16.31	14.23
children who are walking	3.73	6.55	15.10	9.76	6.61	8.28
teens who are walking	18.69	9.54	12.58	15.65	10.30	9.49
adults who are walking	53.89	72.48	54.75	55.99	63.20	58.76
older adults who are walking	23.67	11.43	17.58	18.60	19.89	23.47
children who are vigorous	0.00	19.59	6.12	17.02	29.89	22.64

[4] Method for Observing pHysical Activity and Wellbeing (MOHAWk): validation of an observation tool to assess physical activity and other wellbeing behaviours in urban spaces | Research Explorer | The University of Manchester

teens who are vigorous	12.76	4.12	17.69	8.51	18.39	15.09
adults who are vigorous	80.85	67.01	21.43	68.09	45.98	50.94
older adults who are vigorous	6.38	9.28	54.76	6.38	5.75	11.32
females who are sedentary	39.24	51.88	20.83	33.33	39.47	39.31
males who are sedentary	60.75	48.12	79.17	66.67	60.53	60.69
females who are walking	34.26	47.22	48.82	45.59	46.08	47.28
males who are walking	65.73	52.78	51.18	54.41	53.92	52.72
females who are vigorous	19.14	29.23	9.41	19.15	38.64	24.53
males who are vigorous	80.85	70.77	90.59	80.85	61.36	75.47

Table 23 Values of Physical Activity Level KPIs for one week (post-greening

The participatory and governance methods and workshops also has wider conclusions.

- The pilot projects with stronger teamwork with citizens gave better levels of engagement over time. Even if involvement was not huge it generated more impact than large one-off effort involvements. The work directly led to the creation of meeting and coexistence spaces to promote neighbourhood support networks and strengthen the associative fabric of the neighbourhood.
- Citizen participation in the design process created innovative propositions that fitted both within the project and the neighbourhood needs and improve the naturalisation and pedestrianisation processes.

6.6 Economic Objectives (Challenge 10)

A Cost Benefit Analysis (CBA) was carried out by Trinomics[5]. CBA is used in policy analysis to assess the overall benefits of a policy option compared to its costs and can also be used to assess the relative merits of alternative options available to decision-makers. CBA is a preferred policy tool in decision-making because it provides a ‘decision rule’ on whether an option can be justified for implementation, using the benefit-cost ratio (BCR). If a BCR is greater than 1, then the investment produces higher quantified benefits than the costs incurred to deliver them, and the investment is justified in economic terms. CBA can be used to compare benefits and costs that occur at different times over a long time period (say, 25 years), by discounting future costs and benefits to present day terms, allowing for options to be compared on a ‘like for like’ basis.

In public policy, the range of benefits and costs extend beyond purely financial items (expenditures and revenues) to consider a broader range of non-financial or non-market benefits, typically reflecting environmental or social outcomes, in what is referred to as ‘social cost-benefit analysis’. This approach is applied here, using a discounted cash flow analysis over 25 years, discounting future costs and benefits using a real discount rate of 3% (as recommended by the EC’s Better Regulation Toolbox[6]).

[5] Project partner - Trinomics B.V. is a consultancy firm offering bespoke policy advice related to energy, environment and climate change issues.
[6] https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox_en

6.6.1 Capital Costs

The capital cost of the Valencia interventions is shown in Table 24:

Capital Cost Per Site	
SITE 1 - Vertical Ecosystem	66.163,00
SITE 2 - Green Roof	35.333,00
SITE 3 - Green Corridor	49.252,32
SITE 4 - SUDs	37.442,84
SITE 5 - Square	88.732,68
SITE 6 - Small Forest	187.048,92
TOTAL	**463.972,76**

Table 24 Capital Cost per Site - Valencia

The costs include design, installation and construction costs, plus other materials and labour not included elsewhere.

6.6.2 Operating Costs

Operating costs were collected from each stakeholder. The main costs are labour costs, gardening maintenance materials, cleaning services, lighting services and monitoring costs of Universitat Politècnica de València (UPV) and the costs to run the interventions (monitoring and water analytics are the half of the costs). Future replication interventions could have lower operating costs if monitoring was to be excluded.

	OPERATING COSTS PER SITE /YEAR				
	2019	**2020**	**2021**	**2022**	**TOTAL**
SITE 1 - Vertical Ecosystem	2.500,00	18.220,00	15.970,00	6.025,00	**42.715,00**
SITE 2 - Green Roof		4.074,00	4.074,00	-	**8.148,00**
SITE 3 - Green Corridor		-	9.557,24	17.238,20	**26.795,44**
SITE 4 - SUDs		-	8.290,15	13.436,92	**21.727,07**
SITE 5 - Square		-	1.220,01	3.660,03	**4.880,05**
SITE 6 - Small Forest		-	19.823,85	37.917,21	**57.741,06**
TOTAL	**2.500,00**	**22.294,00**	**58.935,26**	**78.277,36**	**162.006,62**

Table 25 Operating Costs Per Site /Year

6.6.3 Property Betterment

Two datasets were collected and compared for real estate market analysis, differentiating the three areas - Benicalap, Ciutat Fallera, and Nou Benicalap. The collection was March 2021 and at the end of April 2022. Data was gathered in two ways: the dataset was collected manually from the contents of the website throughout a week giving 632 real estate assets and the second was automated with 716 entries.

For the second data set, a script was used to extract the information from the source pages of the idealista. The website is constantly being updated, i.e., users post or take out their offers (the period of time an offer remains on the web varies, usually for two months but change if the property is taken off in a week or even days). There are periods when frequency varies both daily, weekly and at other times a request can remain for months.

6.6.4 Results

The data shows a difference in the number of offers for apartments for sale in the Benicalap area between March 2021 (78) and April 2022 (299) with an average price of 16%. In Nou Benicalap new build apartments for sale have come on stream. This changed the changed the market with increases of more than double and causes accuracy issues.

In the Benicalap area prices fluctuate approximately by up to 16.7%. Apartments for rent cost less by €1.2 per square metre. Prices for the Ciutat Fallera area have stayed at the same level. The only exception is apartments for sale which were more expensive in April 2022 (29.74%). This could be because the cheapest ones are sold, and people are attracted to what might be seen as an up-and-coming area. However, this remains a presumption as the website does not provide insight into the sold or withdrawn offers.

A decrease is taking place for some properties in the Nou Benicalap area. Apartments for rent are less expensive by 24%, but double for sale. The results are not conclusive and further analysis is needed to investigate the price changes.

The data used was from Idealista (idealista, 2022[7]). The prices shown are from 2016 and 2021, giving an estimate of the average annual values from the monthly average values. The analysis takes the cumulative inflation rate of 7.72%, (Inflation tool, 2022) and the 2021 price, excluding inflation. Figure 55 compares the price developments from 2016 and 2021.

In Valencia prices have increased for rental apartments by 1,7€ per square metre and in Benicalap by 1,9€. The cost of properties for sale in Valencia have risen at 348,6€ per square metre, while Benicalap at 317,2 €. As a result, the increase was 25% for Valencia and 32% for Benicalap. Despite this, prices, in absolute terms, remain lower than the city average.

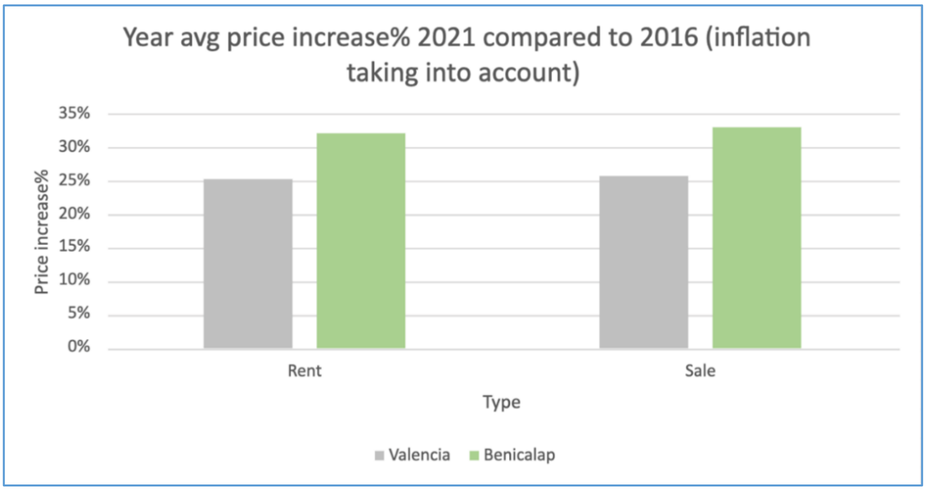


Figure 55 Price increase in Valencia and Benicalap areas.

The impact of the implemented NbS (from 2018) on real-estate development cannot be thoroughly evaluated at this stage. The project may have impacted accelerated the rise of the Benicalap real estate market, however, the new residential developments in the Nou Benicalap area provides homes, work environments and business opportunities. There have been price increases due to inflation and global markets.

6.6.5 Direct Jobs and Indirect Jobs

Table 25 is an estimate of the direct jobs (person/months) per year for Valencia by site providing an estimate of the person month for tendering, design, construction and maintenance.

[7] idealista, 2022 - Real Estate in Spain. Website. https://www.idealista.com/en/ (Accessed: 7.-11.03.2022)

	Estimated Person Months						
	2017	2018	2019	2020	2021	2022	Total
Municipality (all sites)	0	0	0	4,80	0,00	0	4,80
SITE 1 - Vertical Ecosystem	2	7	7	2	1,50	1,5	21,00
SITE 2 - Green Roof	0	10	10	1,5	3,00	1,5	26,00
SITE 3 - Green Corridor	0	1,5	1,5	1,35	6,45	0	10,80
SITE 4 - SUDs	0	1,5	1,5	1,3	3,60	0	7,90
SITE 5 - Square	0	1,5	1,5	1,35	7,88	0	12,23
SITE 6 - Small Forest	0	1,5	1,5	1,25	13,58	0	17,83
TOTAL	**2**	**23**	**23**	**8,75**	**36,00**	**3**	**95,75**

Table 26 Estimated Person Months - Valencia

The indirect jobs created by the project interventions is complex and it is not possible to make an estimate at this stage. There has however been a gradual revitalisation of the economy in line with the interventions.

7 Innovation

The neighbourhood of Benicalap and Ciutat Fallera have become living labs to demonstrate and showcase NbS innovative solutions. It goes beyond the technological development and includes citizen participation.

- The Vertical Garden is technological innovation providing temperature regulation, soundproofing and filtering the school's wastewater. The main innovation is the way the green wall is constructed with a series of buffer tanks to store the water as it passes through each process, a water softener, a reverse osmosis membrane and an ultraviolet lamp for disinfection. The water is then used to irrigate the plants and the school garden: https://growgreenproject.eu/greenest-school-valencia-vertical-garden-reused-water-irrigation/

- Flood prevention was a key objective for the Sustainable Forest. The SuDS typologies are bio-retention systems e.g. three infiltration basins connected by cascades; perimeter filter ditches and connection ditches between basins; and permeable pavements. The improvement in biodiversity is achieved by creating different strata of vegetation (trees, shrubs, and terrestrial plants) in a space that was previously mainly barren, encouraging bio-diversity. To improve thermal comfort in the area, tall vegetation in the form of some trees such as pines has been implemented. https://growgreenproject.eu/new-forest-valencia/

- All the pilot interventions were designed and implemented collaboratively with residents. The co-creation and participatory design stands out as an innovative process. A dynamic participation guarantees both the knowledge and training of citizens.

- A local monitoring group was set up made up of members of the municipality, UPV, practitioners responsible for the NbS and architects. This group defined the goals and targets for monitoring.

- Actions took place in public spaces to communicate the intentions of the pilot projects to the local residents. Visual messages and painted floor signs were used in public spaces to explain the location of the projects and the environmental improvements they would create.

- Three online initiatives were key to the innovatory approach :

- A participatory process called #MésVerdBenicalap (#GreenerBenicalap)
- A mobile app to help local people to learn about plants and wildlife in Valencia and a 'solidarity basket' will connect food producers and consumers. Video that shows how it works. https://www.youtube.com/watch?v=HetHzF15z2Y&t=10s
- Collaborative Green Initiatives Contest https://growgreenproject.eu/espai-verd-benicalap-opens-15-plots-urban-vegetable-gardens/

8 Lessons Learnt

8.1 Design

It is vital to include the correct stakeholders to create a viable and lasting design. This should include local politicians, municipal officers and future users. The design and implementation of the pilots offer a number of learning points:

- **Sustainable Forest:** it is important to take to account of regulations. The area had legal protection due to classification as a with cultural heritage site and this slowed the administrative process.
- **Green Blue Corridor**: there was complexity due to working in an urban area and the abundance of buried infrastructure. This limited the actions and types of NbS that could be implemented.
- **Vertical Ecosystem**: It is important to take into account of the characteristics of the water and to work with plants resistant to extreme temperatures and substances that can reach the plants and block the irrigation pipes. It is essential to assess the control, monitoring and use of water, and the costs of it depending its use. Is also important to plan for continuous maintenance as there will be rapid growth, attracting negative public opinion if the plants are too dry for too long,.
- **Dispositive of Urban Resilience**: the project supervised by the Conselleria d'Educació, (responsible for education at a regional level) and who permit the replicability of the DRU in other schools. The project is adapted to the existing capacities and resources in the neighbourhood to increase its efficiency.
- **Cistella Solidaria**: this model is scalable. This would mean an economy of scale for local farmers, but involves a higher level of complexity, bringing new challenges.
- **Biodiversity APP**: Learning outdoors makes the learning more interesting and improve environmental with real experiences.

8.2 Construction and Capital Costs

Going forward the focus is less about external finance but promoting green solutions as part of municipal management i.e. mainstreaming. Breaking inertia and promoting change requires the appropriate regulatory framework and transformative actions:

- Larger interventions (in m^2) have greater impact and are more cost-effective than small in terms of investment (€) per result achieved. Small interventions are a good option for localised and/or low-cost benefits. Cost effective interventions (e.g. urban agriculture and/or the traditional orchards that envelop the city of Valencia) with low implementation costs can be effective from an environmental, social and economic point of view.
- Green roofs and walls are expensive to implement but offer wider benefits e.g. energy savings.

- The performance of each intervention for CO_2 sequestration, heat stress reduction and energy savings needs to be compared to investment (€). The €/CO2 avoided ratio is useful to assess the cost/effectiveness of an intervention from an environmental view.
- Procurement processes needs to consider future maintenance and administration.

8.3 Citizen Engagement

At the beginning of the project, the commitment of the local neighbourhood was not clear. Through the process of citizen engagement, a positive impact with the local residents brought significant support. Even so there was a drop off of citizen involvement post project development. It is vital to have a plan for constant communication and dissemination. Offers to primary and secondary schools generated a low response rate in the dissemination stage of the project. Direct communication with school management and teaching staff is important.

There are opportunities for involvement from higher education centres to learn about the project from NbS through to the citizen participation processes. This included university studies such as design, geography and environmental sciences. The outcome of these sessions showed that it is important to reach those relevant to future replication and management i.e. present and future professionals that could work in NbS.

8.4 Monitoring and Impact Evaluation

Monitoring is expensive and requires maintenance. Modelling can also provide useful data to monitor and assess heat stress using reference weather stations.

Heat stress mitigation through NbS implementation is a slow process associated with tree growing. New trees provide high heat stress reduction but are limited to the shadow area they create. Changing heat stress in the short term is difficult to achieve. Small areas or shadow corridors can improve thermal comfort for pedestrians. These focus planting on a reduced percentage of area (5-10%). In long term, 25-30 years, the shadow corridors combine with well distributed trees to provide thermal comfort improvement for the total target area.

In addition to new trees, carbon stock maintenance is also very important to adequate management strategies of dead trees or trees in poor condition which still provide CO^2 sequestration.

8.5 On-going Management and Maintenance

SuDs require active maintenance. Where a contractor is less familiar with SuDS, a more on site approach is needed. The reality is that vegetation has its own timing and in Valencia, the months the trees were planted, they required more water to survive the summer heat. After garbage and fallen leaves from the trees obstructed the inlets, problems with maintenance developed because the municipal urban cleaning services did not know how SuDs work. This situation is a lesson about planning the integration of SuDS in and integrating NbS work in municipal services.

Maintenance costs can be critical for the cost/effectiveness of solutions. Decision makers should always include and compare maintenance costs in the analysis.

The green wall presented its own challenges. Due to costs, the school will be unable to maintain it going forward and it will not continue beyond the project. The view is that the TRL level has matured enough to be updated from the level 5 to the level 6. This means that the model has successfully be developed from a laboratory scenario to valid demonstration of viability and functionality.

8.6 Sustainability

The maintenance of the green infrastructure is a crucial issue and needs to be thought through in the design phase. From the start all municipal services impacted by the construction and maintenance were invited to meetings. This included department in charge of the construction or installation along with the lighting service, urban waste, integral water cycle, parks and gardens.

8.7 Political

The Urban Agenda of Valencia is aligned with the European community and with the agendas of the state and regional governments. The demonstration areas are a practical way to promote the changes which support the city's response to climate change. The challenge of local politics is that municipal projects often just last one or two years due to electoral constraints. European projects have the advantage of being longer, four plus years. The science behind innovation projects needs input from a range of bodies (public space managers, scientific community) in order to develop and coordinate.

8.8 Governance

The project required the coordinated participation and teamwork of stakeholders from all sectors in the city: public, private, academia, NGOs and the media. The abundance of requirements for the execution of public works and the need to adjust to the project deadlines made interdepartmental coordination essential.

9 Replication and Impact

The ability to create demonstration projects through co-design represents a milestone in good practice that will be useful in the planning of new projects, both public and private. The expansion of the Benicalap Park will spread nature through the district. This will not only integrate the forest but benchmarks criteria and solutions. The municipal office involved in GrowGreen, Las Naves, plays a key role in introducing innovations to local government actions.

9.1 Replication

One function of Las Naves is the generation of knowledge and the promotion of innovation. One of the main purposes of Las Naves is a methodology for the transfer of results. This involves establishing a system that will guide the steps and establish a system.

In June 2022 Las Naves held a transfer session with students from a school of the district of Benicalap, and in July of 2022 they held activities with a leisure approach, open to all citizens. In September 2022 as a part the transfer results plan, Las Naves held a workshop to share good practice to public and political actors from the municipality and the regional sectors. This included businesses involved in NbS.

In October 2022 Las Naves went to a gardening and innovation fair and participated in a round table discussion. A group of specialist assisting the Urban Health Congress, developed in Valencia, attended in 2022 for a transfer session.

Las Naves has also prepared different sessions and workshops for October/November of 2022 from schools to higher level students e.g. universities..

The workshops and sessions in Benicalap have had 250-300 individuals participating to date.

9.2 Financial Implications

The cost effectiveness analysis is challenging for NbS. The ability to calculate value and show to decision-makers, companies, and citizens the real benefits of NbS compared to traditional solutions is an opportunity. To assess this, Las Naves and UPV are working to inform decision makers on investments in NbS.

- Developing two interactive tools to help and inspire decision makers in finding suitable NbS interventions that fit their needs or achieve specific green goal by calculating the results of the actions, comparing costs and benefits. An open version will be made available.
- To manage the complexity of the identification and definition of the different benefits and metrics of NbS, the data used for calculations must be adapted to each type of intervention. A customized calculator tool for different types of NbS is being developed. The tool for green roofs is complete.
- Calculating the impact of the GrowGreen pilots needs real data to calculate the cost-effectiveness of the different models. This will be the next phase.

9.3 Nature Based Solutions for Energy Poverty Homes

In WP1 Task 1.2.2 technical analysis focused on the options to integrate the NbS integration in the urban areas and a tool for the measurement of the impact that energy poverty has on the wellbeing of people. This is linked with the proposal of renewable and green solutions for homes experiencing energy poverty, an issue not uncommon in Ciutat Fallera and in other areas of Benicalap. This tool was created with the participation of civil associations working in health, poverty, social services and energy. The final product includes a questionnaire for citizens that aims to estimate the level of energy poverty and the impact on the quality of life. It also includes recommendations about interventions of energy efficiency and NbS. This work presents a precedent of NbS interventions, bringing together urban planning and social issues.

10 Conclusions

The main results to be highlighted are:

- Biodiversity is significantly improved in the NbS applied in the various pilots of the project.
- The proportion of the five canopy types of the NbS (tree cover, bare soil, etc.) is balanced.
- Improved resilience of the introduced vegetation in relation to diseases and adaptation to the local climate.
- Increased environmental services, especially surface runoff management through increased soil permeability, improved climatic comfort, air quality and increased CO2 absorption.
- The Mohawk method makes it possible to analyse the use of space and user behaviour. The following positive aspects are detected:
- Increased interest has been generated by the changes made in the neighbourhood where the pilots have been installed.
- NbS has contributed to meeting people's growing need to spend more time outdoors after the pandemic by improving the conditions of the district's open spaces.
- Thermal stress changes are very gradual. It is difficult and very slow to change the heat stress response in a whole action area but more feasible for immediate changes limited to the immediate vicinity of the vegetation.
- Air temperature is a key parameter but is not sufficient for the assessment of heat stress.
- In trees, slow and gradual changes are detected, for which it is important to take actions to maintain the carbon stock (debris from tree pruning and dead, diseased trees). This monitoring can be carried out on the basis of annual measurements.

- On water resilience SuDs delayed the impact of water flow by up to 4 - 5 hours. In addition to delaying the inflow of water into the collectors, they reduce the amount of water reaching the collectors by between 66 - 100 % (volumetric efficiency).
- Sediment can potentially clog features such as permeable pavement, however despite this it can still function.
- The SuDS at the Sustainable Forest retained all the runoff water generated in the park. This is 100% improvement in comparison to pre- construction.
- On water quality the SuDs can reduce the concentrations of a range of pollutants.
- There have been price increases due to inflation and global markets and whilst the impact on real estate costs cannot be totally evaluated at this stage, there is as view that the implementations may have impacted accelerated the rise of the Benicalap real estate market.

11 Annex 1: Species List

Trees and Plants

Following the implementation the tree biodiversity in the neighbourhood overall is made up of 8900 trees from 134 species in the Benicalap District. This includes the trees retained from before the project commenced.

50% of the tree cover is represented by 8 species (sycamore, Platanus hispanica; orange tree, Citrus aurantium; privet, Ligustrum japonicum, hackberry, Celtis australis, chinaberry tree, Melia azedarach, Mexican Fan Palm, Washingtonia robusta; European palm, Chamaerops humilis; and Jacaranda, Jacaranda mimosifolia). The most dominant species is sycamore (Platanus hispanica; 12 % of the tree cover).

Most of the vegetation in the park is in small woods mainly composed of olive trees (Olivo, *Olea europaea*), Pinus Alepo Pine (*Pinus halepensis*), black pine (Pino negral, *Pinus nigra*), maritime pine (Pino marítimo o rodeno, *Pinus pinaster*), cypress (Ciprés, *Cupressus sempervirens*), European palm (Palmito, Chamaperops humilis), holm oak (encina, *Quercus ilex*), laurel (laurel, *Laurus nobilis*) and mulberry (Morera, *Morus alba*). In total, the park has 1400 trees corresponding to 103 species.

Birdlife

There is a good bird presence from surrounding areas like La Huerta de Valencia or the natural areas, Albufera Natural Park and Turia Natural Park.

The most common species in Benicalap Park are sparrow (gorrión común; *Paser domesticus*), goldfinch (jilguero; *Carduelis carduelis*), zitting cisticola (buitrón; *Cisticola juncidis*), white wagtail (lavandera blanca; *Motacilla alba*), starling (estornino negro; *Sturnus unicolor*), greenfinch (verdecillo; *Serinus serinus*), pigeon (paloma bravía; *Columba livia var*.), common chiffchaff (mosquitero común; *Phylloscopus collybita*), common house martin (avión común; *Delichon urbica*) and pitpit (bisbita común, *Anthus pratensis*).