URBAN GreenUP

D2.4: MONITORING PROGRAM TO VALLADOLID

WP 2 , T 2.6

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0 Executive summary

The Urban GreenUP project is a 5-year project combining practical implementation of nature-based solutions (NBS) with social, ecological, and economic research. NBS have been presented as an innovative way to address the many challenges facing urban areas. This project tests whether – and to what extent – NBS can contribute to solving biophysical, social, and economic challenges in urban areas by first undertaking 1 year of baseline research, then implementing targeted NBS interventions, followed by a 2-year post-intervention monitoring period.

This document outlines the monitoring protocols proposed for the City of Valladolid URBAN GreenUP interventions, following Task 2.6: Development of the monitoring programme, and in line with the higher order principles outlined in D5.3: City Diagnosis and Monitoring Procedures (Urban GreenUP 2018). This monitoring protocol focuses on the principles and procedures of the biophysical and social monitoring, as structured by the Eklipse framework (Raymond et al. 2017) and KPIs selected in the City of Valladolid.

For each KPI, the document describes the rationale for measuring the indicator, including associated literature that suggests why it may be important and/or relevant. The monitoring procedures are then outlined in general terms, with respect to the methods and approaches appropriate for each discipline. To allow for these disciplinary differences, the document is divided into two parts, with the first outlining biophysical monitoring procedures and the second part outlining socio-economic monitoring procedures. Each section concludes with a plan for management and sharing of the data generated over the course of the Urban GreenUP project and beyond.

1 Introduction

The Urban GreenUP project is a 5-year project combining practical implementation of nature-based solutions (NBS) with social, ecological, and economic research. NBS have been presented as an innovative way to address the many challenges facing urban areas. This includes both challenges that are primarily biophysical (e.g. climate change, poor air quality, poor water quality and ecosystem degradation), as well as the linked social challenges prevalent in urban areas (declining participation in governance, socio-economic inequalities, and economic development). This project tests whether – and to what extent – NBS can contribute to solving these challenges by first undertaking 1 year of baseline research, then implementing targeted NBS interventions, followed by a 2-year post-intervention monitoring period.

As directed by the European Commission, Valladolid has selected a set of Key Performance Indicators (KPI) based on the Eklipse framework (Raymond et al., 2017) and in collaboration with the other front-runner cities in the Urban GreenUP project: Liverpool and Izmir. The framework was developed out of a project funded by the EC to provide guidance on how cities can evaluate the efficacy of NBS. It aimed to assist stakeholders across the European Union:

1) To develop an impact evaluation framework with a list of criteria for assessing the performance of NBS in dealing with challenges related to climate resilience in urban areas;
2) To prepare an application guide for measuring how NBS projects fare against the identified indicators in delivering multiple environmental, economic and societal benefits;
3) To make recommendations to improve the assessment of the effectiveness of NBS projects, including the identification of knowledge gaps according to the criteria presented in the impact evaluation framework.

To apply the framework the Eklipse expert panel established ten areas in which cities face urgent challenges, and for which NBS can be used as a partial solution:

- Challenge 1: climate mitigation & adaptation;
- Challenge 2: water management;
- Challenge 3: coastal resilience;
- Challenge 4: green space management;
- Challenge 5: air quality;
- Challenge 6: urban regeneration;
- Challenge 7: participatory planning and governance;
- Challenge 8: social justice and social cohesion;
- Challenge 9: public health and well-being; and
- Challenge 10: potential of economic opportunities and green jobs.

These challenges provide a structure for organising evidence for the efficacy of NBS. Eklipse is not a prescriptive framework, and instead outlines the areas that existing research suggests are relevant to NBS, with broad recommendations on potential KPIs. To establish the parameters of the URBAN GreenUP delivery and monitoring protocols, the Liverpool project team have drawn on the Eklipse documents in developing its KPIs. This has led to the development of set of KPIs that:

1) Are relevant to our interventions;

2) Can be robustly and consistently measured; and

3) Aligns with the human and financial resources available for the project.

These criteria are comparable to the areas of concern and subsequent investigation that would be used by any city interested in evaluating the efficiency and effectiveness of their investment in NBS. Based on these criteria, the Liverpool project team have developed a list of KPIs[2] (Table 1) that will be used to develop a baseline and to monitor post-intervention effectiveness or change.

The table below structures the KPIs by the Eklipse challenges. We recognise that the KPIs do not always fit neatly into one category, and that one KPI may be suitable for several challenge areas. These categories are thus used as a guide rather than a concrete means to delineate between urban challenges and indicators for measuring NBS performance. The KPI number has been included in Column 2 for cross-referencing to D5.3 City Diagnosis and Monitoring Procedures (Urban GreenUP 2018).

Type of Indicator	KPI	Associated NBS
Challenge 1: Climate Change Mitigation and Adaptation		
Environmental (physical)	**Tonnes of carbon removed or stored per unit area per unit time (KPI-1)**	Green shady structures, Shade Trees, Cooling trees, Green Façade, Green parking pavements
Environmental (physical)	**Decrease in mean or peak daytime local temperatures (KPI-7)**	

[2] Note that there are no KPIs for the coastal resilience challenge area, as this are not relevant to the interventions being monitored.

Type of Indicator	KPI	Associated NBS
Environmental (physical)	**Heatwave risks (KPI-9)**	
Economic indicators	**kWh/y and t C/y saved - Energy and carbon savings from reduced building energy consumption (KPI-10)**	Tree related actions; vertical and horizontal green infrastructure; SUDs and raingardens; Urban Carbon sink
Challenge 2: Water Management		
Biophysical indicator	**Run-off coefficient in relation to precipitation quantities (KPI 16)**	Tree related actions; SUDs and raingardens; Urban Carbon sink; horizontal GI
Biophysical indicator	**Flood peak reduction (l/s). Increase in time to peak (%) (KPI-17)**	SUDs and raingardens; Green filter area; smart soils, natural waste water treatment
Biophysical indicator	**Reduction of drought risk (KPI-18)**	SUDs and raingardens; tree related GI; horizontal GI, smart soils
Biophysical indicator	**Absorption capacity of green surfaces, bioretention structures and single trees (KPI-20)**	
Biophysical indicator	**Temperature reduction in urban areas (KPI-22)**	Tree related actions; SUDs and raingardens; horizontal GI; smart soils
Biophysical indicator	**Intercepted rainfall (KPI-26)**	SUDs and raingardens; Green filter area; smart soils, natural waste water treatment
Biophysical indicator	**Share of green areas in zones in danger of floods (KPI-27)**	Tree related actions; SUDs and raingardens; horizontal GI; smart soils
Biophysical indicator	**Population exposed to flood risk (KPI-28)**	Tree related actions; SUDs and raingardens; horizontal GI; smart soils
Biophysical indicator	**Areas (Ha) and**	Tree related actions; SUDs and raingardens;

Type of Indicator	KPI	Associated NBS
	population (inhab) exposed to flooding (KPI-29)	horizontal GI; smart soils
Water quality	**Nutrient abatement; abatement of pollutants (KPI-30)**	Tree related actions; SUDs and raingardens; horizontal GI; smart soils
Water quality	**Water for irrigations purposes (KPI-34)**	Tree related actions; SUDs and raingardens; horizontal GI; smart soils
Socio economic indicators	**Economic benefit of reduction of storm water treated in public sewerage system (KPI-38)**	Tree related actions; SUDs and raingardens; horizontal GI; smart soils
Challenge 4: Green Space Management		
Social	**Distribution of public green space – total surface or per capita (KPI-52)**	Vertical & Horizontal Infrastructure; Tree related actions; Amenity green space, cycle and footpaths, and plazas/public spaces with urban greening.
Social	**Accessibility of urban green spaces for population (KPI-53)**	All NBS interventions
Social	**Recreational cultural value (KPI-54)**	Pollinator verges and spaces; horizontal green interventions; vertical green interventions; SUDs and raingardens
Environmental indicator	**Production of food (KPI-73)**	
Environmental indicator	**Sustainability of green areas (KPI-74)**	All biophysical NBS (pre-intervention/post-intervention) including floating gardens (up to 10 m from surveyor).

Type of Indicator	KPI	Associated NBS
Environmental indicator	**Quality of life for elderly people (KPI-75)**	All NBS interventions
Environmental indicator	**Increased connectivity to existing GI (KPI-76)**	
Environmental indicator	**Pollinator species increase (KPI-77)**	
Environmental indicator	**Perceptions of connectivity and mobility (KPI-78)**	
Challenge 5: Air quality monitoring procedures		
Environmental (chemical)	**Annual mean levels of fine particulate matter (KPI-83)**	Street trees and green walls (or screens)
Environmental (chemical)	**Mean levels of exposure to ambient air pollution (KPI-86)**	Street trees and green walls (or screens), improved highway improvements
Economic	**Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. Use of GI val to calculate the value of air quality improvements (KPI-88)**	
Social	**Air quality parameters (KPI-92)**	
Challenge 6: Urban Regeneration		
Socio cultural	**Assessment of typology, functionality and benefits provided pre and post interventions (KPI-109)**	All technical and non-technical interventions

Type of Indicator	KPI	Associated NBS
Economic	**Savings in energy use due to improved GI (KPI 110)**	Vertical GI, Tree related actions, Horizontal GI
Challenge 7: Participatory Planning and Governance		
Social	**Openness of participatory processes (KPI-111)**	All technical and non-technical interventions
Social	**Perceptions of citizens on urban nature (KPI 115)**	
Challenge 8: Social Justice and Social Cohesion		
Social	**Crime reduction (KPI 123)**	All technical and non-technical interventions
Social	**Green intelligence awareness (KPI-127)**	
Challenge 9: Public Health and Well-Being		
Psychological	**Noise reduction rates applied to UGI within a defined road buffer dB (A) m2 vegetation unit (KPI-128)**	Green cycle lane; Vertical green interventions; Horizontal green interventions; SUDs
Health	**Increase in walking and cycling in and around areas of interventions (KPI-139)**	
Challenge 10: potential of economic opportunities and green jobs		
Economic	**Number of subsidies or tax reductions applied for (private) NBS measures (KPI-140)**	All technical and non-technical interventions
Economic	**Number of jobs created; gross value added (KPI 141)**	
Economic	**New businesses attracted and additional business rates (KPI-143)**	

Type of Indicator	KPI	Associated NBS
Economic	**Consumption benefits: property betterment and visual amenity enhancement (KPI-150)**	
Those KPIs marked with an asterisk (*) do not yet have a KPI reference number.		

Table 1.1: KPIs for Valladolid.

1.1 ABOUT THIS DOCUMENT

This document outlines the monitoring protocols proposed for the City of Liverpool URBAN GreenUP interventions, following Task 2.6: Development of the monitoring programme, and in line with the higher order principles outlined in D5.3: City Diagnosis and Monitoring Procedures. Key information about the City of Valladolid, the rationale for developing the interventions, and their locations are provided in the diagnosis and baseline reports (Urban GreenUP 2017a, 2017b). These provide an important contextual basis for this monitoring protocol, which focuses only on the principles and procedures of the biophysical and social monitoring.

2 CHALLENGE 1: CLIMATE MITIGATION & ADAPTATION MONITORING PROCEDURE

2.1 Environmental indicators

Total amount of carbon stored in vegetation

Climate resilience is based on two interacting concepts: “adaptation”, that is the capacity to react and respond to an external stimulus or stress such as climate change, and “mitigation”, that is the potential of improving the current status of a parameter or driver through active or passive behaviour, in this case through reducing greenhouse gas emissions or sequestering carbon. In the case of NBS, which involve elements of ecosystems, the two concepts are closely linked as any adaptation of an ecosystem can further influence the mitigation potentials (e.g. by sequestering carbon in vegetation), with an overall dramatic effect on climate resilience [1].

A proportion of the CO_2 that is sent into the atmosphere is reabsorbed. The concentration of the gas would otherwise increase exponentially, and would undoubtedly be irreversible. Natural systems are responsible for part of this absorption. They have a limited capacity which can also change the effects of climate change or how different ecosystems are used. Most natural systems have stored carbon, and the amount that is stored at any given time is called a carbon reservoir or carbon stock. If the amount in this system naturally increases over time, then it is described as a sink, which helps reduce the concentration of CO_2 the atmosphere. This process is called carbon sequestration. However, if the amount of carbon in the system declines, this is a CO_2 emission source [2].

Urban vegetation has an important role in offsetting $CO_{2,}$ concentration by acting as a sink for atmospheric CO_2 via photosynthesis and by storing carbon through the growth process [3].

Carbon sinks can be addressed at two spatial scales: within the city and at the urban regional level. Within a city park, green areas and tree plantings can function as carbon sinks, although urban vegetation only sequestrates a small part of annual CO_2 emissions of a city. In fact, urban parks can function as carbon sources because management and the use of parks produce multiple amounts of CO_2 emissions compared to the carbon sequestration capacity of a green area. Although urban carbon sinks do not necessarily have a significant impact on the global carbon balance, urban green areas can have local importance as carbon sinks [4].

This indicator can be applied at street, neighbourhood or city scale depending on the scale of intervention of the NBS to be assessed. Monitoring scheme will depend on the scale of the intervention. Monitoring scope is designed by this purpose.

NBS actions for climate resilience can be aimed at macro-scale mitigation, by enhancing carbon storage and sequestration in vegetation or soil and thus reducing global greenhouse gas concentrations, or at meso and microscale adaptation through planting vegetation to improve the local or regional micro-climate through cooling, shading and shelter. Many actions can achieve both of these impacts.

NBS TYPES

Urban Carbon Sink	Installation of urban woodland with appropriate species adapted to temporary flood condition and with high capacity of carbon sequestration.
Planting Urban Trees (shady places, re-naturing parking, green resting areas)	Use of vegetation as cooling source in urban environments. Plantation of trees: • along the Green Corridor area to provide shady places and to improve the user's well-being; • in the facilities of Football Stadium to improve the parking and leisure area to generate an arboreal shady place, • in City Centre to increase the urban tree population with shade and cooling purposes, • Installation of 3 resting areas with a tree shade area,
Pollinator's modules	The deployment and use of integral pollinator habitat network (housing, plants and water) is an innovative action to promote the conservation and improvement of pollinator presence and biodiversity.
Green Filter Areas (natural wastewater treatment plant and green parking pavements)	URBAN GreenUP will integrate green filters in a new concept of Floodable Park with other NBS. Innovative green pavements combining natural soil, plants and polymeric and cementitious materials will be implemented too.

Table 2.1: NBS to be implemented in Valladolid which will contribute to store carbon in vegetation

METHODOLOGY

This KPI can be estimated as carbon sequestration and it is defined as the process of increasing the carbon content of a reservoir or pool other than the atmosphere. When plants grow, they capture CO_2 from the atmosphere therefore the choice of plant species for urban areas may be set out taking into account their own air amelioration capability. Maximizing the net sequestration of carbon through species selection and management practices will be the aim.

In this KPI, total amount of carbon (tonnes) stored in vegetation will be calculated and used to assess the impact of the NBS. This KPI includes the measurement and calculation of area of new woodland created to complete the study.

Predictive calculations, on the basis of the estimated growth of the species, for the permanence period is the chosen method to calculate CO_2 removals expected to be generated by the project.

Null hypothesis

There is no increase in number of trees so no difference in the estimation of $tCO_{2,sequestered}$ is calculated.

SENSOR / SOFTWARE

No sensor is required.

DATA SAMPLING

Datasets should be identified by Valladolid City Council to know:

- Area of new woodland created [5],
- Type of species,
- Number of species.

Different data sources will be consulted to develop the present study, mainly the Spanish National Forest Inventory (SNFI) and the Spanish Forest Map [6]. The selection of species present at these inventories will be prioritised.

DATA PROCESSING

KPI calculation will be based on CO_2 removals per planted specimen, to subsequently apply this data to the entire project, depending on the number of specimens expected at the end of the period of project development.

Plant structure in each technology will be analysed regarding **type of plant species** and **total number of species**. The choice of plant species for each action shall be specific set out within the project development, taking into account their own air amelioration capability [7].

Total $tCO_{2,sequestered}$ thanks to each NBS detailed before shall be calculated as follows:

$$\frac{tCO_{2,removed}}{year * ha} = \left[\frac{tCO_{2,sequestred}}{specie * n_{years}}\right]_{[4]} * n_{years} * \frac{Number_{species} \text{to be planted within the NBS}}{\text{Total ha of species}}$$

RESULTS

The amount of carbon stored in biomass (leaves, stems, trunk, roots and soil organic matter) to assess the tonnes of carbon removed or stored per unit area (ton CO_2/year * ha) per unit time (ton CO_2/year) shall be obtained at the end of the process for this KPI.

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Decrease in mean or peak daytime local temperatures

This indicator is included in the list of indicators for *Challenge 1. Climate Resilience*. See table below with the total set of KPIs related to Climate Resilience (CR) Challenge.

Urban heat island (UHI) effect refers to the increased temperatures of urban areas compared to surrounding rural areas under a range of meteorological conditions. Temperatures of sealed urban surfaces such as roads and pavements can be significantly higher than air temperature due to the higher capacity of construction materials to absorb and retain heat, releasing it during the night. The UHI effect can exacerbate summer heatwave conditions, with a detrimental effect on human health. Vegetation is well known to mitigate the effects of UHI through the process of evaporative cooling; where leaf stomata open at periods of intense heat to release moisture into the air. Trees additionally contribute to reducing temperatures by providing shade, making public space and travelling routes more comfortable for people on summer days when temperatures in urban areas are high. **We propose to assess heatwave risk ideally by direct measurement**, but optionally by modelling using StarTools.

This indicator can be applied at street/building, neighbourhood or city scale depending on the scale of intervention of the NBS to be assessed. Monitoring scheme will depend on the scale of the intervention. Some of the intervention of Valladolid DEMO will be assessed using this KPI at street and/or building scale. Monitoring scope is designed by this purpose.

City settings: In this KPI, number of combined tropical nights and hot days will be counted on NBS location in comparison with the reference sites to assess the impact of the NBS.

No explicit EQS were found in relation to urban temperature regulation at the European regulatory level, probably because human health vulnerability to temperature extremes depends on a complex interaction between different factors such as age, health status, socio-economic circumstances (e.g., housing) and regional adaptation (Kovats and Hajat, 2008; Fischer and Schär,2010). However, general critical temperature thresholds for health impacts in Europe have been estimated based on the spatial and temporal variance in excess mortality during recent heatwave episodes (Fischer and Schär, 2010). **According to this research, the consecutive occurrence of days with maximum temperature above 35◦C ('hot days') and nights with minimum temperature above 20◦C ('tropical nights') has been found to explain the correlation with excess mortality.** These values match well with specific temperature thresholds officially allocated to cities like Barcelona (Tobias et al., 2012). In any case, the impacts of heatwaves on human health are particularly strong in cities, both in Northern and Southern latitudes, due to the exacerbating effect of the urban heat island (UHI) (EEA, 2012).

NBS TYPES

1. Green shady structures	Pieces of stretched textile structure on which an inert substrate is installed. This inert substrate is covered with seeds, which germinate and grow on the textile structure. This NBS can be fixed to the facades of the buildings on the street or by posts fixed to the sidewalk. This green surfaces creates high leaf surfaces in pedestrian areas.

2. Shade Trees	A selection of trees series positioned in strategic locations to maximise summer time shading. Strategic positioning of shade trees within urban areas can provide shade to buildings, reducing heat loading on building and provide islands of respite from high temperatures in our urban areas. They provide spaces within the urban fabric for respite from direct sunlight and high temperatures at times of heatwave in particular.
3. Cooling trees	Trees series planted to take advantage of evapotranspirative cooling. Species selected are those, which transpire at high rates to maximise their cooling effect. Provision of a constant water supply to such trees is essential to ensure this function is effective. As with shade trees, this NBS requires careful selection of the tree species to enable cooling. Different trees respond in different ways to increased temperature, matching trees that will continue to achieve the cooling effect through their transpiration, with the projected heatwave conditions is possibly the key consideration of this NBS.
4. Green Façade	A green façade is a wall completely or partially covered with greenery. A green façade with climbing plants uses a trellis system to hold the vines of plants that are rooted in the ground or containers. Green façades offer economic, environmental, aesthetic and physiological benefits to the urban environment.
5. Green parking pavements	NBS destined to replace grey urban pavement with 50% vegetal soil and high drainage capacity. This kind of pavements has gaps, which will be filled with smart soil and with specific creeping grass species with a short growing and minimum maintenance and are appropriate for bikes, pedestrian and motor vehicles.

Table 2.2: NBS Types that generate direct impact due to reduced cooling and heating

METHOD

BACI (Before, After, Control, Impact)

Measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention. Calculate the number of tropical nights per month (summertime) and per year following the city location settings. Compare these data to values taken at equivalent locations on equivalent stretches of street without those NBS at a similar time of day on the same dates or continuously.

As a previous work, temporal series of temperature and relative humidity will be studied in order to define peak times and values and mean values of historical data (at night and daytime) for the city in the RCCAVA areas (According its characteristics). This study will serve to stablish a general baseline for the city. On the other hand, RCCAVA measurements will be used as additional references of non-intervention areas.

NULL HYPOTHESIS

There is no difference in air temperatures and relative humidity between samples in stretches of street where green shady structures, street trees/green walls, etc. are present, and samples or measurements taken in stretches of streets without the NBS.

SENSOR / SOFTWARE

Monitoring equipment. Wireless samplers to hang from street lamps or other urban furniture without carrying out works (low weight and low visual impact).

EXAMPLES

The Smart Agriculture models allow to monitor multiple environmental parameters involving a wide range of applications. It has been provided with sensors for air and soil temperature and humidity, solar visible radiation, wind speed and direction, rainfall, atmospheric pressure, etc.

http://www.libelium.com/uploads/2013/02/agriculture-sensor-board_2.0_eng.pdf

Data stored on the device can be downloaded later to a PC using the USB cable and software provided with the monitor.

Price around 1.500€.

Elitech RC-5 USB Temperature Data Logger LCD Display Temperature Recorder 32000 Points High Accuracy Reusable.

https://www.elitechonline.co.uk/RC-5

Price around 25€ (amazon)

MEASUREMENTS

Air temperature and relative humidity will be measured and recorded hourly (at least).

UNIT OF MEASUREMENT

Temperature in ºC and Relative Humidity in %.

CALIBRATION / VERIFICATION

Calibration/verification at laboratory.

STUDY SITES

a) Stretches of street where street shady structures or tree/green wall interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of street (street of similar width and with comparable building heights to intervention site and **orientation**) where street tree/green wall interventions are not proposed (**control study sites**). Control sites should be a sufficient distance away from intervention sites for the observations made to be considered independent from the effects of NBS.

NUMBER OF STUDY SITES

tbc

NUMBER OF SAMPLES

At each study site and control site, a set of sensors will be installed at fixed height (between 1.5m, human height, and 3.5m, height to avoid vandalism) in different locations (same number in right and left side of the street) and avoiding estrange elements which can modify air conditions like exhaust part of an air conditioning or a shop door.

DATA SAMPLING

Both intervention and matched control study sites should be monitor with the same schema during the same time (although with a lower number of sensor points). Each fixed sampling location at a study site should be sampled hourly (at least) for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022).

DATA PROCESSING

Calculation of the number of tropical nights and heatwaves monthly (summertime) and yearly assessing hourly mean values of temperature at each stretch. Comparison of mean values for NBS intervention and control sample locations will be done at each study site.

SPATIAL ANALYSIS SOFTWARE

QGIS is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

RESULTS

The calculated values will be compared qualitatively and quantitatively for the periods before and after the interventions in the NBS and reference sections. Quantitative assessment will be done by using the following expression:

$$\textit{\textbf{Tropical Nights or Heatwaves impact}} = \left(\frac{Number\ after\ intervent.-Number\ Expected\ after\ intervent.}{NBS\ Expected\ Temp.average\ after\ intervent.}\right) \times 100$$

Where *Number after intervent.* is the number of tropical nights or heatwaves after interventions and *Number Expected after intervent.* Is calculated by this expression (supposing that interventions had not been done):

$$\boldsymbol{Number\ Expected\ after\ intervent.} = \left(\frac{Ref.Number\ after\ intervent.}{Ref.Number\ before\ intervent.}\right) \times NBS\ Number\ before\ intervent.$$

Where *Ref. Number after intervent*. is the number of tropical nights or heatwaves in the reference stretch after the intervention, *Ref. Number before intervent.* is the number of tropical nights or heatwaves in the reference stretch before the intervention and *NBS Number before intervent.* is the number of tropical nights or heatwaves in the NBS stretch after the intervention.

Positive or null *Tropical nights or Heatwaves impact* values indicate negative or no impact of the NBS on average temperatures for that implementation. A Negative value indicates a positive impact of that NBS on temperatures.

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2.2 Economic indicators

kWh/y and t C/y saved - Energy and carbon savings from reduced building energy consumption

The implementation of NBS in urban areas can generate energy and carbon savings from direct reduced energy consumption in buildings. Reduced energy demand for heating and cooling is considered as an environmental indicator which can be also quantified with the amount of CO_2 emissions reduced (H2020 Eklipse project report). Therefore, with reference to a baseline situation, the energy not consumed can be accounted for as a reduction of CO_2 Emissions.

Among the NBS implemented in Valladolid the Green Wall and the Green Roof (Table 1) generate direct energy savings in buildings due to reduced energy consumption for cooling and heating. According to bibliography, energy savings are due to different mechanisms such as the shadow produced by the vegetation, the insulation provided by vegetation and substrate, the evaporative cooling through evapotranspiration, and, finally, the barrier effect to wind from which the effect of shadow has the highest impact over the reduction of wall temperature and therefore, the generation of energy savings.

Furthermore, some studies identified four key factors that influence the operation of this type of passive systems (Coma et al., 2017): (1) the sort of construction - green walls or green facades (2) the climatic influence; (3) the type of plant species used; (4) the various mechanisms that make these systems act as passive tools for energy savings in buildings such as the ones detailed before: shadow, insulation, evapotranspiration and wind barrier effects.

To quantify the energy savings generated by the NBS implemented in Valladolid, several methods can be applied. In bibliography, multiple case studies testing different NBS, plants, building temperatures, etc. can be found. From them, reported ranges about the energy savings generated in similar climatic conditions could be used to estimate the energy savings generated by the NBS implemented in Valladolid demosite (OPTION 1). Furthermore, quantifying heat flux through Green Walls and Green Roofs, energy savings can also be calculated (OPTION 2). Finally, energy savings could be directly measured comparing energy consumption before and after the intervention (OPTION 3). Among the options proposed and considering the purpose of this project the OPTION 2 was de one selected. However, the other two are still defined in this card in order to serve as the base in other case studies.

NBS Types

1. Green façade	The green façade will have 1,400 m^2 and will be installed in a public building. It will consist on a modular system with low costs and low maintenance due to the use of a smart specific substrate, a saving water system and a selection of specific plants able to resist both frost and drought conditions.
2. Green roof	The Green Roof will be installed in the Campillo Market building to connect this area with España Square. It will consist on a vegetal roof that will integrate specific vegetation requiring minimum maintenance. Its structural features provide water for plants, humidity for the air and CO2 capture. Likewise, the green roof contributes to reduce the energy consumption due to the isolation improvement.

Table 2.3: NBS Types that generate direct energy savings in buildings due to reduced cooling and heating

ENERGY SAVINGS

OPTION 1: ESTIMATION FROM PREVIOUS STUDIES

Among all the NBS implemented in Valladolid there are two main configurations which directly generate energy savings which are the Green Wall and the Green Roof. Various studies in bibliography reported the energy savings associated to different Green Infrastructures. However, there is a clear difficulty to establish a proper comparison between studies, when the construction system, materials, climate, plants species and other parameters (orientation, thickness foliage, etc.) are different between them (Coma et al., 2017). For example, at city scale, increasing Chicago's urban tree cover by 10 per cent was estimated to reduce average air temperatures by 1°C, which would translate into 5-10 % reductions in total heating and cooling energy use (IEEP, 2011). Similar modelling with regard to green roofs in the US indicates reductions in electricity consumption of 2 to 6 % compared to conventional roofs (Foster et al, 2011).

To estimate the energy savings from bibliography, some studies evaluating different configurations and parameters are summarized in this section. Although some studies directly measured energy savings, most of them used simulation tools. Also, Green Walls and Green Roofs are independently studied in bibliography. Accordingly, considering the type of infrastructure and the parameters defined in bibliography (roof insulation, temperature set-point, plant species, etc.) the estimation that better approaches the technical solutions implemented in Valladolid will be applied.

1.a Green Walls and Façades

In the study presented by Coma et al. 2017, energy savings where quantified by means of 3 real scale cubicles. While one of them was left uncovered and used as a control, the other two were covered with either double-skin façade using deciduous creeper plants (Green façade, GF) or a green wall made with evergreen species (Green Wall, GW). By controlling internal temperature at a set-point, energy savings due to vertical greenery where directly quantified during a period of around 10 days. This study was conducted at the city of Lleida (Spain), with continental climate as Valladolid. As detailed in Table 2, different internal temperature set-points were established and their corresponding energy savings quantified.

Set point (ºC)	Days	Energy saving (kWh/year)		Energy saving (%)	
		GW	GF	GW	GF
Cooling period					
18	10	0.558	0.094	31.2	5.3
21	11	0.410	0.194	42.9	20.3
24	12	0.781	0.448	58.9	33.8
Heating period					
22	9	0.128	0.058	4.2	1.9

Table 2.4: Energy savings due to Green Wall (GW) or Green Façade (GF) installation at building level. Adapted from Coma et al. 2017

1.b Green Roofs

Niachou et al. (2001) quantified the energy savings generated by the introduction of a green roof by means of simulation tools. In the study, apart from the effect of a green roof implementation, different supporting roof insulation scenarios (non-insulated, moderate, well) were compared. These scenarios are characterized by having different conductance coefficients, defined in the article. It also considers different building ventilation options according to its air changes per hour coefficient (ACH). Indoor temperature in buildings was set at 20ºC during the heating period and at 26ºC during the cooling period. Yearly and percentage energy savings for heating and cooling are detailed in Table 3.

Insulation grade	ENERGY LOADS (kWh/m2/year)											
	WITHOUT GREEN ROOF			WITH GREEN ROOF			ENERGY SAVING (KWh/m^2/year)			ENERGY SAVING (%)		
	H	C	T	H	C	T	H	C	T	H	C	T
Night ventilation not applied												
Non	42	116	158	23	64	88	19	52	70	45	45	44
Moderate	15	57	72	13	55	67	2	2	5	13	4	7
Well	12	53	65	11	53	64	1	0	1	8	0	2
Night ventilation applied during summer period with 4 ACH												
Non	42	111	153	23	51	74	19	60	79	45	54	52
Moderate	15	44	59	13	40	53	2	4	6	13	9	10
Well	12	38	50	11	38	49	1	0	1	8	0	2
Night ventilation applied during summer period with 10 ACH												
Non	42	107	149	23	42	65	19	65	84	45	61	56

Moderate	15	36	50	13	32	44	2	4	6	13	11	12
Well	12	29	41	11	29	40	1	0	1	8	0	2

Table 2.5: Energy savings due to Green Roof installation according to roof insulation grade (non, moderate, well) and building ventilation. Hot (H), Cold (C), and Total (T) periods are considered. Adapted from Niachou et al. (2001)

Different Green Roof thickness and their corresponding energy savings were quantified in Silva et al. (2016). More into detail, extensive, semi-intensive and intensive green roofs were considered. An extensive roof is characterized by a thin growing medium (6–25 cm), small plants, light and minimal maintenance. Intensive green roofs are heavier and thicker (15–70 cm), require more maintenance and support a wider variety of plants. Semi-intensive roofs show intermediate characteristics. Results presented in Table 4 come from a simulation which was calibrated with data from a case study in Lisbon, Portugal. Simulations were carried out assuming different supporting roof insulation levels (thicknesses from 0 to 8 cm of Extruded polystyrene (XPS) with a thermal conductivity of = 0.040 W/m °C were considered). This helps understanding the energetic benefits of installing Green Roofs in old buildings, usually with no insulation, and in newer and well insulated ones. Annual energy savings comparing conventional black and white roofs with the implementation of green roofs (extensive, semi-intensive and intensive) both during heating (H) and cooling (C) periods and along the year (A) are detailed in Table 4.

	GREEN ROOF VS BLACK ROOF									GREEN ROOF VS WHITE ROOF								
	EXTENSIVE			SEMI-INTENSIVE			INTENSIVE			EXTENSIVE			SEMI-INTENSIVE			INTENSIVE		
XPS (cm)	H	C	A	H	C	A	H	C	A	H	C	A	H	C	A	H	C	A
YEARLY ENERGY SAVINGS (KWh/m^2/year)																		
0	16.0	4.4	6.2	14.1	39.9	17.5	16.2	50.2	21.5	43.0	-41.9	-1.3	41.1	-6.4	10.0	43.2	3.9	14.0
2	9.3	-8.8	-0.2	6.1	16.4	7.3	6.4	24.1	9.9	21.6	-32.1	-4.4	18.4	-6.9	3.1	18.7	0.8	5.8
4	6.4	-7.1	-0.5	3.6	11.4	4.9	3.5	17.1	6.7	14.2	-23.8	-3.8	11.4	-5.3	1.6	11.3	0.4	3.5
8	3.5	-5.1	-0.7	1.8	6.8	2.8	1.4	11.1	4.1	8.2	-16.0	-2.9	6.5	-4.1	0.5	6.1	0.2	1.9
ENERGY SAVINGS IN PERCENTAGE (%)																		
0	48	7	21	42	67	59	48	84	72	71	-315	-6	68	-48	45	71	29	63
2	52	-26	-1	34	48	44	36	71	59	71	-297	-35	61	-64	25	62	7	46
4	53	-26	-4	30	41	38	29	62	53	72	-218	-40	58	-49	17	57	4	37
8	53	-23	-7	27	31	30	21	50	44	73	-142	-41	58	-36	8	54	2	26

Table 2.6: Energy savings due to Green Roof installation comparing different supporting roof insulation levels (XPS thickness) and colour (black and white) and different Green Roof thickness (extensive, semi-intensive and intensive). Adapted from Silva et al. (2016).

Finally, Ascione et al. (2013) compared different roof solutions with different plant species and different climatic conditions through Europe (Table 5). Energy savings were simulated at a building level, and the Green Roof considered had 986 m^2. Set-point temperatures established were 26ºC during cooling period (C) and 20ºC during heating (H) period. The effect of rainfall was also considered in this study.

Tenerife		Sevilla		Rome		Amsterdam		London		Oslo	
H	C	H	C	H	C	H	C	H	C	H	C

YEARLY ENERGY SAVINGS (KWh/m^2/year)												
Cool roof	0.0	12.8	-1.0	9.8	-2.2	8.8	-3.4	3.7	-3.5	3.9	-4.9	3.4
Sedum short	0.0	1.2	0.5	-0.7	1.2	0.1	2.7	0.0	2.9	-0.3	6.1	-0.3
Sedum tall	0.0	8.4	0.2	5.4	1.0	3.8	3.6	1.2	3.1	1.6	6.5	1.4
Grass lawn	0.0	7.0	0.2	5.4	0.9	3.2	3.3	0.9	2.8	1.3	6.1	1.2
Short gramineous	0.0	8.4	0.2	5.8	0.8	3.8	3.2	1.1	2.7	1.4	6.0	1.2
Tall gramineous	0.0	11.5	0.0	8.5	0.4	5.7	2.5	2.1	2.0	2.5	5.5	2.2
ENERGY SAVINGS IN PERCENTAGE (%)												
Cool roof	0	12	-60	13	-29	12	-8	15	-9	16	-4	16
Sedum short	0	1	29	-1	16	0	6	0	8	-1	6	-1
Sedum tall	0	8	12	7	13	5	8	5	8	7	6	7
Grass lawn	0	7	14	7	12	5	7	4	7	5	6	6
Short gramineous	0	8	14	7	11	5	7	5	7	6	5	6
Tall gramineous	0	11	-3	11	5	8	6	9	5	10	5	11

Table 2.7: Energy savings due to Green Roof installation comparing different plant species and climatic conditions through Europe. Adapted from Ascione et al. (2013)

OPTION 2: ESTIMATION FROM WALL THERMAL TRANSMITTANCE AND TEMPERATURE MEASUREMENT

For the Green Wall and Green Roof, energy savings could also be estimated though the measurement of wall/roof thermal transmittance reduction.

The thermal transmittance (U-value) is the rate of heat transfer per unit area, measured in W/m^2·K. To estimate energy savings, wall/roof U-values should be known before and after the intervention (before and after green roof/wall implementation). To obtain the U-value before the intervention, some approaches can be considered:

2a. Direct measurement by means of a heat flux sensor

2b. Estimation based on wall materials thickness and their thermal conductivity

2c. Estimation through bibliographic reports

The thermal resistance associated to the implementation of the green solution is dependent on its configuration and the materials used. To calculate the U-value of the building envelope after Green Infrastructure implementation the thermal resistance associated to the Green wall/roof (Table 6) will be added to the resistance of the wall before the intervention. In Table 6 the specific U-values of the solutions implemented in Valladolid are provided. This values correspond to theoretical estimations which include a conventional wall/roof envelope and the elements contained in the green wall/roof. However, the effect of vegetation is not considered.

Partner	Green Infrastructure	Thermal resistance	Thermal transmittance
		m^{2}K/W	W/m^{2}K
Singular Green	Green Façade	XXXXX	XXXXX
Singular Green	Green Roof - Fitum	0.4488	2.2282
Singular Green	Green Roof - Rizoma	1.297	0.7710

Table 2.8: Thermal resistance and transmittance of the NBS implemented in Valladolid and generating energy savings due to building insulation. Adapted from Singular Green (2018)

2a. Direct measurement by means of a heat flux sensor

Thermal transmittance can be directly measured by means of a heat flux sensor such as the one provided by Greenteg (https://www.greenteg.com/U-Value/). Two temperature sensors are also included. The approach they use is standardized in ISO 9869, ASTM C1046 and ASTM C1155 (Figure 1). Although the direct measurement of wall's U-value is the most accurate option, sensors installation requires a wall spot through which sensors wiring connect outdoor and indoor temperature sensors. This physical connection between outdoor and indoor sensors may not be possible due to building structure.

Figure 2.1: Heat flux sensor and two temperature sensors to measure U-value of a building envelope

2b. Estimation based on wall materials thickness and their thermal conductivity

For complex building envelopes, thermal transmittance can be also estimated by calculating the added thermal resistance as indicated below:

$$\mathrm{U-value} = \frac{1}{R - value_{tot}}$$

$$R - value_{tot} = R_{si} + \sum R - value_i + R_{se}$$

$$R - value_i = \lambda_i \cdot d_i$$

Where,

U-value → Thermal transmittance of the building envelope (wall/roof) [W/m^{2}K]

R-value$_{tot}$ → Thermal resistance of the building envelope (wall/roof) [m^{2}K/W]

R_{si} → Internal surface resistance [m^{2}K/W]

R_{se} → External surface resistance [m^2K/W]

R-value$_i$ → Thermal resistance of the single layer [i] made of a specific material [m^2K/W]

λ_i → thermal conductivity the material [i] [W/mK]

d_i → thickness of the material [i] [m]

Thermal conductivities can be found in official Data sets provided by most governments. In Spain, the Ministry of Development (Ministerio de Fomento) provides the Computing Catalogue of Constructive Elements (Catálogo informático the elementos constructivos) included in the Technical Code of edification (Código técnico de la edificación) (https://itec.cat/cec/). In this catalogue, the thermal conductivity of most of the construction materials can be found.

Internal and external surface resistances (R_{si} and R_{se}) are established in EN ISO 6946:2007 Building components and building elements (Table 6).

Surface Resistance	Direction of heat flow		
(m^2K/W)	Upwards	Horizontal	Downwards
R_{si}	0.10	0.13	0.17
R_{se}	0.04	0.04	0.04

Table 2.9: Internal and external surface resistances.

2c. Estimation through technical catalogues

Thermal transmittance of most common building envelopes (including all their corresponding materials) can be also found in official Data sets, as well as thermal conductivities, in Computing Catalogue of Constructive Elements (Catálogo informático the elementos constructivos) included in the Technical Code of edification (Código técnico de la edificación) (https://itec.cat/cec/).

2.1 Sensor

External and internal sensors for temperature recording will be required for the estimation of energy savings. The type of sensors installed will be similar to other sensors used in the context of Urban Green Up project for the quantification of the KPI 9: "Decrease in mean or peak daytime local temperatures" (see the corresponding card).

Specific sensors for the quantification of internal and external temperatures could be avoided by considering the following values:

- Internal temperature: cooling or heating set-point in the building. Assuming temperature is homogeneous through all the indoor space.
- External temperature: using the records of the nearest temperature sensor assuming there are no significant differences between the external wall/roof temperature and the one at the sensor used.

2.2 Data processing

Once thermal transmittances are calculated before and after green solution integration (U_{before} and U_{after}) and internal and external temperatures are recorded, energy savings can be estimated by means of the following steps:

(1) Internal and external temperature conversion to Kelvin [K]

$$T\ (K) = T\ (ºC) + 273.15$$

(2) Heat loss calculation (Ø) [W]

$$Ø_{before} = NBSArea \cdot\ U_{before}\ (T_{ext} - T_{int})$$

$$Ø_{after} = NBSArea \cdot U_{after}\ (T_{ext} - T_{int})$$

Where,

$Ø_{before}$ → Heat loss before NBS implementation [W]

$Ø_{after}$ → Heat loss after NBS implementation [W]

$NBSArea$ → Green Façade or Green Roof area [m^2]

T_{ext} → External temperature [K]

T_{int} → Internal temperature [K]

(3) Energy savings calculation (ES) [kWh/year]
In the calculation of order to consider the effect of shade on energy savings a shade factor (SF < 1) will be considered.

$$ES = \left(Ø_{before} - Ø_{aftre}\right) \cdot \frac{1KW}{1000W} \cdot \frac{8760\ h}{1\ year} \cdot SF$$

2.3 Results

Results will be the ones obtained by calculation through the method explained in Data processing. In that case, energy savings are calculated through a period of 1 year; if other periods want to be considered, Step (3) of the Energy Savings calculation procedure can be adapted.

OPTION 3: DIRECT MEASUREMENT

3.1 Method

3.1.1 **MEASURED KPI**
This KPI is calculated from measured data using a methodology defined by URBAN GreenUP Project.

3.1.2 BACI (Before, After, Control, Impact)
Building energy consumption will be measured for heating and cooling during cold and warm periods, respectively and before and after interventions. Energy consumptions during pre- and post-intervention scenarios and will be compared between periods of analogous meteorological conditions.

3.1.3 Null hypothesis
There is no difference in energy consumption for heating and cooling between periods of comparable meteorological conditions pre and post interventions.

3.2 Sensor

Energy consumption for heating and cooling will be measured depending on the type of cooling and heating installation of each building. Every energy source consumed for this purpose (i.e. electricity, gas, central heating oil, etc.) will be measured independently.

In the case there is no possibility to install a sensor to specifically measure the energy consumption of the cooling and heating electrical lines, building owners will be asked to request to their corresponding energy companies the load curve in which the entire building hourly consumption is specified.

EXAMPLES

An example of a sensor with the capacity to measure the consumption of an electrical line is provided (Figure 2). However, other types of sensors can be considered as function of the heating and cooling system of the buildings where NBS are implemented.

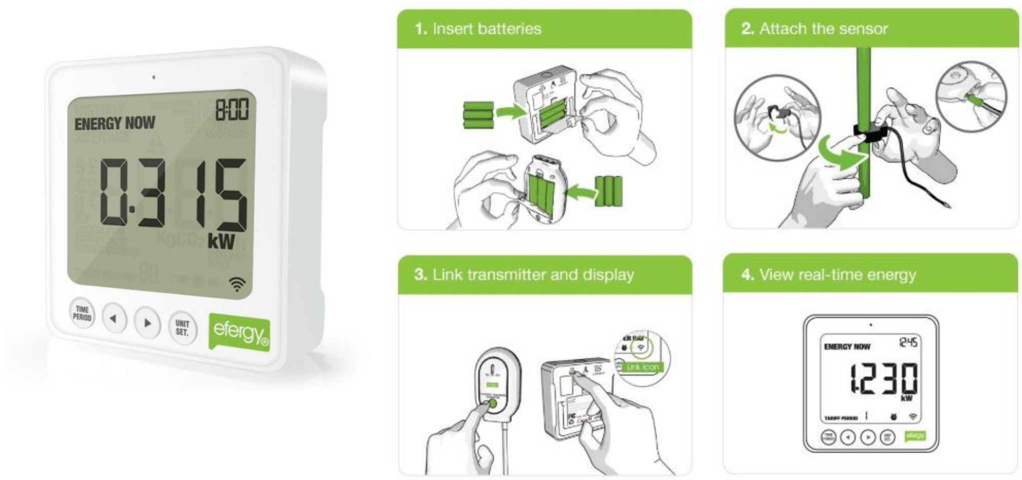

Figure 2.2: E2 Classic electrical meter. Source: https://efergy.com

E2 Classic electrical meter (Figure 2) shows in the display and records data regarding electricity consumption in an electrical line. The sensor incorporates an USB port from which data can be downloaded. It has also the capacity to convert the electrical consumption into carbon consumption (Efergy, 2018).

3.3 Measurements

Daily energy consumption for heating and cooling

3.3.1 Unit of measurement

Electricity - kWh/day – Kilowatt hours per day of energy consumed for heating and cooling

However, units of measurement will depend on the energy source consumed for heating and cooling (see Table 7).

Fuel	Reference unit
Electricity	KWh
Natural Gas	m^3 (gas)
Diesel Oil	Litre

Propane	Kg (liquid)
Butane	Kg (liquid)
Liquefied petroleum gas	Litre
Biogas	m^3 (gas)

Table 2.10: Units of measurement regarding the energy source used for cooling and heating

3.3.2 Calibration/Verification

Electrical meter will be calibrated according to manufacturer specifications.

3.3.3 Study sites

Measurement sites will be the buildings at which NBS are implemented (Green Wall and Green Roof).

3.3.4. Number of study sites

According to the cooling and heating systems configuration.

3.3.5 Number of samples

Continuous monitoring in the selected points every day.

3.3.5 Data sampling

Continuous monitoring in the selected points every day.

<u>Data example</u>

Figure 2.3: Example of the data provided by the E2 Classic electrical meter. Source: https://efergy.com

<u>3.4 Data processing</u>

Mean energy consumptions (daily, weekly or monthly) will be calculated for each energy source at each specific building taking into account all the gathered measurements.

The energy consumption measurement units will be different depending on the energy source (see Table 7). To normalize these values, they will be converted to kWh regardless the energy source and according to the following conversion factors established by the Spanish Institute of Energy (IDAE, 2017) (Table 8).

Fuel	Reference unit	KWh/Reference unit
Electricity	KWh	1
Natural Gas	m^3 (gas)	11.6
Diesel Oil	Litre	10.3
Propane	Kg (liquid)	12.9
Butane	Kg (liquid)	12.6
Liquefied petroleum gas	Litre	6.4
Biogas	m^3 (gas)	11.6

Table 2.11: Conversion factors from different energy sources to KWh. Source: IDAE (2017)

To calculate energy savings, these mean normalized values of consumed energy will be compared during periods of analogous meteorological conditions (i.e. temperature, humidity, rainfall) before and after NBS implementation.

Comparable periods of time before and after the interventions will be evaluated by:

a. Duration: comparable period must have similar duration (i.e. 4 months each)
b. Meteorological conditions: data to evaluate the comparability between periods will be taken from the State Agency of Meteorology (Agencia Estatal de Meteorologia, AEMET) which provides hourly recordings for temperature, humidity, wind and rainfall.

According to this, the following information will be required for the quantification of this KPI (Table 9):

Parameter	Unit	Source
Temperature	ºC	State Agency of Meteorology (AEMET) http://www.aemet.es (Ministry of Ecological Transition, *Ministerio para la transición ecológica)*
Humidity	%	
Wind	Km/h	
Rainfall	mm	

Table 2.12: Information required for the determination of comparable climate period before and after intervention

Once comparable periods are established, energy savings (ES) at a certain period of time (pi) will be calculated according to the following expression (E1):

$$\boldsymbol{ES_{pi}} = Energy\ consumption\ before\ NBS\ implementation_{\ pi} - Energy\ consumption\ after\ NBS\ implementation_{\ pi}$$

__3.5 Results__

Results of this KPI are the ones calculated with E1 and E2.

CARBON SAVINGS

Finally, carbon savings will be estimated converting the energy savings into CO_2 by means of conversions factors established by the Spanish Institute of Energy (IDAE, 2017) (Table 10):

Fuel	Conversion factor (CF_{CO2})

	Kg CO_2 / kWh final energy
Electricity	0.357
Natural Gas	0.252
Diesel Oil	0.311
Liquefied petroleum gas	0.254
Carbon	0.472
No densified biomass	0.018
Densified biomass (pelleted)	0.018

Table 2.13: Conversion factors from different energy sources to KWh. Source: IDAE (2017)

Taking into account these conversion factors, the estimation of the carbon savings (CS_{pi}) of a certain period of time (pi) will be calculated according to the following expression (E2):

$$CS_{pi} = ES_{pi} \cdot CF_{CO2} \qquad [\text{kg } CO_2]$$

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3 CHALLENGE 2: WATER MANAGEMENT MONITORING PROCEDURES

3.1 Biophysical KPIs

Run-off coefficient in relation to precipitation quantities

This indicator is included in the list of indicators for *Challenge 2. Water Management* from *"An impact evaluation framework to support planning and evaluation of nature-based solutions projects"* document. This indicator has been mainly defined for **Urban SUD´s** but it could also be applied to scale the impact of other types of NBS on runoff reduction efficiency.

NBS TYPES

SUDs	SUDs are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies. SuDS take inspiration from natural features and processes like uptake of water by plants, soil infiltration, pools, ponds, marshes, wetlands, springs, streams and rivers.
Natural Wastewater Treatment Plant	Wastewater treatment plant based on the combination of natural treatment systems, such as constructed wetlands and ponds, following the concept of waterharmonica. The flow-sheet can be completed by sand filtration and chlorination (disinfection) for the later water reuse. These systems provide more than just simple purification, because while treating the water, they are also regulating temperature and providing valuable habitats for biodiversity.
Rain Gardens	A rain garden is a bioretention shallow basin designed to collect, store, filter and treat water runoff. To optimise its functions, it must include a porous soil mixture, native vegetation and some hyperaccumulator plants, capable of phytoremediation.
Floodable park	Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits

	that floodable parks can provide are among others, delivering amenity and biodiversity benefits.
Green Parking pavements	NBS destined to replace grey urban pavement with 50% vegetal soil and high drainage capacity. This kind of pavements has gaps, which will be filled with smart soil and with specific creeping grass species with a short growing and minimum maintenance and are appropriate for bikes, pedestrian and motor vehicles.

Table 3.1: NBS types related to Run-off coefficient in relation to precipitation quantities

METHOD

Sensor/Software

No sensor is required. Data are acquired by statistic and rainfall and soil available information in each intervention.

The runoff reduction will be compared before and after the installation of the NBS to know if the intervention has influenced the study area.

Spreadsheet software can be required.

METHODOLOGY

This is an estimated KPI using a cost-effective hydrologic model based on the Soil Conservation Service Curve Number (SCS-CN) method (*NRCS, 1986*).

The SCS-CN model is able to estimate the volume of runoff reduction by urban green spaces in each of the different sites where NBS´s will be allocated. The SCS-CN method has been used for a wide range of watershed areas, ranging from 0.25 ha to 1000 km^2, applied to various climatic zones and functions well both in natural or urban areas. *(Boughton, 1989; Ebrahimian et al., 2012; El-Hames, 2012; Baker and Miller, 2013).*

This model is based on empirical studies of ungauged watersheds to estimate runoff from rainfall events (*NRCS, 1986*). Minimal input data are needed to simulate direct surface runoff. Specifically, the calculations require only rainfall abstraction, without considering other complex factors such as groundwater recharge and baseflow (*Yao et al., 2015*).

Three parameters are used to calculate surface runoff: rainfall depth, initial abstraction of the rainfall, and the potential maximum storage of the soil (*Boughton, 1989*). The equations for the SCS-CN model are as follows (*NRCS, 1986*):

$$Q = \begin{cases} (P - I_a)^2/(P - I_a + S), & P \geq I_a \\ 0, & P < I_a \end{cases}$$

$$S = \frac{25,400}{CN} - 254$$

$$I_a = \lambda \cdot S$$

Where:

- Q: the runoff depth (mm).
- P: the rainfall depth (mm).
- I_a: the initial abstraction of the rainfall (mm).
- S: represents potential maximum soil−water capacity.
- λ: The initial abstraction coefficient which is a constant, usually defined as 0.2 (*El-Hames, 2012; Kadam et al., 2012; Singh et al., 2013*).
- CN: is a dimensionless parameter, ranging from 0 to 100. The US Natural Resources Conservation Service (NRCS) has developed CN values for various land-cover categories based on their hydrologic characteristics.

Daily rainfall data from each intervention site are needed to calculate runoff. In case of the interventions developed in Spain, rainfall data can be obtained from the *AEMET* Service.

Determination of the CN value for the SCS-CN model mainly depends on the corresponding hydrologic soil group (HSG), land-cover type, and antecedent moisture condition (AMC) of each intervention site. Based on the minimum infiltration rates for various soil textures, NRCS divides soils into four HSGs (A, B, C, and D) (*NRCS, 1986*). Group A has the lowest runoff potential and the highest infiltration capacity, whereas soils in Group D have the highest runoff potential and the lowest infiltration capacity. Furthermore, NRCS classified AMCs as “dry conditions” (AMC I), “moderate/normal conditions” (AMC II), and “wet conditions” (AMC III) to represent the relative moisture of the pervious surfaces prior to the rainfall event (*NRCS, 1986*). Therefore, the determination of the AMC of each rainfall event will depend on rainfall amount during the previous 5 days and the season. Finally, the CN values might be determined using the TR-55 look-up tables (*NRCS, 1986*). In this meaning, a CN of 98 could be assigned to represent the hydrologic characteristics of 100% impervious surfaces for the runoff reduction calculation (*Yao et al., 2015*).

Runoff reduction calculation

Since the reduction of surface runoff is achieved by replacing fully impervious surfaces with urban green spaces, two variables have been defined to evaluate the potential hydrologic benefits of runoff reduction: the total amount of runoff reduction due to urban green spaces (ΔV) and the runoff reduction coefficient (Cr).

- **DV**, as defined by *Zhang et al., 2012*, is used to represent differences in total runoff reduction volume and characterize the general benefit provided by URBAN GreenUP interventions in terms of reducing rainfall-runoff.

- **Cr** is similar to the runoff coefficient (runoff depth/rainfall depth) (*Weng, 2001; Costa et al., 2003*) and is generated by dividing DV by the total amount of rainfall in a specific area. Unlike DV, Cr represents differences in runoff reduction efficiency.

DV is calculated as follows:

$$\Delta V = \sum_{i=1}^{3} 0{,}001x(Q_{b-}Q_i)xA_i$$

Where:

- DV: is the runoff reduction (m^3) due to the URBAN GreenUP intervention assessed.
- I: the type of urban green space within the intervention considered.
- Q_b: the runoff depth (mm) generated from a 100%impervious surface with a CN value of 98.
- Q_i: the runoff depth (mm) from urban green space type I within the intervention considered.
- A_i: the area (m^2) of urban green space type I within the intervention assessed.

Cr is calculated as follows:

$$C_r = \Delta V x (0{,}001 x P x A)^{-1}$$

Where:

- Cr: the runoff reduction coefficient,
- P: the daily rainfall depth (mm),
- A: the area (m2) of the intervention considered.

Results

The calculated values of DV and Cr will be assessed and then compared quantitatively in two scenarios (before and after the installation of the NBS) for each intervention.

A higher DV value means greater potential hydrologic benefits provided by the NBS studied, whereas a higher Cr indicates less need to improve future urban rainwater management in a specific area.

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Flood peak reduction. Increase in time to peak (%)

INTRODUCTION

This indicator is included in the list of indicators for *Challenge 2. Water Management* from *"An impact evaluation framework to support planning and evaluation of nature-based solutions projects"* document. This indicator has been mainly defined for **Urban SUD´s** but it could also be applied to scale the impact of other types of NBS on flow peak reduction and increase in time to peak.

NBS: TYPES:

- SUDs
- Natural Wastewater Treatment Plan
- Rain Gardens
- Floodable park
- Green Parking pavements

METHOD:

Sensor/Software

No sensor is required.

Needed data to run the model will be acquired though rainfall information provided by *AEMET*; digital land cover maps from *CORINE land cover project;* and topography from digital elevation models (DEM) of each intervention.

The flood peak reduction and the increase in time to peak estimations will be compared before and after the installation of the NBS to know if the intervention has influenced the study area.

In order to estimate this KPI, a precipitation-run-off model will be used. This type of model is included in **hydrologic software** such as *Hec HMS* (free software license)*, SWWM* (free software license)*, Mike SHE, Autocad Sewer*, among others.

METHODOLOGY

As explained in the previous paragraph, a precipitation-run-off model will be applied to assess this KPI. Main steps to build and run a precipitation-run-off model is shown below (extracted from *Hec HMS user´s manual*):

1. **Defining the Basin Model (Study Area):** The study area of the NBS considered is the entire land area draining to the stream reach or sewer point of interest. This requires that the hydrology, stormwater run-off and recharge time series are modeled at the subbasin or watershed level.

2. **Determine Precipitation Gage Weights:** Precipitation gage weights for computing basin average precipitation in the region and their location with respect to the watershed must be estimated. However, due to the relatively small size of the interventions in which this KPI will be applied, the used of a single precipitation gage weight could be valid.

3. **Parameterize the Basin Model:** According to the digital land cover maps, the hydrologic soil group and landuse shall be stablished. Moreover, hydrologic methods of computation will be required as well as the basin and subbasins physical parameters that would be involved in the method of calculation chosen according to the location of the NBS.

4. **Create a Metereologic Model:** In this step, the boundary conditions for every subbasin shall be defined at the same time as every meteorological parameter involved in our calculations such as time series data, gridded data or any other parameter, whether it were a measured or a calculated data.

5. **Create and run a simulation:** In order to create a simulation run, the metereologic model and control specifications from previous steps need to be defined in the project. A simulation run must be selected before it can be computed.

RESULTS

The calculated hydrograph for a given rainfall event will be calculated and then compared quantitatively in two scenarios (before and after the installation of the NBS) for each intervention.

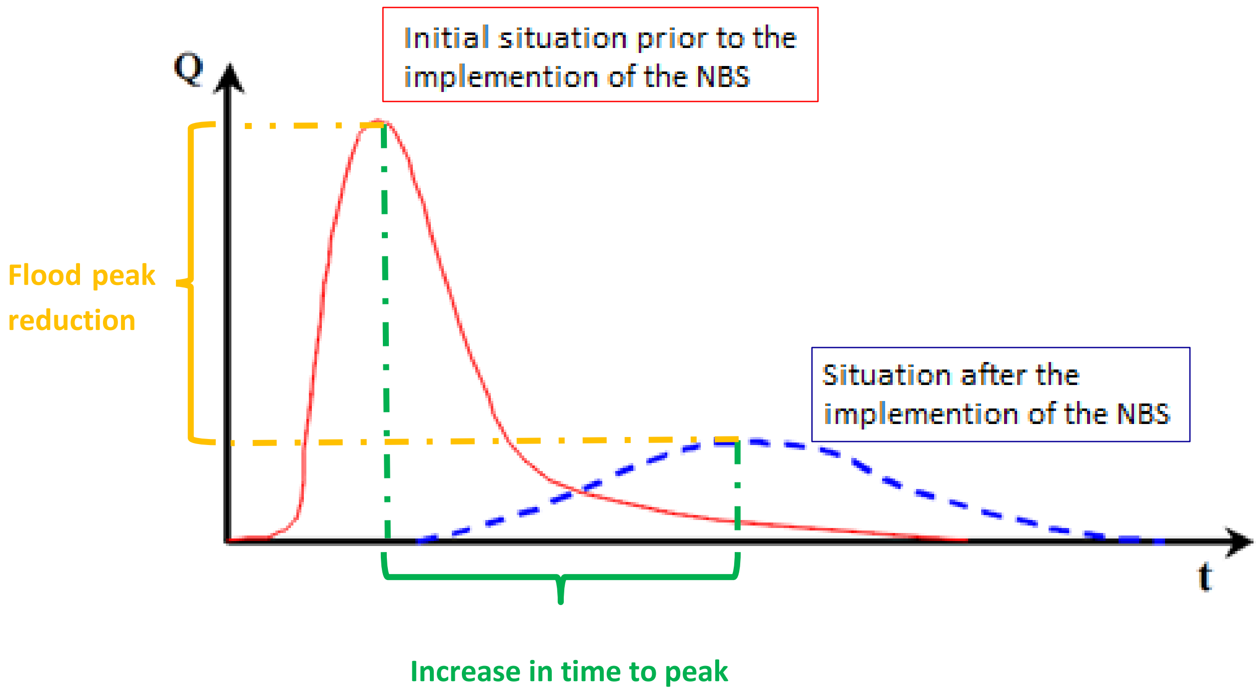

Figure 3.1: Hydrograph scheme

Flow peak reduction (shown in orange) represents the decrease in peak flow expressed in liters per second (**l/s**) between the initial situation prior to the implementation of the NBS and the situation after its implementation.

Higher values of flow peak reduction means greater potential hydrologic benefits provided by the NBS studied.

Increase in time to peak (shown in green) represents the increase in time until peak flow is reached and is expressed in terms of percentage (**%**) between the time to peak flow in the initial situation prior to the implementation of the NBS and the time to peak flow in the situation after its implementation.

Higher values of increase in time to peak flow also means greater potential hydrologic benefits provided by the NBS studied.

REFERENCES

- AEMET (Agencia Estatal de Meteorología): http://www.aemet.es/es/portada.
- Hec HMS user´s manual: http://www.hec.usace.army.mil/software/hec-hms/documentation/HEC-HMS_Users_Manual_4.2.pdf

Reduction of drought risk

INTRODUCTION

The traditional classification of drought types has evolved primarily from the meteorological and hydrological sciences (meteorological and hydrological droughts) to reflecting agricultural and socio-economic impacts. Today, a myriad of drought types exist with few accepted definitions:

- A meteorological drought (hazard): a temporary, negative and severe deviation from the average precipitation values for a significant period of time across a river basin or region.
- A blue-water drought (hazard): an unusual and significant deficiency of groundwater, stream flow, or lake storage.
- A green-water drought (hazard): an unusual and significant deficiency in water stored in or on top of the soil or vegetation.
- Drought risk: an emergent property of the human and natural system, reflecting the interaction between climate (meteorological drought), the hydrological response of the basin (blue-water drought and green-water drought) and the vulnerability of the people, ecosystems and economies exposed to it. Drought risk reflects two components: the chance that a drought hazard will occur and the magnitude of the associated impacts.

Another related concept, of importance in the city level, is *water scarcity* which is defined as a situation where insufficient water resources are available to satisfy long-term average requirements. It refers to long-term water imbalances, where the availability is low compared to the demand for water, and means that water demand exceeds the water resources exploitable under sustainable conditions. While the terms 'water scarcity' and 'drought' are commonly used interchangeably, they are quite different phenomena affected water management practices and natural causes respectively.

Some NBS in Urban GreenUP Project are addressed to the proper management of water in the cities (i.e., rainwater or wastewater). Concretely, some of the planned actions may increase the resources of water in the local level. For example, the reclaimed water in the NWTP (or electrowetland) might be use for the irrigation of green areas; SUDs are designed for enhancing the infiltration rate of rainwater thus, reducing the runoff and increasing the groundwater level. All these actions have a large potential to alleviate water stress in particular in water-scarce urban regions.

NBS TYPES

1. Natural wastewater treatment	Wastewater treatment plant based on the combination of natural treatment systems, such as constructed wetlands and ponds, following the concept of waterharmonica. The flow-sheet can be completed by sand filtration and chlorination (disinfection) for the later water reuse. These systems provide more than just simple purification, because while treating the water, they are also regulating

	temperature and providing valuable habitats for biodiversity.
2. Floodable park	Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits that floodable parks can provide are among others, reducing air temperature of the surroundings together with delivering amenity and biodiversity benefits.
3. Tree related actions	This NBS includes individual large street trees, as well as the larger areas of woodland in the urban fringes. Trees perform multiple functions in urban areas.
4. Green filter area	Green filter is a land application system for treating water (wastewater). It consists of a plot area, sized according to the influent to be treated, which has forests installed and is irrigated with wastewater. These systems provide more than just simple purification, because while treating the water, they are also regulating temperature and producing biomass with high economic value.
5. Rain Garden	A rain garden is a bioretention shallow basin designed to collect, store, filter and treat water runoff. To optimise its functions, it must include a porous soil mixture, native vegetation and some hyperaccumulator plants, capable of phytoremediation.
6. SUDs	SUDS are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies. SuDS take inspiration from natural features and processes like uptake of water by plants, soil infiltration, pools, ponds, marshes, wetlands, springs, streams and rivers. SuDS work by holding rainwater back, treating pollution and releasing it slowly, without overwhelming the watercourse or sewer system into which it flows, thereby reducing flooding.
7. Green parking pavements	NBS destined to replace gray urban pavement with 50% vegetal soil and high drainage capacity. This kind of pavements has gaps, which are filled with smart soil and with specific creeping grass species with a short growing

	and minimum maintenance and are appropriate for bikes, pedestrian and motor vehicles.
8. Electrowetland	An Electrowetland is a natural wastewater treatment system that generates electricity from the oxidation of the organic matter. It is based on a conventional Horizontal Subsurface Flow Constructed Wetland (HSSF CW) in which electrodes are introduced. Therefore, it consists on a planted and permanently flooded gravel basin in which wastewater flows horizontally from one side to the other of the system crossing the electrode layer.

Table 3.2: NBS types related to drought risk

METHOD

As explained in the introduction section, the reduction of drought risk in the frame of Urban GreenUP project can be expressed as a reduction of the "level of water stress". This indicator provides an estimate of pressure by all sectors on the country/region's renewable freshwater resources (UNWater). It can be also adapted to the local level. A low level of water stress indicates a situation where the combined withdrawal by all sectors is marginal in relation to the resources, and has therefore little potential impact on the sustainability of the resources or on the potential competition between users. A high level of water stress indicates a situation where the combined withdrawal by all sectors represents a substantial share of the total renewable freshwater resources, with potentially larger impacts on the sustainability of the resources and potential situations of conflicts and competition between users.

The indicator is computed based on three components, as described below:

1. **Total renewable freshwater resources (TRWR)** are expressed as the sum of (a) internal renewable water resources (IRWR) and (b) external renewable water resources (ERWR). The term “water resources” is understood here as freshwater resources.
2. **Total freshwater withdrawal (TFWW)** is the volume of freshwater extracted from its source (rivers, lakes, aquifers) for agriculture, industries and services. It is estimated at the country/region level for the following three main sectors: agriculture, services (including domestic water withdrawal) and industries. Freshwater withdrawal includes primary freshwater (water not withdrawn before), secondary freshwater (water previously withdrawn and returned to rivers and groundwater, such as discharged treated wastewater and discharged agricultural drainage water) and fossil groundwater. It does not include direct use of non-conventional water, i.e. direct use of treated wastewater, direct use of agricultural drainage water and desalinated water.
   TFWW is in general calculated as being: [the sum of total water withdrawal by sector] minus [direct use of wastewater, direct use of agricultural drainage water and use of desalinated water]. In formula:
   $$TFWW = \sum ww_s - \sum du_u$$
   where:
   TFWW= Total freshwater withdrawal

ww_s= Water withdrawal for sector “s”. s = agriculture, industry, energy, etc. du_u= Direct water use from source “u”. u = direct use of wastewater, direct use of agricultural drainage water and use of desalinated water.

3. **Environmental flow requirements (EFR)** are the quantities of water required to sustain freshwater and estuarine ecosystems.

Data

In order to be able to disaggregate the indicator, it would be advisable that the components described above are in turn computed by aggregating the variables per subsector, as follows:

Total renewable water resources (km³/year)

Total Renewable Water Resources (TRWR) are the sum of internal and external renewable water resources.

Internal Renewable Water Resources (IRWR) (km³/year)

The long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation (resources produced within the territory), taking into consideration the overlap between them.

External Renewable Water Resources (ERWR) (km³/year)

The part of the country/region’s renewable water resources that is not generated within the country. The ERWR include inflows from upstream countries (groundwater and surface water), and part of the water of border lakes or rivers. It takes into consideration the quantity of flows reserved to upstream and downstream countries/regions through agreements or treaties.

Source of data:

Regional level: Duero River Basin Management Plan. Confederación Hidrográfica del Duero.

Local level: AQUAVALL. Municipality of Valladolid.

Agricultural water withdrawal (km³/year)

Annual quantity of self-supplied water withdrawn for irrigation, livestock and aquaculture purposes. It includes water from primary renewable freshwater resources and secondary sources of water, as well as water from over-abstraction of renewable groundwater or withdrawal of fossil groundwater, direct use of agricultural drainage water and (treated) wastewater, and desalinated water.

Source of data: Duero River Basin Management Plan. Confederación Hidrográfica del Duero.

Industrial water withdrawal (km³/year)

Annual quantity of water withdrawn for industrial uses. It includes water from primary renewable freshwater resources and secondary sources of water, as well as over-abstraction of renewable groundwater or withdrawal of fossil groundwater and potential use of desalinated water or direct use of (treated) wastewater. This sector refers to self-supplied industries not connected to the public distribution network.

Source of data:

Regional level: Duero River Basin Management Plan. Confederación Hidrográfica del Duero.

Local level: AQUAVALL. Municipality of Valladolid.

Services water withdrawal (km³/year)

Annual quantity of water withdrawn primarily for the direct use by the population. It includes water from primary renewable freshwater resources and secondary sources of water, as well as potential over-abstraction of renewable groundwater or withdrawal of fossil groundwater and the potential use of desalinated water or direct use of treated wastewater. It is usually computed as the total water withdrawn by the public distribution network. It can include that part of the industries, which is connected to the municipal distribution network.

Source of data:

Regional level: Duero River Basin Management Plan. Confederación Hidrográfica del Duero.

Local level: AQUAVALL. Municipality of Valladolid.

Environmental flow requirements

Determination of the EFR can be done by application of various methods ranging from a simple hydrological approach to comprehensive holistic models. The approach should progressively take into account the variability of flow regime during time and space, leading to the most recent Hydraulic /Habitat models (Parasiewicz, 2007)

Source of data: Regional level: Duero River Basin Management Plan. Confederación Hidrográfica del Duero.

<u>Calculation</u>

The indicator is calculated with the following formula:

$$Water\ Stress\ (\%) = \frac{TFWW}{TRWR - EFR} * 100$$

Where:

- TFWW=Total freshwater withdrawn, where year to which it refers will be provided
- TRWR=Total renewable freshwater resources
- EFR= Environmental flow requirements

<u>Results</u>

The data for this indicator should be collected annually. However, a reporting period up to three years can still be considered acceptable.

This reporting periodicity allows the assessment of the effectiveness of NBS implemented in the framework of Urban Green UP and their impact on the reduction of water scarcity associated to drought and water shortages.

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Absorption capacity of green surfaces, bioretention structures and single trees

INTRODUCTION

The use of urban greenspace, in particular urban forests, is increasingly being identified as a tool to reduce runoff and so mitigate the negative effects of urbanization upon the hydrology of urban areas (Bartens *et al*., 2008). Rainwater which lands on trees either evaporates to the air or drips down to the ground below, where it can soak into the soil. Surface water from nearby areas can also flow into the permeable area around the trees, which further increases the amount of water that can soak away and reduces demand on stormwater drains.

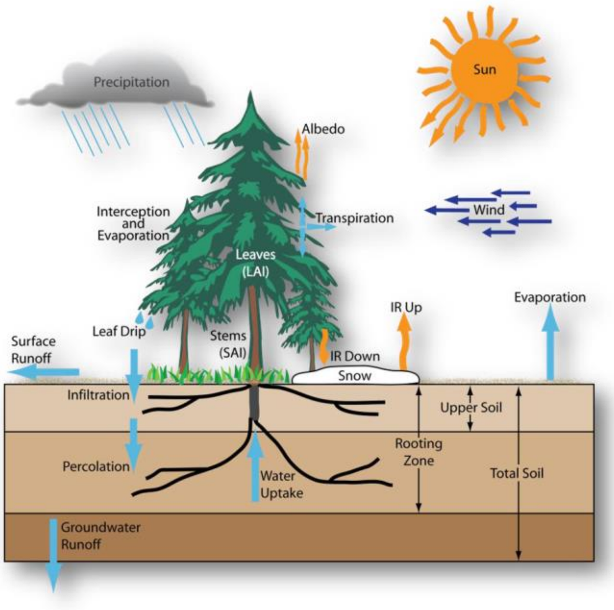

Figure 3.2: Water balance in green areas (Source: USGS)

The absorption capacity of a green area /NBS is then related to the soil infiltration and retention capability and the interception of the rainfall and evapotranspiration by the vegetation.

This indicator can be applied at urban/street/building scale depending on the scale of intervention of the NBS to be assessed.

NBS TYPES

1. Natural wastewater treatment	Wastewater treatment plant based on the combination of natural treatment systems, such as constructed wetlands and ponds, following the concept of waterharmonica. The flow-sheet can be completed by sand filtration and chlorination (disinfection) for the later water reuse. These systems provide more than just simple purification, because while treating the water, they are also regulating temperature and providing valuable habitats for biodiversity.
2. Floodable park	Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits that floodable parks can provide are among others, reducing air temperature of the surroundings together with delivering amenity and biodiversity benefits.
3. Tree related actions	This NBS includes individual large street trees, as well as the larger areas of woodland in the urban fringes. Trees perform multiple functions in urban areas.
4. Green filter area	Green filter is a land application system for treating water (wastewater). It consists of a plot area, sized according to the influent to be treated, which has forests installed and is irrigated with wastewater. These systems provide more than just simple purification, because while treating the water, they are also regulating temperature and producing biomass with high economic value.
5. Rain Garden	A rain garden is a bioretention shallow basin designed to collect, store, filter and treat water runoff. To optimise its functions, it must include a porous soil mixture, native vegetation and some hyperaccumulator plants, capable of phytoremediation.

6. SUDs	SUDS are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies. SuDS take inspiration from natural features and processes like uptake of water by plants, soil infiltration, pools, ponds, marshes, wetlands, springs, streams and rivers. SuDS work by holding rainwater back, treating pollution and releasing it slowly, without overwhelming the watercourse or sewer system into which it flows, thereby reducing flooding.
7. Green parking pavements	NBS destined to replace gray urban pavement with 50% vegetal soil and high drainage capacity. This kind of pavements has gaps, which are filled with smart soil and with specific creeping grass species with a short growing and minimum maintenance and are appropriate for bikes, pedestrian and motor vehicles.
8. Electrowetland	An Electrowetland is a natural wastewater treatment system that generates electricity from the oxidation of the organic matter. It is based on a conventional Horizontal Subsurface Flow Constructed Wetland (HSSF CW) in which electrodes are introduced. Therefore, it consists on a planted and permanently flooded gravel basin in which wastewater flows horizontally from one side to the other of the system crossing the electrode layer.

Table 3.3: NBS types related to absorption capacity of urban green areas.

METHOD

Two methods are proposed for measuring this KPI: one is an estimation and the second supposes a direct measure of the water runoff.

Method 1

This is an estimated KPI using the water balance approach to calculate the absorption capacity of the NBS by comparing precipitation and runoff data for watersheds. Concretely, the difference between the rainfall in a storm event (mm/m^2) and the runoff produced (mm/m^2) is the water retained by the green/vegetated area. This KPI is directly related to KPI 16 *RUN-OFF COEFFICIENT IN RELATION TO PRECIPITATION QUANTITIES* as the estimation of the runoff is based on the on the Soil Conservation Service Curve Number (SCS-CN) method (*NRCS, 1986*). This common methodology facilitates the evaluation of the efficiency of the NBS implemented (after and before).

Meteorological data (daily rainfall and temperature) can be obtained directly from the Spanish Meteorological Agency- *AEMET*. Rainfall rate and rainfall event timings shall be recorded, if possible. Temperature will also be recorded. If data is not available from the official network of meteorological stations of the National Agency, then a simple meteorological station will be place in the surroundings of the NBS to be monitored.

As mentioned above, the surface runoff is calculated according to the Soil Conservation Service Curve Number (SCS-CN) method (*NRCS, 1986*). The runoff curve number is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area.

The runoff curve number is based on the area's hydrologic soil group, land use, treatment and hydrologic condition. Three parameters are used to calculate surface runoff: rainfall depth, initial abstraction of the rainfall, and the potential maximum storage of the soil (*Boughton, 1989*). The equations for the SCS-CN model are as follows (*NRCS, 1986*):

$$Q = \begin{cases} (P - I_a)^2/(P - I_a + S), & P \geq I_a \\ 0, & P < I_a \end{cases}$$

$$S = \frac{25,400}{CN} - 254$$

$$I_a = \lambda \cdot S$$

Where:

- Q: the runoff depth (mm).
- P: the rainfall depth (mm).
- I_a: the initial abstraction of the rainfall (mm).
- S: represents potential maximum soil–water capacity.
- λ: The initial abstraction coefficient which is a constant, usually defined as 0.2 (*El-Hames, 2012; Kadam et al., 2012; Singh et al., 2013*).
- CN: is a dimensionless parameter, ranging from 0 to 100. The US Natural Resources Conservation Service (NRCS) has developed CN values for various land-cover categories based on their hydrologic characteristics. The lower the curve number, the more permeable the soil is.

As can be seen in the curve number equation, runoff cannot begin until the initial abstraction has been met. It is important to note that the curve number methodology is an event-based calculation, and should not be used for a single annual rainfall value, as this will incorrectly miss the effects of antecedent moisture and the necessity of an initial abstraction threshold.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting.

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1] Average runoff condition, and $I_a = 0.2S$.
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Figure 3.3: Runoff curve numbers for urban areas (NRCS, 1986)

NRCS classified the antecedent moisture condition –AMC- as “dry conditions” (AMC I), “moderate/normal conditions” (AMC II), and “wet conditions” (AMC III) to represent the relative moisture of the pervious surfaces prior to the rainfall event (*NRCS, 1986*). Therefore, the determination of the AMC of each rainfall event will depend on rainfall amount during the previous 5 days and the season.

The **absorption capacity** of the NBS /green area will be then calculated as the difference between the rainfall and the subsequent surface runoff in a specific storm event.

Method 2

The calculation of the absorption capacity of green/vegetated areas is based on the determination of the water runoff produced in storm events in an specific area/plot of land. It is directly related to the runoff coefficient. Concretely, the difference between the rainfall in a storm event (mm/m2) and the runoff produced (mm/m2) is the water retained by the green/vegetated area. Total Daily Rainfall will be obtained from the meteorological data provided by the Spanish Agency of Meteorology. Meteorological data (daily rainfall and temperature) can be obtained directly from the Spanish Meteorological Agency. Rainfall rate and rainfall event timings shall be recorded, if possible. Temperature will also be recorded. If data is not available, then a simple meteorological station will be place in the surroundings of the NBS to be monitored.

For the determination of the water runoff tipping bucket flow gauges will be employed according to the methodology proposed by Armson, D. *et al.* (2013). Plots of 3 m x 3 m will be delimited in the area occupied by the NBS to be assessed (in case the NBS surface is lower, the whole surface will be considered for the calculation). The plot will be surrounded by edging stones that protruded a minimum of 30mm above the surface, to contain the rainfall captured by the individual plot (Fig. 1).

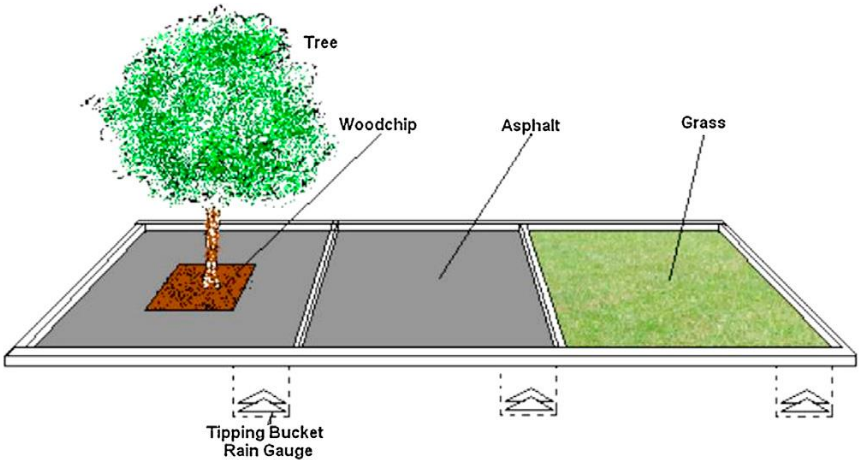

Figure 3.4: Diagram of the test plots used to measure surface water runoff (Armson D. *et al.*, 2013)

Surface drains will be located in the lower areas of the test plots where surface runoff is directed. Surface drains then directed the collected water into tipping bucket flow gauges (Fig. 2).

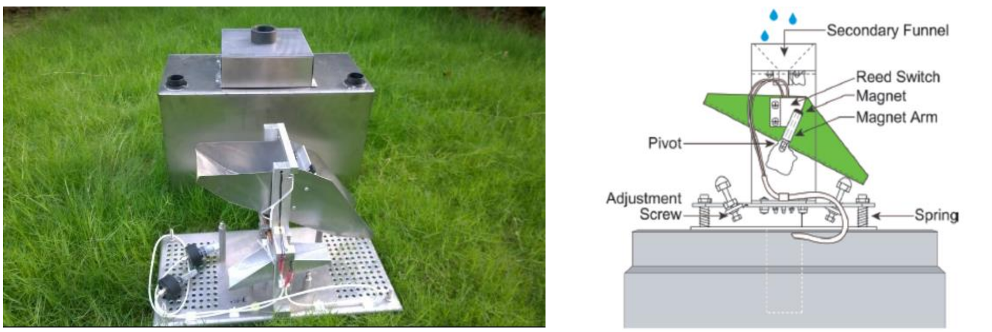

Figure 3.5: Tipping bucket flow gauges

Tipping bucket gauges for directly measuring run-off from small catchment areas have been largely applied (Edwards, I.J. *et l.*, 1974).

The number of tips can be manually recorded or using a datalogger (most recommended option). This allowed the total runoff for each 24-hour period to be calculated. The depth of the daily runoff could then be calculated by dividing the volume of daily runoff by the area of the test plot.

SENSOR /SOFTWARE

This determination requires de use of a tipping bucket flow gauge. Periodical calibration of the systems is required. For processing the data am Excel sheet can be used.

DATA SAMPLING

Water runoff might be determined continuously for a long period of time (at least 1 year). During the evaluation period, the meteorological data (total daily rainfall and temperature) must be also recorded.

Sampling points: tbd (depending on the available budget for the acquisition of the equipment).

DATA PROCESSING

(1) Remove the days when no rainfall had occurred or days where results had not been taken. The days are then divided, at least, in winter (leaf out) and summer seasons.

(2) Calculation of the daily runoff by dividing the volume of water captured by the surface area of test plot.

(3) Graphs of daily surface water runoff (in mm) against daily rainfall are then produced for each test plot in both summer and winter.

(4) Regression analysis is done, forcing the lines of best fit through zero; the results of this regression give the mean and standard deviation of the runoff coefficients for test plot in both winter and summer. The slope of the regression lines is equal to the runoff coefficient of each plot in winter and summer. The runoff coefficient is directly related to the water absorption capacity of the plot (bioretention = rainfall - water runoff).

RESULTS

Several figures are produced in the application of the method proposed by Armson *et al*. (2013).

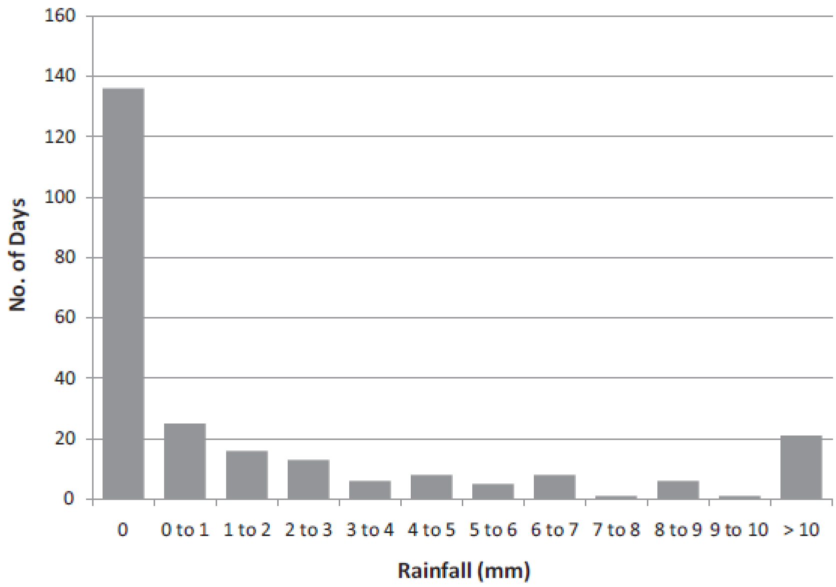

Figure 3.6: Histogram showing the daily rainfall during the study period (Armson *et al.,* 2013)

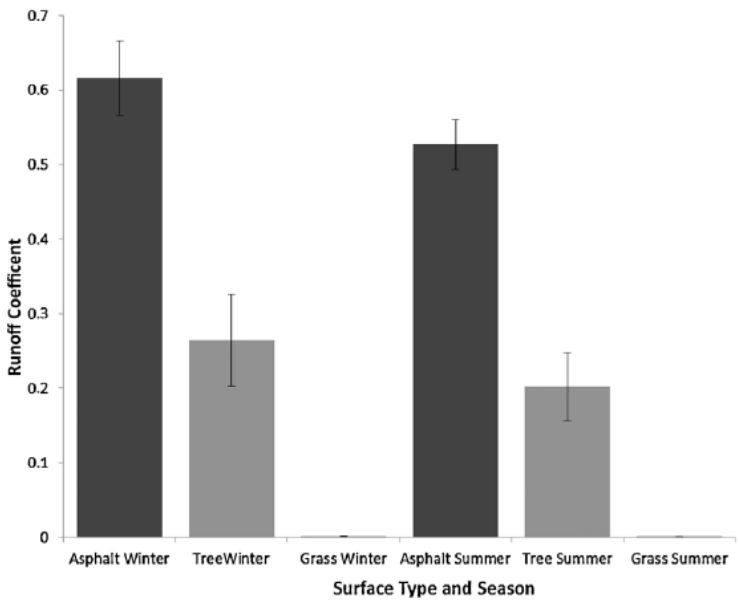

Figure 3.7: Runoff coefficient for different surfaces in winter and summer time (Armson *et al.,* 2013)

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Temperature reduction in urban areas

INTRODUCTION

Green and blue urban infrastructure can play a role in climate change adaptation through reducing air and surface temperature by providing shading and enhancing evapotranspiration, which leads to two benefits: improved thermal comfort and reduced energy use. We address the thermal comfort and reduced energy benefits via physical indicators such as ambient temperature, turbulent fluxes and energy savings.

This indicator can be applied at street/building, neighbourhood or city scale depending on the scale of intervention of the NBS to be assessed. Monitoring scheme will depend on the scale of the intervention.

In this KPI, mean and peak daytime local temperatures will be calculated and used to assess the impact of the NBS. This KPI includes the measurement and calculation of mean and daytime local relative humidity to complete the study.

NBS Types

4. Natural wastewater treatment	Wastewater treatment plant based on the combination of natural treatment systems, such as constructed wetlands and ponds, following the concept of waterharmonica. The flow-sheet can be completed by sand filtration and chlorination (disinfection) for the later water reuse. These systems provide more than just simple purification,

	because while treating the water, they are also regulating temperature and providing valuable habitats for biodiversity.
5. Floodable park	Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits that floodable parks can provide are among others, reducing air temperature of the surroundings together with delivering amenity and biodiversity benefits.
3. Urban catchment forestry	The drainage patterns of towns and cities have been modified greatly. Catchment areas for water are now based on road and building layout, with underground sewer system taking on the role of the streams and rivers as the collecting and discharge points for water in the city. This NBS is based on renaturing these urban catchments by planting urban trees, with specific design to “slow the flow” of water through the catchment. The impact of well-planned urban catchment forestry interventions is reduced flood risk and a reduced amount of polluted water entering the sewerage system.
9. Green filter area	Green filter is a land application system for treating water (wastewater). It consists of a plot area, sized according to the influent to be treated, which has forests installed and is irrigated with wastewater. These systems provide more than just simple purification, because while treating the water, they are also regulating temperature and producing biomass with high economic value.

Table 3.4: NBS types related to urban temperature reduction.

Method

BACI (Before, After, Control, Impact)

Measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of street without those NBS at a similar time of day on the same dates or continuously.

As a previous work, temporal series of temperature and relative humidity will be studied in order to define peak times and values and mean values of historical data (at night and daytime) for the city in the RCCAVA areas (According its characteristics). This study will serve to stablish a general baseline for the city. On the other hand, RCCAVA measurements will be used as additional references of non-intervention areas.

Null hypothesis

There is no difference in air temperatures and relative humidity between samples in stretches of street where green shady structures, street trees/green walls, etc. are present, and samples or measurements taken in stretches of streets without the NBS.

Sensor / software

Monitoring equipment. Wireless samplers to hang from street lamps or other urban furniture without carrying out works (low weight and low visual impact).

EXAMPLES

Figure 12: Smart Agriculture Waspmote Plug & Sense! model

The Smart Agriculture models allow to monitor multiple environmental parameters involving a wide range of applications. It has been provided with sensors for air and soil temperature and humidity, solar visible radiation, wind speed and direction, rainfall, atmospheric pressure, etc.

http://www.libelium.com/uploads/2013/02/agriculture-sensor-board_2.0_eng.pdf

Data stored on the device can be downloaded later to a PC using the USB cable and software provided with the monitor.

Price around 1.500€.

Elitech RC-5 USB Temperature Data Logger LCD Display Temperature Recorder 32000 Points High Accuracy Reusable.

https://www.elitechonline.co.uk/RC-5

Price around 25€ (amazon)

Measurements

Air temperature and relative humidity will be measured and recorded hourly (at least).

Unit of measurement

Temperature in ºC and Relative Humidity in %.

Calibration / Verification

Calibration/verification at laboratory.

Study sites

a) Stretches of street where street shady structures or tree/green wall interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of street (street of similar width and with comparable building heights to intervention site and **orientation**) where street tree/green wall interventions are not proposed (**control study sites**). Control sites should be a sufficient distance away from intervention sites for the observations made to be considered independent from the effects of NBS.

Number of study sites

tbc

Number of samples

At each study site and control site, a set of sensors will be installed at fixed height (between 1.5m, human height, and 3.5m, height to avoid vandalism) in different locations (same number in right and left side of the street) and avoiding estrange elements which can modify air conditions like exhaust part of an air conditioning or a shop door.

Data sampling

Both intervention and matched control study sites should be monitor with the same schema during the same time (although with a lower number of sensor points). Each fixed sampling location at a study site should be sampled hourly (at least) for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022).

Data processing

Calculation of dairy, weekly, monthly and annual mean levels (night and day) of temperature and relative humidity at each stretch. Comparison of mean values for NBS intervention and control sample locations will be done at each study site before and after of the interventions.

Calculations for comparison purposes must be done using comparable periods of time before and after the interventions (i.e. if measurement period before of the intervention goes from nov18-oct19, measurement period must be from nov19-oct21 at least and processing can be done for either years or yearly).

Spatial Analysis software

QGIS is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

Results

The calculated values will be compared qualitatively and quantitatively for the periods before and after the interventions in the NBS and reference sections. Quantitative assessment will be done by using the following expression:

$$\boldsymbol{Temperature\ impact} = \left(\frac{NBS\ Temp.average\ after\ intervent. - NBS\ Expected\ Temp.average\ after\ intervent.}{NBS\ Expected\ Temp.average\ after\ intervent.}\right) \times 100$$

Where *temperatures average after intervent.* is the average value of measurements after interventions and *Expected temperature value after intervent.* (but supposing that interventions had not been done) is:

$$\boldsymbol{Temperature\ Expected\ average\ after\ intervent.} = \left(\frac{Ref.Temp.average\ after\ intervent.}{Ref.Temp.average\ before\ intervent.}\right) \times NBS\ Temp.average\ before\ intervent.$$

Positive or null temperature impact values indicate negative or no impact of the NBS on average temperatures for that implementation. A negative value indicates a positive impact of that NBS on temperatures (and/or humidity, same procedure).

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Intercepted rainfall

INTRODUCTION

When rain falls on to a vegetated surface (gross rainfall), a part is intercepted by the canopy and evaporated directly back into the atmosphere (interception loss). The remainder of the rainfall reaches the ground (net rainfall) both through gaps and by dripping from the canopy (through fall), or by running down the main stem (stem flow). The canopy storage capacity is the minimum amount of water necessary to completely saturate the canopy surface. The maximum storage capacity of a leaf ranges from 1 to 2 l/m^2.

In case of low rainfalls (< 5 mm/m^2), the interception capacity and the rainfall are similar. For a heavier rainfall, the interception is about 10% of the precipitation. In a simplified mode, the interception can be calculated as the product of the rainfall and a coefficient α, which depends on the type of vegetation cover. In wet areas with a huge vegetated cover, α varies from 0.1 to 0.2 and it is 0 in arid regions.

Interception loss is conventionally measured as the difference between the incident gross rainfall, and the sum of *throughfall* and *stemflow*. It is usually a significant component of the overall evaporation and may play an important role in watershed water balance. The total amount of interception loss depends on the rate of evaporation from the wet canopy, the canopy storage capacity, and the distribution and intensity of rainfall. Interception loss is particularly high in forests due to their high aerodynamic roughness.

Available models range from empirical relationships to physically based conceptual models. Within the latter, the Rutter-type models are those that have been taken up as the more generally applicable technique.

NBS TYPES

1. Natural wastewater treatment	Wastewater treatment plant based on the combination of natural treatment systems, such as constructed wetlands and ponds, following the concept of *waterharmonica*. The flow-sheet can be completed by sand filtration and chlorination (disinfection) for the later water reuse. These systems provide more than just simple purification, because while treating the water, they are also regulating temperature and providing valuable habitats for biodiversity.
2. Floodable park	Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits that floodable parks can provide are among others, reducing air temperature of the surroundings together with delivering amenity and biodiversity benefits.
3. Tree related actions	This NBS includes individual large street trees, as well as the larger areas of woodland in the urban fringes. Trees perform multiple functions in urban areas.
4. Green filter area	Green filter is a land application system for treating water (wastewater). It consists of a plot area, sized according to the influent to be treated, which has forests installed and is irrigated with wastewater. These systems provide more than just simple purification, because while treating the water, they are also regulating temperature and producing biomass with high economic value.
5. Rain Garden	A rain garden is a bioretention shallow basin designed to collect, store, filter and treat water runoff. To optimise its functions, it must include a porous soil mixture, native vegetation and some hyperaccumulator plants, capable of phytoremediation.
6. SUDs	SUDS are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a

	sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies. SuDS take inspiration from natural features and processes like uptake of water by plants, soil infiltration, pools, ponds, marshes, wetlands, springs, streams and rivers. SuDS work by holding rainwater back, treating pollution and releasing it slowly, without overwhelming the watercourse or sewer system into which it flows, thereby reducing flooding.
7. Green parking pavements	NBS destined to replace gray urban pavement with 50% vegetal soil and high drainage capacity. This kind of pavements has gaps, which are filled with smart soil and with specific creeping grass species with a short growing and minimum maintenance and are appropriate for bikes, pedestrian and motor vehicles.
8. Electrowetland	An Electrowetland is a natural wastewater treatment system that generates electricity from the oxidation of the organic matter. It is based on a conventional Horizontal Subsurface Flow Constructed Wetland (HSSF CW) in which electrodes are introduced. Therefore, it consists on a planted and permanently flooded gravel basin in which wastewater flows horizontally from one side to the other of the system crossing the electrode layer.

Table 3.5: NBS types related to the KPI

METHOD

Two methods are proposed for the determination of the intercepted rainfall: one estimative based on Rutter el al model (1971) and other direct, which requires de use of rain gauges.

Method 1 (estimation of intercepted rainfall)

The estimation of the intercepted rainfall in the different NBS implemented in the frame of Urban GreenUP project will be based on the Rutter model.

The Rutter model (Rutter et al., 1971) represents the interception process by a running water balance of rainfall input, storage and output in the form of drainage and evaporation. Since drainage and evaporation rates both depend on the amount of water stored in the canopy, they vary throughout the event.

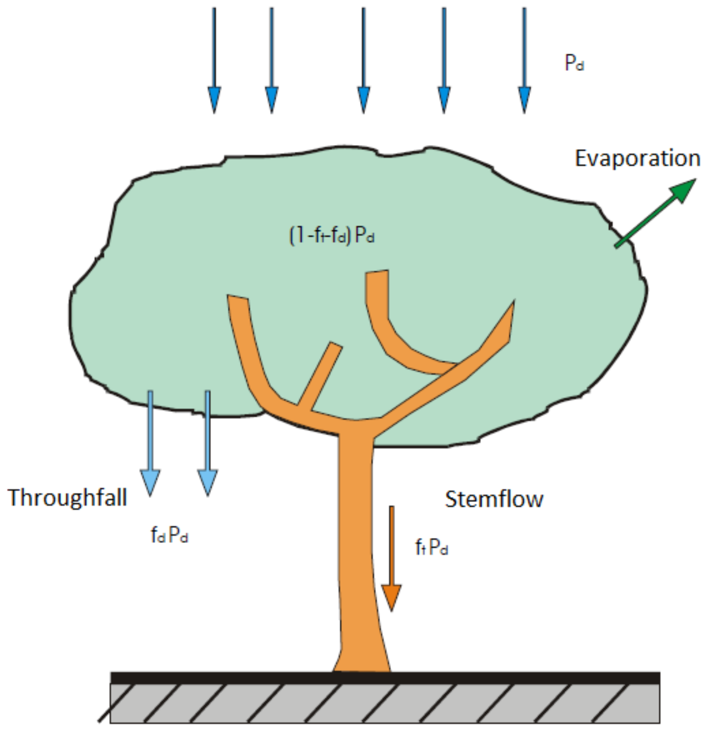

Figure 3.8: Representation of Rutter et al model (1971).

Rutter et al. (1975) developed the model's definitive version by adding a stemflow module, in which a fraction of the rainfall input is directly diverted to a compartment comprising the trunks. Figure 2 shows the conceptual structure of the Rutter model.

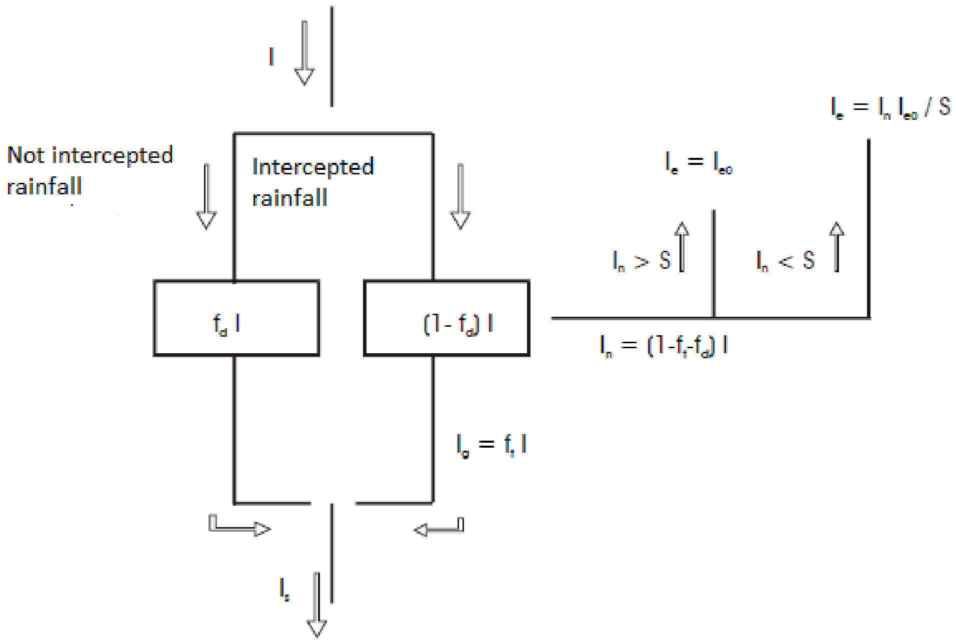

Figure 3.9: Conceptual structure of Rutter et al model (1971)

On Figure 2, I is the gross rainfall, I_n is the intercepted rainfall, S is the total storage capacity, I_{e0} is the potential evaporation intensity of the storage water and I_g is the throughfall. The evaporation intensity both in the canopy and the stem (I_e) is the product of the potential evaporation intensity (I_{e0}) and a proportional coefficient of excess water over the storage capacity (S).

The water mass balance is as follows:

$$\frac{dI_n}{dt} = (1 - f_d) \cdot I - I_e - I_g$$

The non intercepted rainfall (I_s) is calculated the following equation:

$$I_s = f_d \cdot I + I_g$$

I_g depends on the maximum canopy storage capacity, I_{nmx}, and the minimum value, I_{nmn} and has been estimated through different equations.

Authors	Equation
Rutter et al. 1971	$I_g = \exp(\alpha + \beta I_n)$
Massman, 1981	$I_g = I_{g0}[\exp(\alpha I_n / I_{nmx} - 1)] \cdot [\exp(\alpha)]^{-1}$
Pitman, 1989	$I_g = \exp[\alpha(I_n - I_{nmn})] - 1$

Table 3.6: Equations for the estimation of I_g

The intercepted rainfall, I_n, is then calculated through the following equations

$$I_n = \begin{cases} I_{nmx}[1 - \exp(-t/k)] \text{ para } t \le t_r \\ I_{nr} - (I_{e0}/I_{nmx} + 1/k) \cdot (t - t_r) \text{ para } t \ge t_r \end{cases}$$

where I_{nr} is the intercepted rainfall for a rainfall event in a period t_r.

Type of vegetation		S
Conifers	Pinus sylvestris	1.6
	Picea abies	1.5
	Pseudotsuga meziensii	2.1
	Pinus nigra	1.6
Deciduous forests	Carpinis betulus (summer)	1.0
	Carpinis betulus (winter)	0.6
	Quercus robur (summer)	1.0
	Quercus robur (winter)	0.4
Ericaceae	Calluna vulgaris	2.0
Herbaceous vegetation	Zea mays	0.4-0.7
	Lolium perenne (10 cm height)	1.6
	Lolium perenne (48 cm height)	2.8
	Molinia cerulea	0.7
	Pteridium aquilinum	0.9

Table 3.7: the storage capacity, S, for different canopies is summarized

Method 2 (direct measurement of intercepted rainfall)

The common method to determine interception in the field is measuring the net precipitation under canopies. The net precipitation is a combination of stemflow and throughfall. When the gross precipitation is known, the interception can be calculated as the difference of the gross precipitation and the net precipitation(Robinson & Ward, 2000).

Measuring throughfall is mostly done by placing gauges outside and under canopies and measure the amount of water in the gauges after a rainfall event (stemflow is neglected). The gross precipitation is measured in the open field, away from canopy influences.

Data

The meteorological data required for the determination of the intercepted rainfall according to the method described above, will be obtained from the Spanish Meteorological Agency for the city of Valladolid.

For each NBS implemented, the intercepted rainfall will be determined, considering the data in tables 1 and 2. In case the NBS presents heterogeneous vegetation, the total surface will be divided in smaller surfaces with similar plants composition and the intercepted rainfall will be determined individually for each section. Later, those individual values will be added to obtain the total interception rainfall on each NBS.

In case there are not enough data for applying the model proposed by Rutter et al (1971), directs measurements as explained in method 2 should be done.

Results

The total intercepted rainfall in Valladolid city (in m^3/year) will be calculated before and after the implementation of the planned NBS.

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Share of green areas in zones in danger of floods

INTRODUCTION

This indicator is included in the list of indicators for **Challenge 2. Water Management**. This **physical** indicator evaluates the increases of public green spaces in those zones which are susceptible to flooding.

Urban green infrastructures can provide important Ecosystem Services to the cities, including provisioning, regulating, supporting and cultural services. Some of them have a measurable impact on flood controlling. In fact, Increasing the area of (or avoiding the loss of) green space, particularly wetlands and tree cover contributes to increased flood regulation (Raimond et al, 2017).

On the other hand, the urbanization processes related to the growth and development of the cities affects the flooding areas associated with the surface water. Land covering with buildings and constructions and the waterproofing of the soil by the asphalting of sidewalks and roads increases the runoff and drastically decreases the absorption capacity of the soil.

Green infrastructures can balance that effect, by creating green surfaces that can be able to absorb or manage rainwater and flooding peaks. Thus, the more green areas be installed within zones in danger of floods, the more safety can be reached for the population.

NBS TYPES

This KPI can evaluate NBS that involving **horizontal green infrastructures**, especially those that are located within flooding risk areas, and also are able to generate an influence on flood controlling. The floodable park area is a great example of that.

METHOD

Needed data to assess this KPI will be acquired though rainfall information provided by *AEMET*; digital land cover maps from *CORINE* land *cover project;* green areas from the municipality of Valladolid, and topography from digital elevation models (DEM) of each intervention.

In order to estimate this KPI, the use of a numerical two-dimensional model for simulation of free surface flow and environmental processes in river hydraulics is proposed.

It is in this regard that **Iber software** (version 2.4.3) is seen as a good option to achieve the pretended output results of this KPI.

Iber is a kind of free software whose range of application covers river hydrodynamics, dam-break simulation, flood inundation modelling, sediment transport calculation and tidal currents in estuaries.

Furthermore, at European level, the European Commission approved in November 2007 the Directive 2007/60/EC on the assessment and management of flood risks. Basically, the aim of this European Directive is to reduce and manage the risks that floods involve to human health, the environment, cultural heritage and economic activity. These regulations require Member States to conduct a series of steps which are briefly explained in the lines below:

In the first place, Member States would have carried out a Preliminary flood risk assessment by 22 December 2011. It is essential that action will only be taken in areas where potential significant flood risks exist or are reasonably foreseeable in the future. For that purpose, based on available or readily derivable information, such as records and studies on long term developments, in particular impacts of climate change on the occurrence of floods, a preliminary flood risk assessment shall be undertaken by Member States in order to provide an assessment of potential risks. The city of Valladolid is among one of those areas due to the influence of the rivers Pisuerga and Esgueva.

Secondly, Member States would have also prepared flood hazard maps and flood risk maps, at the most appropriate scale for those areas identified in the preliminary flood risk assessment by 22 December 2013.

These flood hazard maps and flood risk maps were developed in order to increase public awareness; support the process of prioritizing, justifying and targeting investments and developing sustainable policies and strategies; and support flood risk management plans, spatial planning and emergency plans.

Flood hazard maps cover the geographical areas which could be flooded according to the following scenarios:

- Floods with a medium probability (likely return period ≥ 100 years).
- Floods with a high probability (return period = 10 years).

For each scenario studied the following elements shall be taken into account:

- The flood extent.
- Water depths or water level, as appropriate.
- The flow velocity or the relevant water flow, where appropriate.

On the other hand, flood risk maps show the potential adverse consequences associated with flood scenarios referred to potential significant flood risks areas and expressed in terms of the following:

- The indicative number of inhabitants potentially affected.

- Type of economic activity of the area potentially affected.
- Installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (1) which might cause accidental pollution in case of flooding and potentially affected protected areas identified in Annex IV(1)(i), (iii) and (v) to Directive 2000/60/EC.
- Other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur and information on other significant sources of pollution.

In this regard, and for those NBS located in the city of Valladolid, flood hazard maps and flood risk maps of Pisuerga and Esgueva rivers as they flow through Valladolid for a 10 and 100 years return period flooding would be used to assess and quantify this KPI for the initial situation prior to the implementation of the NBS considered.

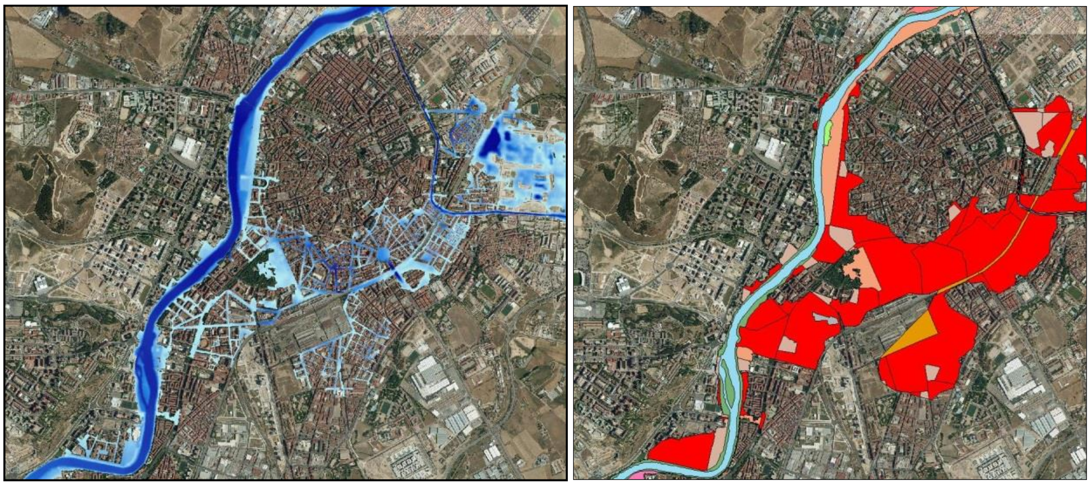

Figure 3.10: Flood hazard map and flood risk map, respectively, of Pisuerga and Esgueva rivers as they flow through the city of Valladolid for a 100 years return period flood.

As explained in the previous paragraphs, a numerical model for hydraulic simulations will be applied to assess this KPI for the situation after the implementation of the NBS that is pretended to be studied. Main steps to build and run a hydraulic simulation in Iber software is shown below (extracted from *Iber user´s manual*) and *Bladé et al. (2014)*:

1. **Create or import a geometry of the study Area:** The study area of the NBS that is pretended to be assessed is the entire land area draining to the stream reach or sewer point of interest. Iber presents a user interface in which geometries can be created from scratch, drawing points (directly in the screen or entering coordinates), lines and surfaces. At the same time, different standard geometry formats can be imported (.dxf, .shp, among others). Finally, digital terrain models can be imported from Arc Info ASCII format files.

2. **Assign a series of input parameters:** Spatial distribution of roughness and other hydraulic parameters are needed at this step to create the numerical model. Also, boundary and initial conditions need to be assigned.

3. **Build a numerical mesh:** The numerical mesh is a key element in order to obtain good results from the computation. In Iber there are various ways of getting a good computational mesh. Depending on the characteristics of the problem, the choice of a specific mesh type can produce better results and reduce the computational time. Iber can work with triangular or quadrilateral elements, or with mixed meshes. The computational meshes can be regular or irregular, as well as structured or non-structured.

4. **Run the computation:** To launch a computation, all the input computation parameters must be set beforehand. At this step, it is also necessary to set the problem data (time of calculation, numerical scheme parameters, and additional modules requirements, among others).

5. **Results visualization:** Once the computation is over, or even during the simulation process, the post-process interface can be accessed in order to visualize and analyze the results. Moreover, Iber allows exporting the results in Arc Info ASCII grid format.

Once the hydraulic flooding layer has been developed from the model, it must be integrated in a GIS and combined with the constructed NBS feature layer. These layers must include all the attributes needed to check some kind of calculations between layers (e.g. area).

SENSOR/SOFTWARE

Data are acquired by statistic and GIS processing, so **no sensor is required**.

Spatial Analysis software is required. **QGIS** is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

Spreadsheet software can be required.

DATA SAMPLING

Datasets are provided by **Valladolid City Council**. All Datasets need to follow INSPIRE principles. An appropriated Coordinate Reference Systems must be defined for each location (city). The image below shows the recommended CRS for Valladolid location.

Figure 3.11: coordinate system to use for Valladolid.

This is considered as a very stable KPI, so **frequency** could be the same as city council's demographic statistics, therefore, **annual**. In order to set the starting situation a preliminary study is also needed.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Green infraestructures surface	Green infrastructures cartography	m^2	Shapefile – Polygon	Required study data for this KPI. This dataset can also require an ID value.
Flooding surface	Considered area in danger of flooding	m^2	Shapefile – Polygon	According to KPIs 28 and 29

Table 3.8: Required and recommended inputs for the calculation of this KPI.

DATA PROCESSING

The first step consists in intersect both shapefiles (green areas and flooding exposed areas) to create a new shape-file containing only GI under flooding danger throughout the tool **Intersection**. As a result, a new shape-file is obtained, with an attribute table similar to the original GI shapefile.

A new field has to be calculated using **Field Calculator tool**, which represent the total green area in zones of flooding.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
KPI 027	Green area surface by neighborhood / Flooding risk area surface	% (m^2/m^2)	Shapefile – Polygon	Derived variable obtained by GIS processing.

Table 3.9: Summary of the KPI data.

Overall statistics can also be calculated by a QGIS tool called **Basic statistics for numeric fields** (based on KPI_052). Te result of this tool is a table (not GIS data), with resume figures of both terms of the KPI, including minimum and maximum values, range, mean and median value, standard deviation and coefficient of variation. The mean value is used to refer green areas to the total flooding area.

The next picture shows the algorithm for this described process.

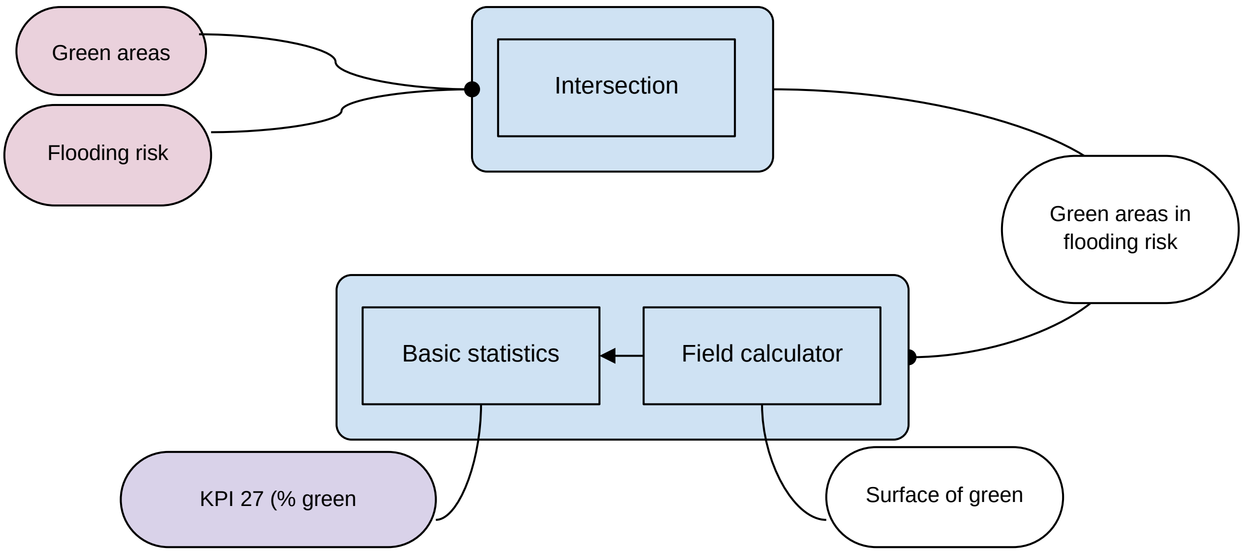

Figure 3.12: KPI dataflow scheme

RESULTS

Flood hazard maps and flood risk maps will be developed and then compared quantitatively with the NBS´s feature layers.

As explained in previous lines, data according to the initial situation prior to the implementation of the NBS located in the city of Valladolid are already available at the *SNCZI* website (http://sig.mapama.es/snczi/visor.html?herramienta=DPHZI) for both 10 and 100 years return period flooding.

In this website, there are different layers which show flood extent, water depths, number of inhabitants potentially affected or type of economic activity of the area potentially affected, among others, for potential floods with different return periods. These data are useful to assess the current status of the area.

The following table shows the results extracted from SNCZI regarding the assessment of this KPI for the initial situation after the implementation of the floodpark located in the city of Valladolid:

KPI description	Data values (initial situation)
Share of green areas in zones of danger of floods (% of the total area in danger of flood for every scenery)	2,43% (10 years return period flood) 1,05% (100 years return period flood)

Table 3.10: Share of green areas in zones of danger of floods (% of the total NBS´s surfaces concerned by Esgueva´s flooding in the municipality of Valladolid) after the development of the floodpark.

For the evaluation of this KPI after the implementation of the different NBS´s located in Valladolid, different maps, tables and graphs extracted from the post-process interface of Iber software as well as demographic data from the municipality of Valladolid will be the base to develop flood hazard maps and flood risk maps and thus, obtain the following data:

Share of Green Areas in zones of danger of floods (% of the total surface of the municipality of Valladolid in zones of danger of floods vs. total surface of NBS): This value represents the percentage of surface of total NBS´s stablished (10 and 100 years return period) regarding to the total surface in the municipality of Valladolid exposed to flood for every scenery considered. This assessment will be done by using the following expression:

$$\textbf{Share of Green Areas into flooding zones}\ (\%) = \frac{\text{Total Surface of NBS´s stablished}\ (m^2)}{\text{Total Surface of Areas exposed to flooding}\ (m^2)} * 100$$

REFERENCES

- QGIS 2.18 – Userguide. https://www.qgis.org/en/site/
- Spatial Reference - Howard Butler, Christopher Schmidt, Dane Springmeyer, and Josh Livni http://spatialreference.org/
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- Raymond, C.M., Berry, P., Breil, M., Nita, M.R., Kabisch, N., de Bel, M., Enzi, V., Frantzeskaki, N., Geneletti, D., Cardinaletti, M., Lovinger, L., Basnou, C., Monteiro, A., Robrecht, H., Sgrigna, G., Munari, L. and Calfapietra, C. (2017) An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom
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Internacional de Métodos Numéricos para Cálculo y Diseño en Ingeniería, Volume 30, Issue 1, 2014, Pages 1-10, ISSN 0213-1315, DOI: 10.1016/j.rimni.2012.07.004

- Iber user´s manual: http://iberaula.es/space/54/downloads
- SNCZI (Sistema Nacional de Cartografía de Zonas Inundables): http://sig.mapama.es/snczi/visor.html?herramienta=DPHZI

Population exposed to flood risk

This indicator has been mainly defined for the **floodable park** but it could also be applied to scale the impact of other types of NBS on flow peak reduction and increase in time to peak.

NBS Types

Floodable park	Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits that floodable parks can provide are among others, delivering amenity and biodiversity benefits.

Table 3.11: Related KPI.

METHOD

Sensor/Software

No sensor is required.

Needed data to assess this KPI will be acquired though rainfall information provided by *AEMET*; digital land cover maps from *CORINE* land *cover project;* demographic data from the municipality of Valladolid; and size and topography from digital elevation models (DEM) of each intervention.

The areas and population exposed to flooding will be compared before and after the installation of the NBS to know if the intervention has influence in mitigating effects from flood risks.

In order to estimate this KPI, the use of a numerical two-dimensional model for simulation of free surface flow and environmental processes in river hydraulics is proposed.

It is in this regard that **Iber software** (version 2.4.3) is seen as a good option to achieve the pretended output results of this KPI.

Iber is a free software whose range of application covers river hydrodynamics, dam-break simulation, flood inundation modelling, sediment transport calculation and tidal currents in estuaries.

Furthermore, at European level, the European Commission approved in November 2007 the Directive 2007/60/EC on the assessment and management of flood risks. Basically, the aim of this European Directive is to reduce and manage the risks that floods involve to human health, the environment, cultural heritage and economic activity. These regulations require Member States to conduct a series of steps which are briefly explained in the lines below:

In the first place, Member States would have carried out a Preliminary flood risk assessment by 22 December 2011. It is essential that action will only be taken in areas where potential significant flood risks exist or are reasonably foreseeable in the future. For that purpose, based on available or readily derivable information, such as records and studies on long term developments, in particular impacts of climate change on the occurrence of floods, a preliminary flood risk assessment shall be undertaken by Member States in order to provide an assessment of potential risks. The city of Valladolid is among one of those areas due to the influence of the rivers Pisuerga and Esgueva.

Secondly, Member States would have also prepared flood hazard maps and flood risk maps, at the most appropriate scale for those areas identified in the preliminary flood risk assessment by 22 December 2013.

These flood hazard maps and flood risk maps were developed in order to increase public awareness; support the process of prioritizing, justifying and targeting investments and developing sustainable policies and strategies; and support flood risk management plans, spatial planning and emergency plans.

Flood hazard maps cover the geographical areas which could be flooded according to the following scenarios:

- Floods with a medium probability (likely return period ≥ 100 years).
- Floods with a high probability (return period = 10 years).

For each scenario studied the following elements shall be taken into account:

- The flood extent.
- Water depths or water level, as appropriate.
- The flow velocity or the relevant water flow, where appropriate.

On the other hand, flood risk maps show the potential adverse consequences associated with flood scenarios referred to potential significant flood risks areas and expressed in terms of the following:

- The indicative number of inhabitants potentially affected.
- Type of economic activity of the area potentially affected.
- Installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (1) which might cause accidental pollution in case of flooding and potentially affected protected areas identified in Annex IV(1)(i), (iii) and (v) to Directive 2000/60/EC.
- Other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur and information on other significant sources of pollution.

In this regard, and for those NBS located in the city of Valladolid, flood hazard maps and flood risk maps of Pisuerga and Esgueva rivers as they flow through Valladolid for a 10 and 100 years return period flooding would be used to assess and quantify this KPI for the initial situation prior to the implementation of the NBS considered.

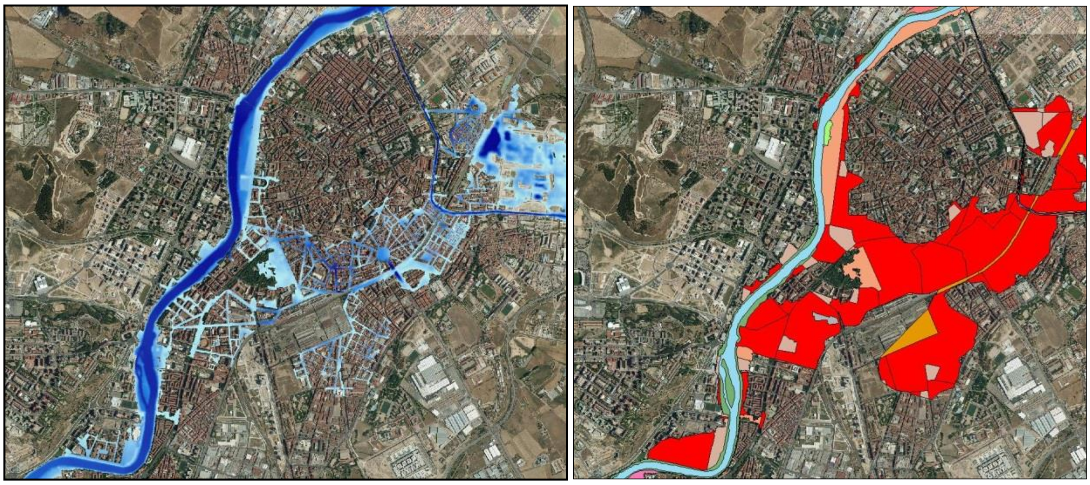

Figure 3.13: Flood hazard map and flood risk map, respectively, of Pisuerga and Esgueva rivers as they flow through the city of Valladolid for a 100 years return period flood.

The SNCZI, promoted by the Ministry of Agriculture and Fisheries, Food and Environment, compiles all these flood hazard maps and flood risk maps already carried out and those which will be prepared in the future in order to implement a tool to facilitate its consultation and management.

METHODOLOGY

As explained in the previous paragraphs, a numerical model for hydraulic simulations will be applied to assess this KPI for the situation after the implementation of the NBS that is pretended to be studied. Main steps to build and run a hydraulic simulation in Iber software is shown below (extracted from *Iber user´s manual*) and *Bladé et al. (2014)*:

6. **Create or import a geometry of the study Area:** The study area of the NBS that is pretended to be assessed is the entire land area draining to the stream reach or sewer point of interest. Iber presents a user interface in which geometries can be created from scratch, drawing points (directly in the screen or entering coordinates), lines and surfaces. At the same time, different standard geometry formats can be imported (.dxf, .shp, among others). Finally, digital terrain models can be imported from Arc Info ASCII format files.

7. **Assign a series of input parameters:** Spatial distribution of roughness and other hydraulic parameters are needed at this step to create the numerical model. Also, boundary and initial conditions need to be assigned.

8. **Build a numerical mesh:** The numerical mesh is a key element in order to obtain good results from the computation. In Iber there are various ways of getting a good computational mesh. Depending on the characteristics of the problem, the choice of a specific mesh type can produce better results and reduce the computational time. Iber can work with triangular or quadrilateral elements, or with mixed meshes. The computational meshes can be regular or irregular, as well as structured or non-structured.

9. **Run the computation:** To launch a computation, all the input computation parameters must be set beforehand. At this step, it is also necessary to set the problem data (time of calculation, numerical scheme parameters, and additional modules requirements, among others).

10. **Results visualization:** Once the computation is over, or even during the simulation process, the post-process interface can be accessed in order to visualize and analyze the results. Moreover, Iber allows exporting the results in Arc Info ASCII grid format.

RESULTS

The numerical outputs from the hydraulic models should be then processed with GIS software to reach the best way to represent the flood hazard maps and flood risk maps. After that, these maps will be compared quantitatively in two scenarios (before and after the installation of the NBS) for each intervention.

As explained in previous lines, data according to the initial situation prior to the implementation of the NBS located in the city of Valladolid are already available at the *SNCZI* website (http://sig.mapama.es/snczi/visor.html?herramienta=DPHZI) for both 10 and 100 years return period flooding.

In this website, there are different layers which show flood extent, water depths, number of inhabitants potentially affected or type of economic activity of the area potentially affected, among others, for potential floods with different return periods. These data are useful to assess the current status of the area.

The following table shows the results extracted from SNCZI regarding the assessment of this KPI for the initial situation before the implementation of the NBS located in the city of Valladolid:

KPI description	Data values (initial situation)
Population exposed to flood risk (% of the total number of inhabitants in the municipality of Valladolid).	17,47% total inhabitants (10 years return period flood) 31,88% total inhabitants (100 years return period flood)

Table 3.12: Population exposed to flood risk (% of the total number of inhabitants in the municipality of Valladolid) before the development of the NBS´s.

For the evaluation of this KPI after the implementation of the NBS´s located in Valladolid, different maps, tables and graphs extracted from the post-process interface of Iber software as well as demographic data from the municipality of Valladolid will be the base to develop flood hazard maps and flood risk maps and thus, obtain the following data:

Population exposed to flood risk (% of the total number of inhabitants in the municipality of Valladolid): This value represents the percentage of the citizens living in parts of land that are flooded for the different scenarios considered (10 and 100 years return period) in respect to the total population in the municipality of Valladolid. This assessment will be done by using the following expression:

$$\textbf{Population exposed to flood risk } (\%) = \frac{\text{Population exposed to flood risk (inhab)}}{\text{Total population in the municipality of Valladolid}} * 100$$

Finally, the higher decrease in the percentage of population exposed to flood risk when comparing the values prior and after to the implementation of the NBS considered, the greater potential benefits in mitigating flood risks will be achieved.

REFERENCES

- AEMET (Agencia Estatal de Meteorología): http://www.aemet.es/es/portada.
- Bladé, E., Cea, L., Corestein, G., Escolano, E., Puertas, J., Vázquez-Cendón, E., Dolz, J., Coll, A., 2014. Iber: herramienta de simulación numérica del flujo en ríos. Revista Internacional de Métodos Numéricos para Cálculo y Diseño en Ingeniería, Volume 30, Issue 1, 2014, Pages 1-10, ISSN 0213-1315, DOI: 10.1016/j.rimni.2012.07.004
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Areas (Ha) and population (inhab) exposed to flooding

This indicator has been mainly defined for the **floodable park** but it could also be applied to scale the impact of other types of NBS on flow peak reduction and increase in time to peak.

NBS TYPES

Floodable park	Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits that floodable parks can provide are among others, delivering amenity and biodiversity benefits.

Table 3.13: NBS related to areas (Ha) and population (inhab) exposed to flooding

METHOD

Sensor/Software

No sensor is required.

Needed data to assess this KPI will be acquired though rainfall information provided by *AEMET*; digital land cover maps from *CORINE* land *cover project;* demographic data from the municipality of Valladolid; and size and topography from digital elevation models (DEM) of each intervention.

The areas and population exposed to flooding will be compared before and after the installation of the NBS to know if the intervention has influence in mitigating effects from flood risks.

In order to estimate this KPI, the use of a numerical two-dimensional model for simulation of free surface flow and environmental processes in river hydraulics is proposed.

It is in this regard that **Iber software** (version 2.4.3) is seen as a good option to achieve the pretended output results of this KPI.

Iber is a free software whose range of application covers river hydrodynamics, dam-break simulation, flood inundation modelling, sediment transport calculation and tidal currents in estuaries.

Furthermore, at European level, the European Commission approved in November 2007 the Directive 2007/60/EC on the assessment and management of flood risks. Basically, the aim of this European Directive is to reduce and manage the risks that floods involve to human health, the environment, cultural heritage and economic activity. These regulations require Member States to conduct a series of steps which are briefly explained in the lines below:

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Secondly, Member States would have also prepared flood hazard maps and flood risk maps, at the most appropriate scale for those areas identified in the preliminary flood risk assessment by 22 December 2013.

These flood hazard maps and flood risk maps were developed in order to increase public awareness; support the process of prioritizing, justifying and targeting investments and developing sustainable policies and strategies; and support flood risk management plans, spatial planning and emergency plans.

Flood hazard maps cover the geographical areas which could be flooded according to the following scenarios:

- Floods with a medium probability (likely return period ≥ 100 years).
- Floods with a high probability (return period = 10 years).

For each scenario studied the following elements shall be taken into account:

- The flood extent.
- Water depths or water level, as appropriate.
- The flow velocity or the relevant water flow, where appropriate.

On the other hand, flood risk maps show the potential adverse consequences associated with flood scenarios referred to potential significant flood risks areas and expressed in terms of the following:

- The indicative number of inhabitants potentially affected.
- Type of economic activity of the area potentially affected.
- Installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (1) which might cause accidental pollution in case of flooding and potentially affected protected areas identified in Annex IV(1)(i), (iii) and (v) to Directive 2000/60/EC.
- Other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur and information on other significant sources of pollution.

In this regard, and for those NBS located in the city of Valladolid, flood hazard maps and flood risk maps of Pisuerga and Esgueva rivers as they flow through Valladolid for a 10 and 100 years return period flooding would be used to assess and quantify this KPI for the initial situation prior to the implementation of the NBS considered.

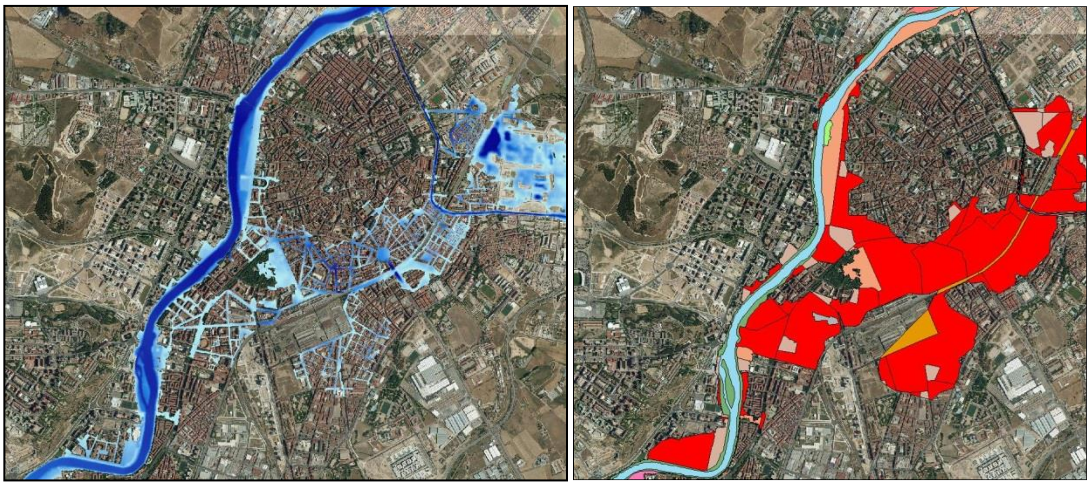

Figure 3.14: Flood hazard map and flood risk map, respectively, of Pisuerga and Esgueva rivers as they flow through the city of Valladolid for a 100 years return period flood.

The SNCZI, promoted by the Ministry of Agriculture and Fisheries, Food and Environment, compiles all these flood hazard maps and flood risk maps already carried out and those which will be prepared in the future in order to implement a tool to facilitate its consultation and management.

Methodology

As explained in the previous paragraphs, a numerical model for hydraulic simulations will be applied to assess this KPI for the situation after the implementation of the NBS that is pretended to be studied. Main steps to build and run a hydraulic simulation in Iber software is shown below (extracted from *Iber user´s manual*) and *Bladé et al. (2014)*:

11. **Create or import a geometry of the study Area:** The study area of the NBS that is pretended to be assessed is the entire land area draining to the stream reach or sewer point of interest. Iber presents a user interface in which geometries can be created from scratch, drawing points (directly in the screen or entering coordinates), lines and surfaces. At the same time, different standard geometry formats can be imported (.dxf, .shp, among others). Finally, digital terrain models can be imported from Arc Info ASCII format files.

12. **Assign a series of input parameters:** Spatial distribution of roughness and other hydraulic parameters are needed at this step to create the numerical model. Also, boundary and initial conditions need to be assigned.

13. **Build a numerical mesh:** The numerical mesh is a key element in order to obtain good results from the computation. In Iber there are various ways of getting a good computational mesh. Depending on the characteristics of the problem, the choice of a specific mesh type can produce better results and reduce the computational time. Iber can work with triangular or quadrilateral elements, or with mixed meshes. The computational meshes can be regular or irregular, as well as structured or non-structured.

14. **Run the computation:** To launch a computation, all the input computation parameters must be set beforehand. At this step, it is also necessary to set the problem data (time of calculation, numerical scheme parameters, and additional modules requirements, among others).

15. **Results visualization:** Once the computation is over, or even during the simulation process, the post-process interface can be accessed in order to visualize and analyze the results. Moreover, Iber allows exporting the results in Arc Info ASCII grid format.

Results

The numerical outputs from the hydraulic models should be then processed with GIS software to reach the best way to represent the flood hazard maps and flood risk maps. After that, these maps will be compared quantitatively in two scenarios (before and after the installation of the NBS) for each intervention.

As explained in previous lines, data according to the initial situation prior to the implementation of the NBS located in the city of Valladolid are already available at the *SNCZI* website (http://sig.mapama.es/snczi/visor.html?herramienta=DPHZI) for both 10 and 100 years return period flooding.

In this website, there are different layers which show flood extent, water depths, number of inhabitants potentially affected or type of economic activity of the area potentially affected, among others, for potential floods with different return periods. These data are useful to assess the current status of the area.

The following table shows the results extracted from SNCZI regarding the assessment of this KPI for the initial situation before the implementation of the NBS located in the city of Valladolid:

KPI description	Data values (initial situation)
Area (Ha) and population (inhab) exposed to flooding in the city of Valladolid.	340 Ha and 54.424 inhabitants (10 years return period flood) 620 Ha and 99.312 inhabitants (100 years return period flood)

Table 3.14: Area (Ha) and population (inhab) exposed to flooding in the city of Valladolid before the development of the NBS´s.

For the evaluation of this KPI after the implementation of the NBS´s located in Valladolid, different maps, tables and graphs extracted from the post-process interface of Iber software as well as demographic data from the municipality of Valladolid will be the base to develop flood hazard maps and flood risk maps and thus, obtain the following data:

Area (ha) exposed to flooding: This value represents the surface of land expressed in hectares (ha) that is flooded for the different scenarios considered (10 and 100 years return period).

Population (inhab) exposed to flooding: This value represents the number of citizens living in parts of land that are flooded for the different scenarios considered (10 and 100 years return period).

Finally, the higher decrease in both area (ha) and population (inhab) exposed to flooding when comparing the values prior and after to the implementation of the NBS considered, the greater potential benefits in mitigating flood risks will be achieved.

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- AEMET (Agencia Estatal de Meteorología): http://www.aemet.es/es/portada.
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- Iber user´s manual: http://iberaula.es/space/54/downloads
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3.2 Water Quality KPIs

Nutrient abatement; abatement of pollutants

INTRODUCTION

“Nutrient abatement, abatement of pollutants” is included in the *Challenge 2. Water management.* Some NBS related to water management, such as the NTWP and the Electrowetlands, are designed for the removal of organic compounds and nutrients from the wastewater. The treatment of wastewater by means of green solutions supposes the discharge of low loads of organic matter, nutrients and other pollutants (such as heavy metals or emerging contaminants) to the environment. Therefore, the safety discharge to the environment or later reuse for different purposes (such as irrigation of green areas) is ensured.

This KPI aims at determining the organic matter, nutrients and other pollutants removal in the NBS. For that purpose the concentration of the specific contaminants to be monitored are determined both in the influent (raw wastewater) and the final effluent of the NBS. The reduction observed in the concentration is the abatement reached in the monitored system. This KPI involves sampling and analytical determinations in a lab.

In the European Union, the **urban wastewater treatment** is regulated through the Directive 91/271/EEC. This Directive concerns the urban waste water "collection, treatment and discharge of urban waste water and the treatment and discharge of waste water from certain industrial sectors". It aims "to protect the environment from adverse effects of waste water discharges from cities and "certain industrial sectors".

Parameters	Concentration	Minimum percentage of reduction (¹)	Reference method of measurement
Biochemical oxygen demand (BOD5 at 20 °C) without nitrification (²)	25 mg/l O_2	70-90 40 under Article 4 (2)	Homogenized, unfiltered, undecanted sample. Determination of dissolved oxygen before and after five-day incubation at 20 °C ± 1 °C, in complete darkness. Addition of a nitrification inhibitor
Chemical oxygen demand (COD)	125 mg/l O_2	75	Homogenized, unfiltered, undecanted sample Potassium dichromate
Total suspended solids	35 mg/l (³) 35 under Article 4 (2) (more than 10 000 p.e.) 60 under Article 4 (2) (2 000-10 000 p.e.)	90 (³) 90 under Article 4 (2) (more than 10 000 p.e.) 70 under Article 4 (2) (2 000-10 000 p.e.)	— Filtering of a representative sample through a 0,45 μm filter membrane. Drying at 105 °C and weighing — Centrifuging of a representative sample (for at least five mins with mean acceleration of 2 800 to 3 200 g), drying at 105 °C and weighing

(¹) Reduction in relation to the load of the influent.
(²) The parameter can be replaced by another parameter : total organic carbon (TOC) or total oxygen demand (TOD) if a relationship can be established between BOD5 and the substitute parameter.
(³) This requirement is optional.

Analyses concerning discharges from lagooning shall be carried out on filtered samples ; however, the concentration of total suspended solids in unfiltered water samples shall not exceed 150 mg/l.

Table 3.15: Requirements for discharges from urban waste water treatment plants subject to Articles 4 and 5 of the Directive. The values for concentration or for the percentage of reduction shall apply.

Parameters	Concentration	Minimum percentage of reduction (1)	Reference method of measurement
Total phosphorus	2 mg/l P (10 000 - 100 000 p. e.) 1 mg/l P (more than 100 000 p. e.)	80	Molecular absorption spectrophotometry
Total nitrogen (2)	15 mg/l N (10 000 - 100 000 p. e.) 10 mg/l N (more than 100 000 p. e.) (3)	70-80	Molecular absorption spectrophotometry

(1) Reduction in relation to the load of the influent.
(2) Total nitrogen means : the sum of total Kjeldahl-nitrogen (organic N + NH_3), nitrate (NO_3)-nitrogen and nitrite (NO_2)-nitrogen.
(3) Alternatively, the daily average must not exceed 20 mg/l N. This requirement refers to a water temperature of 12° C or more during the operation of the biological reactor of the waste water treatment plant. As a substitute for the condition concerning the temperature, it is possible to apply a limited time of operation, which takes into account the regional climatic conditions. This alternative applies if it can be shown that paragraph 1 of Annex I.D is fulfilled.

Table 3.16: Requirements for discharges from urban waste water treatment plants to sensitive areas which are subject to eutrophication as identified in Annex ILA (a). One or both parameters may be applied depending on the local situation. The values for concentration or for the percentage of reduction shall

Locally the limits to wastewater treatment and discharge are imposed by the River Basin Authority (Duero River Basin Authority in the case of Valladolid) who may adopt directly the values in tables 1 and 2 (in case declared sensitive areas) or establish more restrictive ones.

NBS TYPES

6. Natural wastewater treatment	Wastewater treatment plant based on the combination of natural treatment systems, such as constructed wetlands and ponds, following the concept of waterharmonica. The flow-sheet can be completed by sand filtration and chlorination (disinfection) for the later water reuse. These systems provide more than just simple purification, because while treating the water, they are also regulating temperature and providing valuable habitats for biodiversity.
7. Electrowetland	An Electrowetland is a natural wastewater treatment system that generates electricity from the oxidation of the organic matter. It is based on a conventional Horizontal Subsurface Flow Constructed Wetland (HSSF CW) in which electrodes are introduced. Therefore, it consists on a planted and permanently flooded gravel basin in which wastewater flows horizontally from one side to the other of the system crossing the electrode layer.

Figure 3.15: NBS types that applies to the KPI

METHOD

This KPIs is calculated from measured data using a methodology defined by URBAN GreenUP Project.

BACI (Before, After, Control, Impact)

Pollutants abatement in the related NBS are determined through the comparison of the concentration of the targeted pollutant in the influent and effluent of the system (NTWP or electrowetland). This KPI implies the sampling of water and later analysis in a lab. Sensors for continuous water quality monitoring are considered complementary.

Null hypothesis

NBS proposed do not remove from municipal wastewater any of the contaminants considered for this KPI and therefore there is no nutrient abatement. Also, if treated wastewater does not fulfil the legislation limits established in the Urban Wastewater Treatment Directive (91/271/EC) (Tables 1 and 2) or the ones imposed by the River Basin Authority.

Analysis: Water quality parameters

To analyse the pollutant abatement, samples at the influent and effluent of the NBS (NTWP and Electrowetland) will be taken and analysed by Aquavall (Municipal Public Entity in charge of water supply and wastewater treatment in Valladolid city).

Measurements and units of measurement

The pollutants to be monitored will be, at least, the parameters listed in the authorisation for wastewater discharge from the River Basin Authority. Commonly, the monitoring parameters are the ones in table 3.

Temperature (ºC)
Dissolved oxygen (mg L^{-1})
pH
Conductivity (µS cm^{-1})
Biochemical Oxygen Demand in 5 days, BOD5(mg O_2 L^{-1})
Chemical Oxygen demand, COD (mg O_2 L^{-1})
Suspended solids, SS (mg L^{-1})
Total Nitrogen, TN (mg N L^{-1})
Ammonium, N- NH4 (mg N L^{-1})
Total Phosphorous, TP (mg P L^{-1})
Chloride (mgCl^{-} L^{-1})
Grease & fats (mg L^{-1})

Table 3.17: Common monitoring parameters for the determination of the efficiency of wastewater treatment plants

Temperature, dissolved oxygen, pH and conductivity are commonly measured in situ by individual sensors or a multiparameter probe. The monitoring of these parameters shall be punctual or continuous (depending on the budget available for the acquisition of sensors and probes and the later maintenance).

The rest parameters will be determined in the lab using standard methods. However, in recent years, on site probes for the determination of some of the parameters listed in table 3 have been deployed in the market (i.e, probes for nitrates, ammonia, suspended solids). Their implementation allows the continuous monitoring of the water quality but might suppose an increase in the capital and running costs of the NBS.

Other pollutants, such as heavy metals or emerging contaminants, shall also be determined if required in the authorisation of wastewater discharge issued by the River Basin Authority.

Calibration / Verification

Water quality laboratory personnel will calibrate and verify equipments and probes used to quantify the above defined parameters over time according to each manufacturer specifications.

Measurement sites

Flow-proportional or time-based 24-hour samples shall be collected at the same well-defined point in the outlet and if necessary in the inlet of the treatment plant in order to monitor compliance with the requirements for discharged waste water laid down in the UWWTD 91/271/EEC.

Figure 3.16: Example of an automatic sampler Sigma 900 HACH.

Good international laboratory practices aiming at minimizing the degradation of samples between collection and analysis shall be applied.

Number of samples

Following the indications of Annex I of the UWWTD 91/271/EEC, the minimum annual number of samples shall be determined according to the size of the treatment plant and be collected at regular intervals during the year:

- 2000 to 9999 p.e.: 12 samples during the first year. Four samples in subsequent years, if it can be shown that the water during the first year complies with the provisions of the Directive; if one sample of the four fails, 12 samples must be taken in the year that follows.
- 10 000 to 49 999 p.e.: 12 samples.
- 50 000 p.e. or over: 24 samples.

<u>**Data**</u>

Data sampling

The analytic results are gathered in a lab work sheet. In case on site probes are installed in the NBS, data can be recorded through a datalogger.

Data processing

The efficiency of the NBS in the abatement of organic matter, nutrients and other pollutants (heavy metals or emerging contaminants) can be expressed as a percentage (% removed) or mass reduction (kg/day).

$$\%\,removed = \frac{C_i - C_e}{C_i} \times 100$$

C_i = concentration in the influent (mg/l)

C_e= concentration in the effluent (mg/l)

$$mass\ reduction\ \left(\frac{Kg}{day}\right) = (C_i \times Qi) - (C_e \times Qe)$$

Qi= inflow rate (m^3/day)

Qe= outflow rate (m^3/day)

Note: normally, Qi and Qe are considered equal (water losses in the system might be considered negligible)

Results

% removed; mass reduction (kg/day)

References

Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment

Water for irrigations purposes

INTRODUCTION

Water for irrigation purposes is included in the *Challenge 2. Water management.*

Some NBS are able to treat wastewater at the time other ecosystem services are provided. As function of the effluent quality, several uses for the regenerated wastewater can be considered, one of which is for irrigation purposes.

Every country has its own specific law regarding the water quality limits that must be fulfilled depending on the final use of the treated wastewater. Accordingly, in Valladolid, the Spanish law *REAL DECRETO 1620/2007, de 7 de diciembre, por el que se establece el regimen jurídico de la reutilización de las aguas depuradas* must be followed.

Considering the nature of the NBS implemented in Valladolid and the potential uses of the treated wastewater generated, some of the uses considered in the Spanish law were selected and summarized in the Table 1. Mainly, agricultural, industrial and environmental uses were rejected while urban uses considered the most probable. Maximum permissible limits for the Urban Uses considered are summarized in Table 2.

1. URBAN USES

WATER QUALITY 1.2: SERVICES a) Green urban areas irrigation (parks, sports camps and similar areas). [1] b) Street washing [1] c) Fire extinction systems [1]
[1] *When exists a water use that can imply water aerosolisation, it is cumpolsory to follow the usage conditions established, in each case, by the sanitary authority. Without the compliance of those conditions, the esmented water use will not be authorised.*

Table 3.18: Planned water uses considered in the *REAL DECRETO 1620/2007*

CONTROL PARAMETER	MAXIMUM PERMISSIBLE VALUE
INTESTINAL NEMATODES [1]	1 egg/10L
ESCHERICHIA COLI	200 CFU/100 mL
SUSPENDED SOLIDS	20 mg/L
TURBIDITY	10 NTU
OTHER CRITERIA	OTHER CONTAMINANTS[2] stablished in the wastewater discharge permit: the entrance of these contaminants to the environment should be limited. In the case of hazardous substances[3], compliance with the EQRs[4] must be guaranteed. Legionella spp. 100 CFU/L (when there is aerosolization risk)

[1] *Consider in all the quality groups at least the generus: Ancylostoma, Trichuris y Ascaris.*

[2] *See Annex II from RD 849/1986, from 11th of April.*

[3] *See Annex IV from RD 907/2007, from 6th of July.*

[4] *Environmental Quality Regulation (EQR). See article 245.5 from RD 849/1986, from 11 of April, modified by the RD 606/2003 from 23rd of May.*

Table 3.19: Maximum permissible values for URBAN USES of water reutilization

NBS TYPES

1. NWWTP	The Natural Wastewater Plant Treatment is a NBS based on the concept of the Waterharmonica in its design. This NBS is included in a urban park to provide sustainable water for irrigation with vertical SSFW (SSFW) working in parallel and followed by a SFW (Surface Flow Wetlands), which will constitute a network with a positive effect on functionality. A very simple calculation. An inhabitant of Valladolid produces around 300 L per day of wastewater. Irrigation needs of an urban green surface in Valladolid are around 4.5L/ m2. This implies that, suitably treated, with the wastewater of every citizen could irrigate 67 m^2 of green areas. This NBS is a very sustainable solution to reduce dramatically drinking water consumption for irrigation.

Table 3.20: NBS related to the KPI

METHOD

This KPIs is calculated from measured data using a methodology defined by URBAN GreenUP Project.

BACI (Before, After, Control, Impact)

Treated wastewater will be reused to irrigate the surrounding gardens. Reclaimed wastewater flow will be quantified by means of flowmeters placed at the effluent of the treatment line. Volumes of reused wastewater for irrigation purposes will be compared to the irrigation volumes of tap water used before for that aim. The surface irrigated with reclaimed water will be also measured. Required water quality parameters will be analysed from samples of treated wastewater to guarantee legislation fulfilment.

NULL HYPOTHESIS

Treated wastewater does not fulfil the legislation limits established for water reutilization for irrigations purposes (Table 2)

WATER VOLUME SENSOR

Monitoring equipment: two different flowmeters permanently installed at the influent and the effluent of the treatment line.

EXAMPLE

Doppler flowmeters use a single-head sensor design allowing mounting on the outside of pipes. The single-head transducer includes both transmit and receive piezo-electric crystals in the same housing. (Greyline, 2007)

MEASUREMENTS

Volume per day of treated water which is reused for irrigation purposes. Only the water that fulfils legal requirements in terms of water quality will be reusable and therefore considered for the KPI.

UNIT OF MEASUREMENT

m^3/day – Daily reused water volume for irrigation purposes.

CALIBRATION / VERIFICATION

Verification of the flowmeters will be conducted by qualified personnel and according to the manufacturer specifications.

MEASUREMENT SITES

The quantity of water reused for irrigation purposes will be measured by a flowmeter placed at the effluent of the NWWT line.

NUMBER OF STUDY SITES

One single point at the effluent of the NWWT line.

NUMBER OF SAMPLES

Influent and effluent NWWTPS wastewater flows will be measured at a continuous mode by the flowmeter and recorded, at least, hourly.

ANALYSIS: WATER QUALITY PARAMETERS

To analyse the water quality parameters stablished at the water reuse legislation, samples at the influent and effluent of the NWWTP will be taken and analysed by Aquavall (Municipal Public Entity in charge of water supply and wastewater treatment in Valladolid city).

MEASUREMENTS AND UNITS OF MEASUREMENT

The monitoring parameters will be determined on the corresponding authorisation for water reuse provided by the River Basin Authority (Confederación Hidrográfica del Duero, in the case of Valladolid). Among other parameters, the following ones are defined in the RD 1620/2007.

INTESTINAL NEMATODES (eggs/10L)
ESCHERICHIA COLI (CFU/100 mL)
SUSPENDED SOLIDS (mg/L)
TURBIDITY (NTU)
OTHER CRITERIA (see Table 2)

All the analytical determinations will be based on standard methods.

CALIBRATION / VERIFICATION

Water quality laboratory personnel will calibrate and verify equipments and probes used to quantify the above defined parameters over time according to each manufacturer specifications.

MEASUREMENT SITES

Water quality parameters will be measured at the samples taken periodically from the outflow of the NWWTP. Quality limits detailed in the Table 2 will allow the determination of the viability of the treated water to be used for irrigation purposes.

NUMBER OF STUDY SITES

There will be only one study site per NBS generating reused wastewater: the effluent of the treatment line from which treated water will be sent to the irrigated area.

NUMBER OF SAMPLES

According to the *REAL DECRETO 1620/2007* water quality parameters will be analysed at the following frequency:

CONTROL PARAMETER	MINIMUM SAMPLING FRECUENCY *
INTESTINAL NEMATODES	1 time / 15 days
ESCHERICHIA COLI	2 times / week
SUSPENDED SOLIDS	1 time / week
TURBIDITY	2 times / week
OTHER CRITERIA	1 time / month
* Frequencies established on this table may be altered according to the criteria established in the REAL DECRETO 1620/2007	

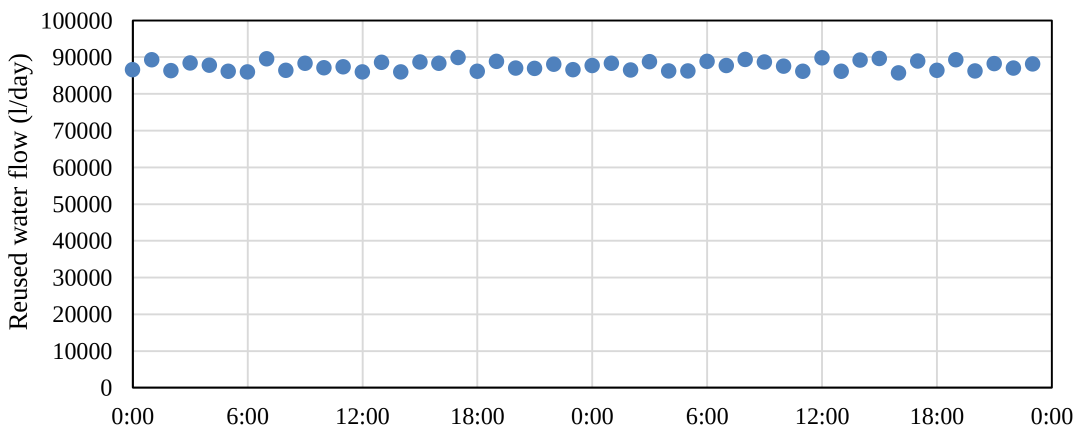
Table 3.21: Minimum sampling frequencies established at the REAL DECRETO 1620/2007

DATA

Data sampling

Continuous monitoring (sensors and water samples) at the outflow and the inflow of the of the NWWTP.

Data example



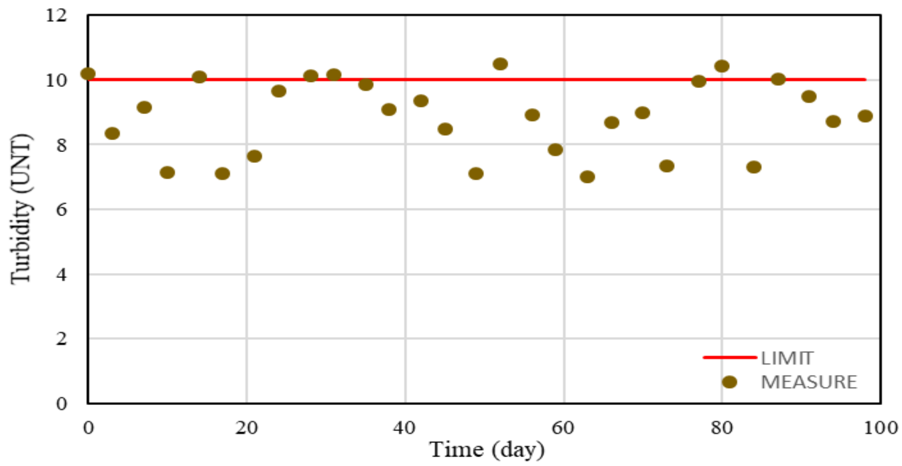


Figure 3.17: Data example graphics

DATA PROCESSING

Calculation of (weekly, monthly and/or yearly) mean levels of reused water volumes.

Volumes of reused wastewater will be normalized to the NBS surface in order to make the KPI comparable to other NBS which also generate reused wastewater for irrigation purposes.

RESULTS

At the location where NWWTP will be located there was no reused wastewater generation before the intervention. Therefore, this KPI constitutes an absolute value of volume of reused wastewater.

$$Daily\ volume\ of\ generated\ reused\ water \quad [\frac{m^3}{day}]$$

To normalize the generated reused water volume respect different NBS that also regenerate wastewater for irrigation purposes, the total volume will be divided to the NBS surface following this expression:

$$Generation\ of\ reused\ water\ for\ irrigation\ purposes =$$

$$= \frac{Daily\ volume\ of\ generated\ reused\ water}{NBS\ surface}$$

$$[\frac{m^3/day}{m^2}]$$

REFERENCES

Greyline (2017). Precision Flow Measurement. Available at: http://www.greyline.com

REAL DECRETO 1620/2007, de 7 de diciembre, por el que se establece el régimen jurídico de la reutilización de las aguas depuradas

3.3 Socio-Economic KPIs

Economic benefit of reduction of storm water treated in public sewerage system

INTRODUCTION

Green infrastructure can prevent rainfall from entering the water treatment system by allowing it to soak into the soil or to evaporate back into the air.

In the case of Valladolid, storm water, domestic sewage and industrial wastewater are collected through a combined sewers system which transports all the wastewater to a sewage treatment plant. The wastewater treatment plant (WWTP) of Valladolid has a treatment capacity for 570,000 population equivalent (future extension up to 750,000 pe) and a maximum flow rate 3 m^3/s.

The foreseen reduction in the surface runoff by the implementation of the different NBS in Valladolid city will reduce the total volume of wastewater collected though the sewers system and, therefore, the volume of water to be treated at the WWTP. Besides, this could reduce both the storage and treatment required to manage CSOs (combined sewer overflows). Thus, will suppose important economic savings.

NBS TYPES

4. Floodable park	Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits that floodable parks can provide are among others, reducing air temperature of the surroundings together with delivering amenity and biodiversity benefits.
5. Rain Garden	A rain garden is a bioretention shallow basin designed to collect, store, filter and treat water runoff. To optimise its functions, it must include a porous soil mixture, native vegetation and some hyperaccumulator plants, capable of phytoremediation.
6. SUDs	SUDS are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies. SuDS take inspiration from natural features and processes

	like uptake of water by plants, soil infiltration, pools, ponds, marshes, wetlands, springs, streams and rivers. SuDS work by holding rainwater back, treating pollution and releasing it slowly, without overwhelming the watercourse or sewer system into which it flows, thereby reducing flooding.
7. Green parking pavements	NBS destined to replace gray urban pavement with 50% vegetal soil and high drainage capacity. This kind of pavements has gaps, which are filled with smart soil and with specific creeping grass species with a short growing and minimum maintenance and are appropriate for bikes, pedestrian and motor vehicles.

Table 3.22: Related NBS

METHOD

The volume of water retained by the NBS will be estimated through KPI 16 and 20, which allows determining the reduction of water runoff. Then, this volume of water (mm/ year; m^3/month), which is not diverted to the sewer system, will be multiplied by:

- The annual cost for the maintenance of the municipal sewer system.
- The annual costs of water treatment (€/m^3 of wastewater treated).
- The costs for the proper management of the CSOs (€/m^3), considering the actual and planned costs of the infrastructure required for this purpose.

The actual costs of the water treatment and management of the CSOs will be provided by AQUAVALL (the public company which manages the urban water cycle in Valladolid).

Those estimations will be checked with the real figures compiled by AQUAVALL and the municipality of Valladolid (such as the total volume of wastewater treated in the WWTP or the CSO) before and after the implementation of the NBS. In this verification, the increase of wastewater production due to the growth of population in Valladolid or the implementation of new water-demanding industries/activities should be taken into account.

Data

- Average annual precipitation in Valladolid (mm/m^2)
- Area of green infrastructures implemented (m2) and the associated runoff reduction (m^3/m^2)
- Average water treatment costs to customers (€/m^3)
- Average capital costs for additional grey infrastructure capacity for the reduction of CSOs (€/m^3).

References

EPA (2007). Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. EPA 841-F-07-006

EPA (2014).The Economic Benefits of Green Infrastructure A Case Study of Lancaster. EPA 800-R-14-007

4 CHALLENGE 4: GREEN SPACE MANAGEMENT MONITORING PROCEDURES

4.1 Social Indicators

Distribution of public green space – total surface or per capita

INTRODUCTION

This indicator is included in the list of indicators for Challenge 4. Green Space Management. This social indicator evaluates the increases of public green spaces in terms of total surface or per capita.

Urban green infrastructures are key part of the sustainable development in our cities. They can provide important Ecosystem Services in them, including provisioning, regulating, supporting and cultural services. The total surface of green areas needs to be relativized in terms of total area or per capita, in order to compare results with other cities or to observe the evolution within the same city.

A survey carried out in 2017 by the AEPJPs for 54 spanish cities found the average value of public green space by the total surface were 3.4%. This survey also evaluates the public green space in terms of total surface per capita, and the average value for this were 12.46 m^2/hab. However, this and other study (Badui et al, 2016) proved the great variability that these indicators have between cities. The values given by the World Health Organization are also variable, since it sets the minimum green area per inhabitant at 9 m^2/hab and the ideal value at 50 m^2/hab.

NBS TYPES

This KPI can evaluate NBS involving **horizontal green infrastructures**, such as new green cycle lane and re-naturing existing bike lanes: Green cycle lane; Green resting areas; Cycle-pedestrian green paths, etc.

CODE	ACTION	SUB-DEMO	CATHEGORY	SUB-CATHEGORY
VAc1	New green cycle lane and re-naturing existing bike lanes	A	Re-naturing Urbanization	Green route
VAc2	Planting 1,000 trees	A	Re-naturing Urbanization	Arboreal interventions
VAc3	Tree shady places (500 trees)	A	Re-naturing Urbanization	Arboreal interventions
VAc4	Shade and cooling trees (600 trees)	B	Re-naturing Urbanization	Arboreal interventions

VAc5	Re-naturing parking trees (250)	C1	Re-naturing Urbanization	Arboreal interventions
VAc7	Urban Carbon Sink	C3	Re-naturing Urbanization	Carbon capture
VAc26	Electro wetland	B	Singular GI	Horizontal GI
VAc27	Green Covering Shelter	B	Singular GI	Horizontal GI
VAc28	Green Roof	B	Singular GI	Horizontal GI
VAc29	Green Shady Structures	B	Singular GI	Horizontal GI

Table 4.1: List of NBS Types that can be measurable with this KPI

METHOD

This KPI can be measured throughout specific software, such as GIS software and spreadsheet software. Results can be displayed throughout maps and/or tables.

This KPI can be considered for the entire municipality of Valladolid, giving a single resulting value for each study campaign. However, a neighbourhood level study is recommended since it can be useful for detecting deficitary areas.

SENSOR/SOFTWARE

Data are acquired by statistic and GIS processing, so **no sensor is required**.

Spatial Analysis software is required. **QGIS** is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

Spreadsheet software is required.

DATA SAMPLING

Datasets are provided by **Valladolid City Council**. All Datasets need to follow INSPIRE principles. An appropriated Coordinate Reference Systems must be defined for each location (city). The image below shows the recommended CRS for Valladolid location.

EPSG:25830

ETRS89 / UTM zone 30N (Google it)

- **WGS84 Bounds**: -6.0000, 34.7500, 0.0000, 62.3300
- **Projected Bounds**: 225370.7346, 3849419.9580, 774629.2654, 6914547.3835
- **Scope**: Large and medium scale topographic mapping and engineering survey.
- **Last Revised**: Oct. 19, 2000
- **Area**: Europe - 6ºW to 0ºW and ETRS89 by country

Input Coordinates: -3, 48.54 Output Coordinates: 500000, 5376321.814613

This is considered as a very stable KPI, so **frequency** could be the same as city council's demographic statistics, therefore, **annual**. In order to set the starting situation a preliminary study is also needed.

The required and recommended inputs for the calculation of this KPI are shown in the following table.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Green infraestructures surface	Green infrastructures cartography	m^2	Shapefile – Polygon	Required study data for this KPI. This dataset can also require an ID value.
City surface	Official City Boundaries cartography	m^2	Shapefile – Polygon	Required data for this KPI. This dataset can also require an ID value.
City population	Official City Boundaries cartography	number of inhabitants	Shapefile – Polygon	Required data for this KPI. This dataset can also require an ID value.
Neighborhood surface	Official Neighborhood Boundaries cartography	m^2	Shapefile – Polygon	Optional data for this KPI. This dataset can also require an ID value.

Neighborhood population	Official Neighborhood Boundaries cartography	number of inhabitants	Shapefile – Polygon	Optional data for this KPI. This dataset can also require an ID value.

DATA PROCESSING

Data processing using QGIS has been designed to obtain one KPI value by neighborhood.

The first step consists in obtain a shape-file in which each GI is associated to its neighbourhood location throughout the tool **Join attributes by location**. As a result, a new shape-file is obtained, with an attribute table associated containing a mixed of both attribute tables entries. In order to obtain a unique **green areas surface** value for each **neighborhood**, a **Single Part to multipart** tool can be used. Then the total surface can be calculated by the **Field Calculator** tool using the *$area* function.

The table below shows the properties of the new variable obtained.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Green areas surface by neighborhood	Green infrastructures joined by location cartography	m^2	Shapefile – Polygon	Derived variable obtained by GIS processing. This variable has to be recalculated after the join.

Two new fields have to be calculated using **Field Calculator tool**, which represent the total green area in terms of total surface or per capita.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
KPI 052 (1)	Green area surface by neighborhood / Neighborhood surface	% (m^2/m^2)	Shapefile – Polygon	Derived variable obtained by GIS processing.
KPI 052 (2)	Green area surface by neighborhood / Neighborhood inhabitants	m^2/hab	Shapefile – Polygon	Derived variable obtained by GIS processing.

Overall statistics can also be calculated by a QGIS tool called **Basic statistics for numeric fields** (based on KPI_052). Te result of this tool is a table (not GIS data), with resume figures of both terms of the KPI, including minimum and maximum values, range, mean and median value, standard deviation and coefficient of variation.

The next picture shows the algorithm for this described process.

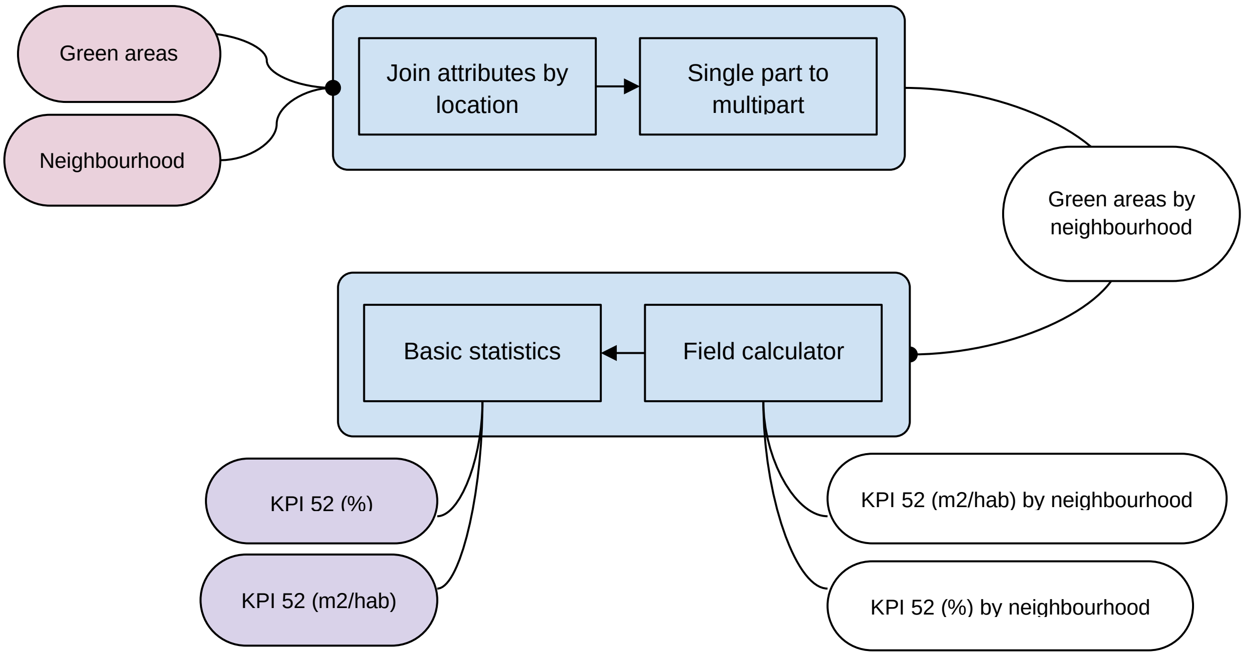


Figure 4.1: KPI algorithim dataflow scheme

RESULTS

Two final figures are obtained at the end of the process for this KPI. One of them shows the distribution of green areas surface in terms of total surface (%), and the other shows the distribution of green areas surface in terms of inhabitants (m^2/hab.).

In addition, a very simple map is proposed to show the KPI results by each neighbourhood. Resume statistics can be displayed also in this map.

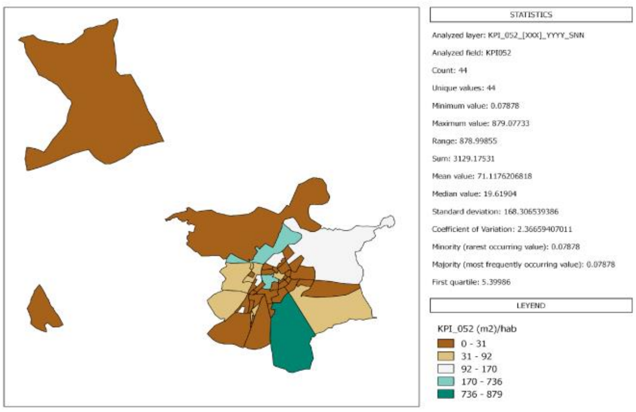


Figure 4.2: Example.

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ANÁLISIS DE LA CONSERVACIÓN DE LA INFRAESTRUCTURA VERDE URBANA EN ESPAÑA 2015 Junio 2017 Asociación Española de Parques y Jardines Públicos

Accessibility of urban green spaces for population

INTRODUCTION

This indicator is included in the list of indicators for **Challenge 4. Green Space Management**. This **social** indicator evaluates the accessibility of urban green spaces for population in terms of total distance or time.

Urban green infrastructures are key part of the sustainable development in our cities. They can provide important Ecosystem Services in them, including provisioning, regulating, supporting and cultural services. They have an important impact in human's health (Ekkel y de Vries, 2017; Tamosiunas et al, 2014).

In fact, Tamosiunas et al (2014) found that the prevalence of cardiovascular risk factors and the prevalence of diabetes mellitus were significantly lower among park users than among non-users. They suggested that public health policies aimed at promoting healthy lifestyles in urban settings could produce cardiovascular benefits. On the other hand, they showed that the accessibility to the urban parks influences the use that the population makes of them. In this way, the closer a park is to its users, the more they will use it.

Accessibility to green spaces indexes can provide an important information to improve urban management policies (Ekkel y de Vries, 2017; Peilei et al, 2017; Tamosiunas et al, 2014).

NBS TYPES

This indicator is related to NBS involving **horizontal green infrastructures**, such as green corridor, urban carbon sink, etc.

CODE	ACTION	SUB-DEMO	CATHEGORY	SUB-CATHEGORY
VAc1	New green cycle lane and re-naturing existing bike lanes	A	Re-naturing Urbanization	Green route
VAc2	Planting 1,000 trees	A	Re-naturing Urbanization	Arboreal interventions
VAc3	Tree shady places (500 trees)	A	Re-naturing Urbanization	Arboreal interventions
VAc4	Shade and cooling trees (600 trees)	B	Re-naturing Urbanization	Arboreal interventions
VAc5	Re-naturing parking trees (250)	C1	Re-naturing Urbanization	Arboreal interventions
VAc7	Urban Carbon Sink	C3	Re-naturing Urbanization	Carbon capture
VAc26	Electro wetland	B	Singular GI	Horizontal GI
VAc27	Green Covering Shelter	B	Singular GI	Horizontal GI
VAc28	Green Roof	B	Singular GI	Horizontal GI
VAc29	Green Shady Structures	B	Singular GI	Horizontal GI

Table 4.2: NBS Types that can be measurable with this KPI.

METHOD

This KPI can be measured throughout specific software, such as GIS software and spreadsheet software. Results can be displayed throughout maps and/or tables.

This KPI can be considered for the entire municipality of Valladolid, giving a single resulting value for each study campaign. However, a neighborhood level study is recommended since it can be useful for detecting deficitary areas.

SENSOR/SOFTWARE

Data are acquired by statistic and GIS processing, so **no sensor is required**.

Spatial Analysis software is required. **QGIS** is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

Spreadsheet software can be required.

DATA SAMPLING

Datasets are provided by **Valladolid City Council**. All Datasets need to follow INSPIRE principles. An appropriated Coordinate Reference Systems must be defined for each location (city). The image below shows the recommended CRS for Valladolid location.

Figure 4.3: coordinate system to use for Valladolid.

This is considered as a very stable KPI, so **frequency** could be the same as city council's demographic statistics, therefore, **annual**. In order to set the starting situation a preliminary study is also needed.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Green infraestructures location	Green infrastructures cartography	-	Shapefile – Polygon	Required study data for this KPI. This dataset can also require an ID value.
Entryway location	Official entryway cartography	-	Shapefile – Point	Required data for this KPI. This dataset can also require an ID value.
Neighborhood location	Official Neighborhood Boundaries cartography	-	Shapefile – Polygon	Optional data for this KPI. This dataset can also require an ID value.

Table 4.3: Required and recommended inputs for the calculation of this KPI

DATA PROCESSING

Data processing using QGIS has been designed to obtain one KPI value for the whole city. In addition, a neighbourhood level study is also recommended in order to find areas in deficit.

The first step is obtain a shape file in which each Entryway is linked to its nearest GI, throughout the tool **Distance to the nearest hub**. As a result, a new shape-file is obtained with an attribute field containing the measured distance in meters.

In order to obtain this KPI in terms of time, **Field calculator** tool can be used. A conversion factor has to be set to measure a pedestrian walking speed. Bosina et al (2017) sets the average for pedestrian speed walking in Spain were 1.59 m/s, which means 95.4 m/min. So the distance value in minutes can be obtained dividing by this value.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Distance to nearest GI.	Entryways linked to its nearest Green infrastructures (line).	m	Shapefile – Polyline	Derived variable obtained by GIS processing.
Time to nearest GI.	Entryways linked to its nearest Green infrastructures (line).	min	Shapefile – Polyline	Derived variable obtained by GIS processing.

Table 4.4: Properties of the new variable obtained.

Overall statistics can also be calculated by a QGIS tool called **Basic statistics for numeric fields.** The result of this tool is a table (not GIS data), with resume figures of both terms of the KPI, including minimum and maximum values, range, mean and median value, standard deviation and coefficient of variation.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
KPI 053 (1)	Accessibility (measured as distance) of urban green spaces for population.	m	table	Derived variable obtained by GIS processing.
KPI 053 (2)	Accessibility (measured as time) of urban green spaces for population.	min	table	Derived variable obtained by GIS processing.

Table 4.5: Properties of the new variable obtained.

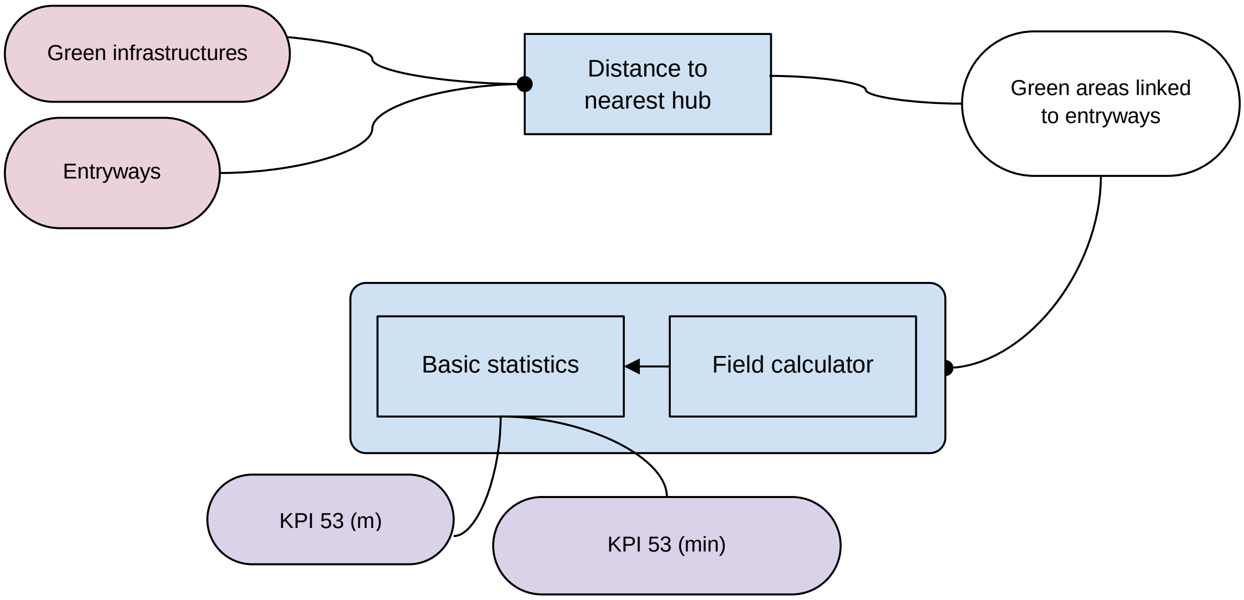

Figure 4.4: Algorithm for the described process.

RESULTS

Two final figures are obtained at the end of the process for this KPI. One of them shows the accessibility for green areas in terms of total distance (m), and the other shows the accessibility for green areas in terms of total time (min).

Tamosiunas et al (2014) classifies the accessibility to green parks using a tertiles method. As a result, they obtained 3 categories showed in the table below. A tertiles distribution is also proposed to use in this case.

Category	High	Moderate	Low
Distance	≤347.8 m	347.81–629.6 m	≥629.61 m

Table 4.6: Classification of the distance.

In addition, a very simple map is proposed to show the KPI results by each neighbourhood. Resume statistics can be displayed also in this map.

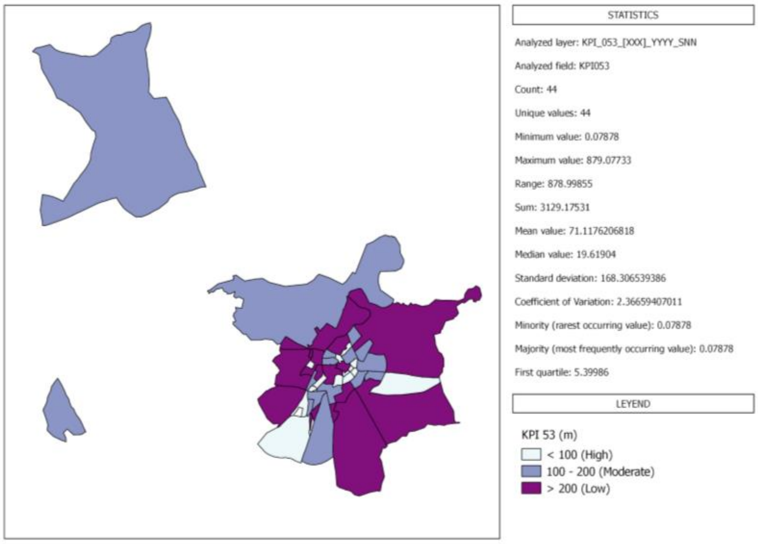

Figure 4.5: Example.

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Recreational cultural value

INTRODUCTION

Kabisch and Haase (2014), define this KPI as recreational (number of visitors, number of recreational activities) or cultural (number of cultural events, people involved, children in educational activities) value.

The KPI "Green intelligence awareness" refers to the number of educational activities related to a NBS; "Recreational or cultural value" intends to apply a different approach. Therefore, this KPI estimates the number of people who interact with a NBS, for cultural, recreational or educational purposes.

NBS Types

Non-technical interventions: Educational activities: Educational paths (A, C); Urban farming educational activities.

Methodology

Quantify the visitors and the number of people participating in the recreational activities per year, related to a NBS:

- Number of people who use urban orchards (nº users).
- Number of visitors: connections between beacons and URBAN GreenUP Mobile APP.
- Number of participants in guided tours.
- Number of participants in educational meetings: courses, conferences, lectures, workshops, seminars, and symposia.
- Number of participants i competition activities.

Sensor/Software

URBAN GreenUP Mobile App

Data sampling

No sensor.

Number of visitors' data is collected by URBAN GreenUP Mobile App.

Data processing

Sum of the numbers of users, visitors and participants of events related to a NBS during a year.

Results

Number of people per year

References

Questionnaires applied to the population for the recreational and cultural benefits of green spaces (Kabisch and Haase, 2014).

4.2 Environmental KPIs

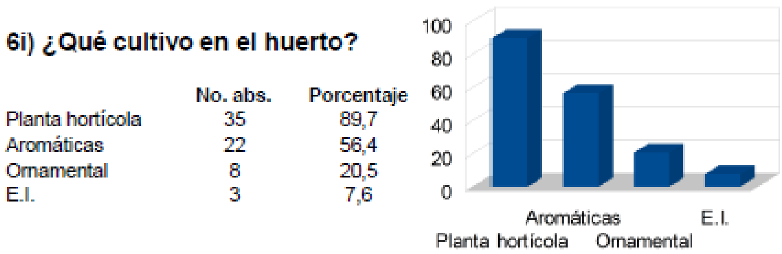
Production of food

INTRODUCTION

This KPI calculates or estimates the Production of food in urban orchards under the URBAN GreenUP project on agriculture activities, such as horticultural plants (tomatoes, cucumber, onion, etc.).

Currently, in Valladolid there are being cultivated horticultural plants, aromatic plant and ornamental plants in the four municipal orchards of the city:

- Valle de Arán (Barrio España) o North zone.
- Parque Alameda (Covaresa) o South zone.
- Santos-Pilarica o East zone.
- Jardín Botánico (La Victoria) o West zone.


6i) ¿Qué cultivo en el huerto?

	No. abs.	Porcentaje
Planta hortícola	35	89,7
Aromáticas	22	56,4
Ornamental	8	20,5
E.I.	3	7,6

Figure 4.6: Elements grown in municipal orchards in Valladolid (Report 2017)

There are two types of municipal orchards: Individual orchards (50 m2 per plot) and community orchards (there are three in North, South and East zones). The following images show the community orchards location in two orchards, Parque Alameda and Santos Pilarica.

Figure 4.7: Parque Alameda's urban orchards.

Figure 4.8: Santos-Pilarica's urban orchards.

NBS Types

Urban farming promotion: VAc31- Urban orchard; Vac32- Community composting; VAc33- Small-scale urban livestock, Vac36- Urban farming educational activities.

Methodology

The KPI will be calculated by the measurement of the amount of food produced. If it cannot be measured with a scale, an estimate of the amount generated will be made by the producers themselves (surveys).

In the individual orchards, currently at the end of the summer campaign (September-October), users will be asked directly using surveys. Every year Valladolid City Council sends a survey to the producers. This year 2018, there will be included a specific question about the amount of food that they produce. The producers might measure (scale) or estimate the quantities (how many bags, how many units).

On the other hand, community orchards measure every year the food amount that the produce, because the products are destined for social purposes. The food production of the community orchards will be measured with a scale, not estimated.

This KPI for food production will be measured/estimated by tones/Ha per year and tones/year.

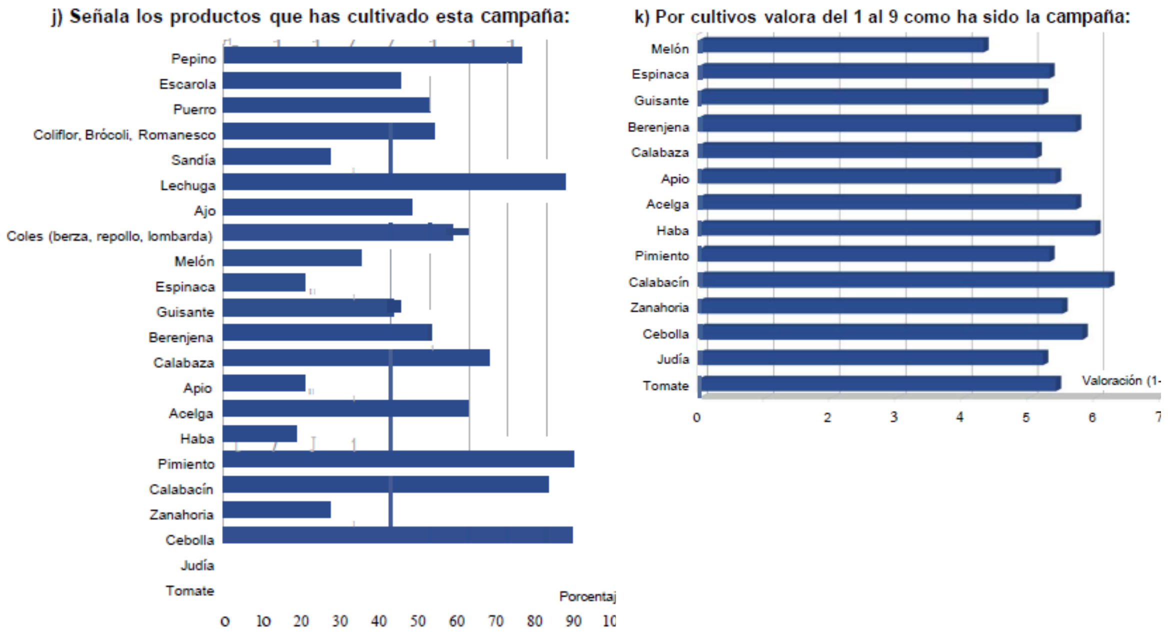


Figure 4.9:. Horticultural products grown in municipal orchards in Valladolid (Report 2017)

Monitoring equipment / Software

Surveys delivered to the producers at the end of September-October (ending summer campaign).

Sampling method

Yearly there have been collected data from periodical surveys made to the orchard producers. The provide information such as satisfaction level, performance level, products they cultivate, success, and others.

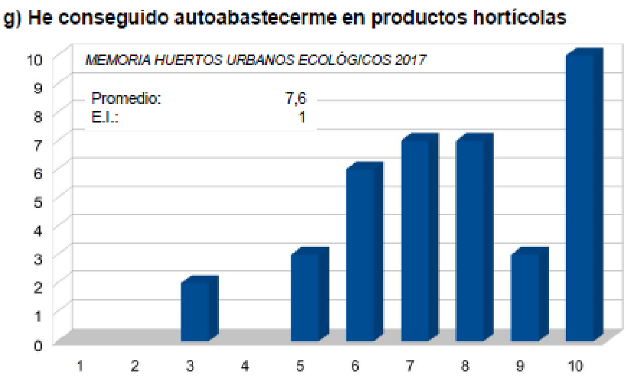


Figure 4.10:. Horticultural products grown in municipal orchards in Valladolid (Report 2017)

Data processing

Sum of the kilograms produced per user in yearly bases.

Results

Kg/Ha year: Kg produced per Ha of the orchard yearly.

Kg/ year: total Kg produced yearly.

References

Ecological orchards of Valladolid Annual Report (2016-2017)

http://pai.inea.org/wp-content/uploads/2016/11/memoria-2016MEJOR-CALIDAD.pdf

http://www.valladolid.es/es/actualidad/noticias/huertos-ecologicos-2016-2017

Sustainability of green areas

INTRODUCTION

Urban green solutions and spaces have to be designed and appropriately managed taking into account the high impacts on the ecological systems and communities.

Among others, they can improve the quality of the life of the neighbours, re-store ecosystems, mitigate the effects of the climate change and promote a healthy and environmentally friendly way to live, reducing the harmful impacts in the present and the future, during all its lifetime.

Sustainability concept integrates social, economic, cultural and environmental aspects. So that, sustainable development of green spaces can be defined ""as a state that in a particular time and space, an urban green system can achieve self-stability; in addition, sustainable development of green space provides the ecosystem service functions needed to protect the environment as well as meeting the needs for sustainable development of society and the economy." (Article: Research on the Sustainable Development of Green-Space in Beijing Using the Dynamic Systems Model Fangzheng Li 1,2, Yinan Sun 1,2, Xiong Li 1,2,*, Xinhua Hao 3, Wanyi Li 1,2, Yun Qian 1,2, Haimeng Liu 4 and Haiyan Sun 1)

NBS TYPES

Sustainability of green areas indicator applies to the following NBS: Green cycle lane; Tree related actions; Vertical and horizontal interventions; Floodable park, NWTP

METHODOLOGY

Sustainability is a wide concept, so the definition of a calculation method is not easy and can be very cumbersome and complicated. Therefore, a simplified method based on a score table, has been defined to have an evaluation approach of the impact of the different Nature Based Solutions (NBS).

The method evaluates different aspects (requisites) organized in three different topics:

1) Impact on ecosystem: the ecological context where a project is placed and developed.
2) Construction and OPERATION: the impact of the execution of the works to implement the NBS and the impact through the life due to the use.
3) Impact on society: improvement of the quality of the community life.

A score table has to be completed, by checking the items that the project meet: a comparison between the state before and after the implementation of the NBS have to be done, in order to asses if the project fulfils the condition of the requisite. Some of the requisites have a KPI related which can help to evaluate the level of fulfilment.

One check means ten points earned, so taking into account that each topic has 10 items, a maximum of 100 points can be achieved per category, and a maximum of 300 points in total.

ECOSYSTEM			
Requisite	Yes	No	Points (10 or 0)
Develop degraded sites			
Air quality improvement (KPI: Air quality parameters: NOx, VOC, PM, etc.			
Reduction of noise pollution (KPI: Noise reduction rates			
Reduction of light pollution			
Water use reduction for landscape irrigation (KPI: Water for irrigations purposes			
Reduction of pollution into water (KPI: Nutrient abatement, abatement of pollutants			
On-site precipitation management (KPI: Run-off coefficient in relation to precipitation quantities (KPI: Reduction of drought risk (probability). (KPI: Absorption capacity of green surfaces, bioretention structures and single trees			
Restore aquatic ecosystems			
Use native plants			
Restore animal habitats of populations of species			
CONSTRUTION / OPERATION			
Requisite	Yes	No	Points (10 or 0)
Integrative design process engaging users and stakeholders			
Conservation of landscapes features			
Conservation of buildings and structures			
Use recycled content materials			
Use regional materials			
Energy use reduction (improvement of energy efficiency) (KPI: Energy and carbon savings from reduced building energy consumption (KPI: Savings in energy use due to improved GI.			
Generation or use of renewable energy			
Reduction of heat island effect (KPI: Decrease in mean or peak daytime local temperatures (KPI: Temperature reduction in urban areas			
Sustainable maintenance planned			
SOCIETY			
Requisite	Yes	No	Points (10 or 0)
Educational and interpretive elements on site			
Educational activities planned (KPI: Green intelligence awareness			
Improvement of sustainable mobility (KPI: Encuestas Agenda21 sobre uso bicicleta			
Improvement of connectivity (KPI: Increased connectivity to existing GI			
Tourism impact			
Production of food (KPI: Production of food			

	Aumento actividad física ciudadanos (paseo, bici) (KPI: Quality of life for elderly people (KPI: Increase in walking and cycling in and around areas of interventions			
	Improvement of social connection			
	Creation of new jobs (KPI: Number of jobs created; gross value added.			
	Satisfacción general (KPI: Assessment of typology, functionality and benefits provided pre and post interventions. (APP			
			TOTAL POINTS =	

Table 4.7: On-site precipitation management8: List of dissemination activities v.1.

RESULTS

The total number of points achieved has to be divided per 3, in order to have a percentage value (de 0% a 100%). Also, four levels have been defined according to the following scale:

Category	Very good	Good	Bad	Very bad
Percentage	65-100	40-65	20-40	0-20

Table 4.9: Scale of KPI's percentage value.

Quality of life for elderly people

RATIONALE

An increase in the population aged 60 and above is a characteristic of the 21st century, all over the world. The World Health Organization (World Health Organization, 2002) refers to a demographic revolution and assumes that by 2025 the world population aged 60 and above will have reached 1.2 billion people, and by 2050 there will be two billion seniors. To make aging a positive experience, it must be accompanied by continuous opportunities for good health, participation, and security (World Health Organization, 2002). A positive aging experience implies not only to continuing with physical activity or work, but also the participation of the elderly in various areas – social, economic, cultural, spiritual and civic.

The key objective is to maintain autonomy and independence, promoting physical and mental health, social inclusion, and quality of life of all aging people, including the disabled and those in need of care (Zamboriová M, 2007).

Nature based solutions contribute to improve the quality of life of elderly people both by reducing the pollution (which is directly linked to health and respiratory problems) and providing new spaces for social interaction and recreational/physical activity development.

Quality of Life is one of the key indicators in elderly people care, a multidimensional and subjective value comprising the individual's perception of their own health, psychological state, independence, expectations, aspirations and concerns (World Health Organization, 1996).

RELATED NBS

Green cycle lane; Tree related actions; Vertical and horizontal green infrastructure; tree related actions, Floodable park, Green resting areas; Cycle-pedestrian green paths.

METHOD

The smartphone application include a generic survey engine that will allow defining different surveys and gathering the responses from the users. The key difference for each indicator will be the questionnaires themselves which are defined in the platform.

Given its relevance in elderly people care, there is plenty of literature in the scientific community regarding QoL evaluation. There are several surveys and questionnaires to evaluate the QoL, some of them for the general public and some of them specifically tailored to Elderly people, which can be used as a reference to assess the QoL. Among them, available surveys include:

- WHOQOL-BREF and WHOQOL-OLD
- EuroQoL-5D
- CASP-19 and CASP-12
- QWB and QWB-SA
- ICECAP and ICECAP-O
- OPQOL-35
- SF-36

DATA ANALYSIS

Periodic surveys can be performed via the smartphone application. However, the application itself will merely be a platform for questionnaire delivery and results gathering. Analysis of the responses needs to be performed afterwards, and given the differences among questionnaires concerning the number and type of the questions, the focus area (general well-being vs health vs social), nature and openness of the responses, etc. an interpretation of the responses and a different threshold level needs to be determined for the responses of each different survey.

A mobile application allows reaching a potential large population. However, it is well possible that the sample population available is too small, particularly at the beginning of the study, so some incentive program is recommended to increase the adoption of the application and the participation of the population.

Also, it conditions the survey, given that it is performed by the user himself, rather than an interviewer, so self-administered/simplified/easy to understand versions of the questionnaires are recommended.

UNIT OF MEASUREMENT

% of survey responses above a certain threshold (which should be set per different questionnaire)

SAMPLING METHOD

Surveys will be published in the mobile application periodically and the responses stored in the system's database. The first survey of the application will allow segmenting the users by different factors, such as age range, postal code, education/occupation status, or usual transportation means.

BASELINE INPUT DATA

Available information from previous surveys could be used for baseline (if available). Alternatively, it is recommended to begin early campaigns of surveys as soon as the platform is ready, and possibly before the NBS are fully deployed.

POST-INTERVENTION DATA

Periodic surveys will allow reaching a larger sample population and evaluate the evolution of the QoL assessment by the elderly population during and post NBS interventions.

Increased connectivity to existing GI

INTRODUCTION

This indicator is included in the list of indicators for *Challenge 4. Green Space Management* because the environmental (biological) indicator evaluates the increases of connectivity related to existing green infrastructures.

The extent and spatial arrangement of accessible green space within each sub-demo area may have an important influence on public health and wellbeing; as well as having the potential to increase biodiversity. Vegetated areas provide cooling on hot days through evapotranspiration; and trees reduce radiant heat by shading, making public space and travelling routes more comfortable for people on days when temperatures in urban areas are high. This KPI will focus on public accessible green space, therefore residential gardens will not be considered here.

NBS TYPES

This indicator is related to NBS involving **green infrastructures**, either horizontal or vertical, such as green corridor, urban carbon sink, etc.

CODE	ACTION	SUB-DEMO	CATHEGORY	SUB-CATHEGORY
VAc1	New green cycle lane and re-naturing existing bike lanes	A	Re-naturing Urbanization	Green route
VAc2	Planting 1,000 trees	A	Re-naturing Urbanization	Arboreal interventions
VAc3	Tree shady places (500 trees)	A	Re-naturing Urbanization	Arboreal interventions

VAc4	Shade and cooling trees (600 trees)	B	Re-naturing Urbanization	Arboreal interventions
VAc5	Re-naturing parking trees (250)	C1	Re-naturing Urbanization	Arboreal interventions
VAc6	Installation of 3 Green Resting Areas	A	Re-naturing Urbanization	Resting areas
VAc7	Urban Carbon Sink	C3	Re-naturing Urbanization	Carbon capture
VAc15	Cycle-pedestrian green paths	A	Singular GI	Cycle-pedestrian infrastructure
VAc22	Green noise barriers	A	Singular GI	Vertical GI
VAc23	Green noise barriers	B	Singular GI	Vertical GI
VAc24	Green Vertical mobile garden	B	Singular GI	Vertical GI
VAc25	Green Façade	B	Singular GI	Vertical GI
VAc26	Electro wetland	B	Singular GI	Horizontal GI
VAc27	Green Covering Shelter	B	Singular GI	Horizontal GI
VAc28	Green Roof	B	Singular GI	Horizontal GI
VAc29	Green Shady Structures	B	Singular GI	Horizontal GI

Table 4.10: NBS Types that can be measurable with this KPI

METHOD

This KPI can be measured throughout specific software, such as GIS software and spreadsheet software. Results can be displayed throughout maps and/or tables.

This KPI can be considered for the entire municipality of Valladolid, giving a single resulting value for each study campaign. However, a neighborhood level study is recommended since it can be useful for detecting deficitary areas.

SENSOR/SOFTWARE

Data are acquired by statistic and GIS processing, so **no sensor is required**.

Spatial Analysis software is required. **QGIS** is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

Spreadsheet software will be used.

DATA SAMPLING

Datasets are provided by **Valladolid City Council**. All Datasets need to follow INSPIRE principles. An appropriated Coordinate Reference Systems must be defined for each location (city). The image below shows the recommended CRS for Valladolid location.

Figure 4.11: coordinate system to use for Valladolid.

This is considered as a very stable KPI, so **frequency** could be the same as city council's demographic statistics, therefore, **annual**. In order to set the starting situation a preliminary study is also needed.

The required and recommended inputs for the calculation of this KPI are shown in the following table.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Green infrastructures	Green infrastructures cartography	-	Shapefile – Point	Required study data for this KPI. This dataset can also require an ID value. This data set includes new cycle lane and tree-lined streets.
Neighbourhood location	Official Neighbourhood Boundaries cartography	-	Shapefile – Polygon	Optional data for this KPI. This dataset can also require an ID value.

Table 4.11: Required and recommended inputs for the calculation of this KPI

DATA PROCESSING

Data processing using QGIS has been designed to obtain one KPI value for the whole city. In addition, a neighbourhood level study is also recommended in order to find areas with deficit.

The first step is obtain a table in which each GI is linked to its nearest GI, throughout the tool **Distance Matrix**. As a result, a new table is obtained with an attribute field containing the measured distance in meters.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Distance to nearest GI.	Distance between a GI and the nearest GI.	m	table	Derived variable obtained by GIS processing.

Table 4.12: Properties of the new variable obtained

Overall statistics can also be calculated by a QGIS tool called **Basic statistics for numeric fields.** The result of this tool is a table (not GIS data), with resume figures of the KPI, including minimum and maximum values, range, mean and median value, standard deviation and coefficient of variation.

The next picture shows the algorithm for this described process.

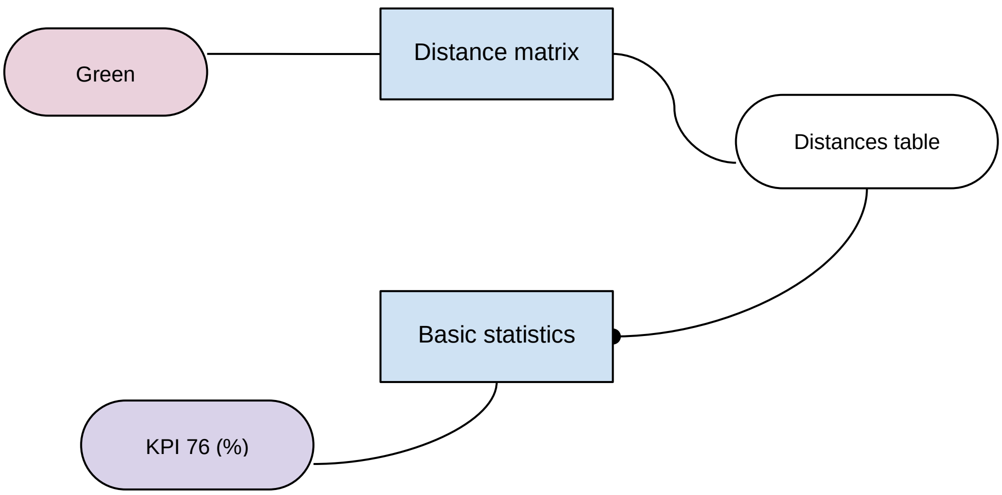


Figure 4.12: KPI algorithim dataflow scheme

RESULTS

Obtained value can be compared to previous value, with a formula:

$$Connectivity\ (\%) = (-1) \cdot \frac{D_j - D_i}{D_i} \cdot 100$$

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
KPI 076	Increased connectivity to existing GI	%	table	Derived variable obtained by GIS processing. Positive value means connectivity has increased, negative value means connectivity has decreased.

Table 4.13: Summary of the new variable obtained

REFERENCES

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Pollinator species increase

INTRODUCTION

This indicator is included in the list of indicators for *Challenge 4. Green Space Management*. . This **environmental (biological)** indicator evaluates the increases of pollinator species.

The presence of pollinating insects such as bees, hoverflies, butterflies and moths visiting flowers is indicative of pollination (ecosystem service). Increased habitat for pollinators in NBS GI may contribute to increased abundance of pollinators in the wider urban area and provide stepping stones or corridors of habitat from a source site such as an urban park to another urban GI site. Flying pollinating insects are an appropriate indicator of pollination and biodiversity in new NBS GI as these taxa are likely to be already present in source sites such as urban parks within normal foraging range of the new NBS. Flying pollinating insects are highly-mobile, and therefore, considered to have the potential to reach the NBS sites within the project monitoring period.

NBS TYPES

Monitoring of pollinator increase will be carried out in all NBS which have herbaceous or shrub vegetation, including floral resources.

CODE	ACTION	SUB-DEMO	CATHEGORY
VAc1	New green cycle lane and re-naturing existing bike lanes	A	Re-naturing Urbanization
VAc2	Planting 1,000 trees	A	Re-naturing

			Urbanization
VAc3	Tree shady places (500 trees)	A	Re-naturing Urbanization
VAc4	Shade and cooling trees (600 trees)	B	Re-naturing Urbanization
VAc5	Re-naturing parking trees (250)	C1	Re-naturing Urbanization
VAc6	Installation of 3 Green Resting Areas	B,C1,C3	Re-naturing Urbanization
VAc7	Urban Carbon Sink	C3	Re-naturing Urbanization
VAc8	SUDs for green bike	A	Water interventions
VAc10	Rain Gardens	C1	Water interventions
VAc11	Floodable Park	C3	Water interventions
VAc12	Green Filter Area	C3	Water interventions
VAc13	Natural Wastewater Plant	C2	Water interventions
VAc19	Natural Pollinator´s Modules	A	Singular GI
VAc20	Compacted Pollinator´s Modules	B	Singular GI
VAc21	Natural Pollinator´s Modules	C2,C3,C4	Singular GI
VAc22	Green noise barriers	A	Singular GI
VAc23	Green noise barriers	B	Singular GI
VAc24	Green Vertical mobile garden	B	Singular GI

VAc25	Green Façade	B	Singular GI
VAc26	Electro wetland	B	Singular GI
VAc27	Green Covering Shelter	B	Singular GI
VAc28	Green Roof	B	Singular GI
VAc29	Green Shady Structures	B	Singular GI
VAc30	Urban Garden Bio-Filter	B	Singular GI
VAc31	Urban orchards	C	Singular GI

Table 4.14: NBS Types that can be measurable with this KPI

METHOD

BACI (Before, After, Control, Impact)

BACI survey design aims to separate the effects of an intervention (impacts) from those of other spatial and temporal variables. An impact site is where a specified impact from the intervention (NBS) is expected to occur. A control site is selected as a location similar - ideally identical - to the impact site pre-intervention, which is expected not to be affected by the intervention. The control site should be located at a sufficient distance from the paired impact site to minimise the likelihood of the same pollinator individuals being recorded at both impact and control sites (independent observations). As the impact and control sites selected are unlikely to be subject to identical ecological baseline conditions, sampling both impact and control sites pre-intervention as well as post-intervention can identify and account for other variables, providing a more robust survey approach.

Sampling method

Once the pollinator modules are located, the zones where the measurements will be made will be selected, the number of samples being sufficient to be representative.

Where the whole study site will not be sampled, observation of pollinator visits to NBS within 1x1m quadrats (at sampling locations selected at random) is proposed as a suitable method to obtain representative sampling of the study site.

Location of samples

Sampling locations within each study area will be selected at random at every survey visit.

Repeated sampling & detectability of focal taxon

Each study site will be sampled once every 4 weeks between April and October (if the average daily temperature in the months prior to April or after October is greater than 15 degrees, sampling will be done.) If the average daily temperature does not reach at 15 degrees, sampling will begin later in April or be completed before October).

Pollinator observations will be carried out in appropriate weather conditions and time of day for detecting pollinator visits to plant resources.

The specific conditions to carry out the sampling will be: temperature ≥ 15 ° C, low wind, no rain and dry vegetation.

Pollinator samples

At each sample location, the pollinator visits the NBS within the 1x1m quadrant or whole if it is smaller in size, will be observed for a continuous period of 15 minutes.

The observer should stand in a position that does not shade the plot.

Variables to be recorded at each pollinator sampling plot (1x1m)

- Date
- GPS location
- Time
- Temperature
- Weather e.g. full sun, breeze, overcast etc.
- Number of visits by pollinating insects – record taxonomic group of each pollinating insect, to species level where possible. Alternatively, higher level pollinator groups can be used corresponding to family or subfamily: bumblebees, solitary bees, hoverflies, butterflies, moths.

DATA ANALYSIS

- For each NBS study site compare annual mean abundances and (or) species-richness of pollinators recorded pre-intervention with those recorded post-intervention.
- Comparison of annual mean abundances and (or) species-richness of pollinators recorded at each NBS study site with those recorded at the matching control site both pre- and post-intervention

SENSOR / SOFTWARE

No specific sensor or software is needed to obtain the data.

A thermo-hygrometer is needed to record humidity and temperature in the sampling area.

A GPS to determine the location.

If possible, cameras will be used to record or photograph the sampling areas.

It is advisable to use prisms or another type of device to amplify the sampling area in case the approach is not possible.

REFERENCES

PROTOCOL TO DETECT AND EVALUATE THE POLLINATION DEFICIT IN CROPS: A MANUAL FOR YOUR. FAO USA 2011

Perceptions of connectivity and mobility

RATIONALE

Transport is a key enabler of social and economic development, and the transport sector accounts for 9 million jobs across the EU. As 68% of EU citizens live in urban areas (EUROSTAT, 2011) urban transport is particularly important to future growth.

Given the high proportion of economic activity that takes place in urban areas (85% of EU GDP), problems with transport infrastructure in those areas can have serious economic consequences. Road congestion in the EU is often located in and around urban areas and costs nearly €100 billion every year, or 1% of the EU's GDP (European Commission, 2009). Urban areas are also particularly exposed to the external costs of transport, with higher levels of air pollution and noise pollution. And urban areas are below average in reducing road fatalities (European Commission, 2018).

Spatial mobility refers to actualized travel across space, whether over short or long distances, and whether for temporary and permanent sojourns (Kaufman, 2002). Spatial mobility can be measured simply as distance travelled, but it is often analysed in several more axis, including organizational capacity (access to car, public transport) time (not only travelled time, and public transport availability), and the physical capacity of the traveller (Walks, 2015).

Connectivity or accessibility describes how well different places are connected to each other using the transport system. The term refers to the ability to reach (or 'interact with') potential existing opportunities, including places of residence, employment, school, shopping, and recreation, that are spatially distributed (Mercado, 2012), and generally it is considered to be higher when such activities are closer and trips are shorter.

There are several methods to objectively measure the connectivity/mobility of an area, using GIS analysis of the region to determine public transport access level, travel time mapping among destinations and catchment analysis (i.e. how many workplaces or services exist within a certain travel time from a starting location) (Transport for London, 2015).

However, this indicator is meant to assess how the citizens perceive the mobility and connectivity opportunities in the city, rather than the measurement of transport availability itself, in hopes of understanding of the problems faced by citizens travelling in urban areas and of the potential support for different approaches to dealing with these problems.

Nature based solutions developed in the project should also improve mobility as part of the sustainable Urban Mobility Plans, be it by providing sustainable transport modes, improving citizen's behaviour in transport activities (promoting walking and cycling) or providing new paths and spaces for walking and cycling.

RELATED NBS

NBS that improve mobility include dedicated walking and cycling infrastructure, park and ride areas, tree related actions; Green resting areas; Cycle-pedestrian green paths, but also other solutions that might make the landscape more enjoyable and promote walking rather than other modes of transport.

METHOD

The smartphone application include a generic survey engine that will allow defining different surveys and gathering the responses from the users. The key difference for each indicator will be the questionnaires themselves which are defined in the platform.

In the case of connectivity and mobility, there are several technical papers analysing methodologies for mobility and accessibility assessment, but most of them are based on empirical observations and GIS analysis, rather than population perception. Thus, unlike the KPI-75, available forms and questionnaires to assess mobility and connectivity are less developed. Available surveys which could be used as a basis for the questionnaires include:

- Attitudes of Europeans Towards Urban Mobility (European Commission, 2013)
- The Life Space Questionnaire (Stalvey, 1999)
- Community Transportation Survey (Straight, 1997)
- EU Survey on issues related to transport and mobility (Fiorello, 2015)
- Enquête nationale transports et déplacements (Ministère de la Transition Écologique et Solidaire, 2018)
- Mobility in Germany 2008 (Clearing House Transport, 2018)

Additionally, it is possible to design custom questionnaires based on the previous references or new studies that appear during the project's lifetime.

DATA ANALYSIS

Periodic surveys can be performed via the smartphone application. However, the application itself will merely be a platform for questionnaire delivery and results gathering. Analysis of the responses needs to be performed afterwards, and given the differences among questionnaires concerning the number and type of the questions, the focus area (mobility habits, public transport quality, and accessibility), nature and openness of the responses, etc. an interpretation of the responses and a different threshold level needs to be determined for the responses of each different survey.

The approach will follow the computer-assisted web interviewing methodology (CAWI), but using an application instead of a web directly. As mentioned in the case of KPI-75, a mobile application allows reaching a potential large population, but given that many people are not receptive to completing questionnaires online (Singer, 2004), some incentive program is recommended to increase the adoption of the application and the participation of the population, decreasing the risk of low quality or incomplete surveys

UNIT OF MEASUREMENT

The unit of measurement will be the percentage (%) of survey responses above a certain threshold.

SAMPLING METHOD

Surveys will be published in the mobile application periodically and the responses stored in the system's database. The first survey of the application will allow segmenting the users by different factors, such as age range, postal code, education/occupation status, or usual transportation means.

BASELINE INPUT DATA

Available information from previous surveys could be used for baseline (if available). Alternatively, it is recommended to begin early campaigns of surveys as soon as the platform is ready, and possibly before the NBS are fully deployed.

POST-INTERVENTION DATA

Periodic surveys will allow reaching a larger sample population and evaluate the evolution of the mobility and connectivity assessment by the citizens during and post NBS interventions.

5 CHALLENGE 5: AIR QUALITY MONITORING PROCEDURES

5.1 Environmental KPIs

Annual mean levels of fine particulate matter in cities concentration recorded ug/m³

INTRODUCTION

This indicator is included in the list of indicators for *Challenge 5. Air Quality*. See table below with the total set of KPIs related to Air Quality (AQ) Challenge.

NBS TYPES

1. Urban Garden BioFilter	This NBS uses a special substrate (mixture of urban by – products) as filter media to capture pollutants (mainly NOx and PM) form the air of underground car parks without waste generation.
2. Urban Trees including: Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking and Arboreal areas around urban areas	This NBS includes individual large street trees, as well as the larger areas of woodland in the urban fringes. Trees perform multiple functions in urban areas. Urban trees are a vital element of our green infrastructure. Strategic positioning of large shade and cooling trees within urban areas can provide shade to buildings, reducing heat loading on building, provide islands of respite from high temperatures and capture some air pollutants (mainly PM) by dry deposition in our urban areas.
3. Green Façade	A green façade is a wall completely or partially covered with greenery. A green façade with climbing plants uses a trellis system to hold the vines of plants that are rooted in the ground or containers. Green façades offer economic, environmental, aesthetic and physiological benefits to the urban environment. Green façades are natural air-filters, creating a cleaner environment and provide high leaf surfaces.
4. Green shady structures	Pieces of stretched textile structure on which an inert substrate is installed. This inert substrate is covered with seeds, which germinate and grow on the textile structure. This NBS can be fixed to the facades of the buildings on the street or by posts fixed to the sidewalk. This green surfaces creates high leaf surfaces in pedestrian areas.
5. Green fences	This NBS is designed to reduce the traffic noise that arrives the pedestrian area and the homes on the street. On the one hand, the green noise barriers have a specific geometry that favors sound reflection and on the other hand, they have a vertical garden modules with a specific

	substrate that favors sound absorption.

Table 5.1: NBS Types that can be measurable with this KPI

METHOD

This KPIs is calculated from measured data using a methodology defined by URBAN GreenUP Project.

BACI (Before, After, Control, Impact)

Measure air concentrations of PM2.5 and PM10 at sampling points at a range of radii from NBS street tree/green wall locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of road without street trees/green wall at a similar time of day on the same dates.

NULL HYPOTHESIS

There is no difference in concentrations of PM2.5 or PM10 between samples in stretches of road where street trees/green walls are present, and samples taken in stretches of road without street trees/green walls.

SENSOR / SOFTWARE

Monitoring equipment: A portable photometric sampler designed to measure ambient PM2.5 and PM10 concentrations. This KPI requires a portable monitor because the quite big measurement points. The option of installing instrument in each location, which is ideal, shall be discarded because the cost will be too high, and the performance of the indicator can be shown following the procedure stablished.

EXAMPLES

Aeroqual Series 500 Portable PM Monitor. A laser and optical sensor are fitted to the sensor head of the monitor to measure light scattered from particles passing through a laser beam. The scattered light is transformed to electrical signals to provide mass measurements of PM2.5 and PM10

(https://www.aeroqual.com/product/portable-particulate-monitor).

Data stored on the device can be downloaded later to a PC using the USB cable and software provided with the monitor.

Price around 2.000€.

http://www.fluke.com/fluke/phen/hvac/iaq-tools/air-testers/fluke-985.htm?PID=74257

Data stored on the device can be downloaded later to a PC using the USB cable and software provided with the monitor.

Price around 4.000€.

Measurements

Concentrations of airborne particulate matter are measured by recording PM mass per cubic metre of air (PM2,5 and PM10).

Unit of measurement

Micrograms (mcg) per cubic metre, µg/m^3. (Microgram (µg) One-millionth of a gram; a milligram (mg) = 1000 micrograms).

Calibration / Verification

Comparison of the readings from the portable PM monitor against those from the static PM monitoring equipment in one station of the Atmospheric Pollution Control Network of the City of Valladolid (RCCAVA) to verify the tool.

Study sites

a) Stretches of road where street tree/green wall interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of road (road of similar width and with comparable building heights to intervention site) where street tree/green wall interventions are not proposed (control study sites). Control sites should be a sufficient distance away from street tree/green wall intervention sites for the observations made to be considered independent from the effects of street trees/green walls.

Number of study sites

tbc

Number of samples

At each study site and control site, depending on the width between road and street buildings, a sample will be taken at fixed locations: ***a)*** at the roadside, ***b)*** 3-5m from the road (where street trees/green walls have been installed the NBS should be situated between this sampling point and the road) ***c)*** 6-10m from the road; with additional measurements at intervals at greater distances from the road for study sites where urban infrastructure constraints allow.

Data sampling

Both intervention and matched control study sites should be sampled on the same occasion during each round of samples (i.e. an intervention site and matched control should be sampled on the same date and at as close a time of day as possible). Each fixed sampling location at a study site should be sampled every (*tbc*) weeks for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022). At each sampling point two readings should be taken: at heights estimated to represent ***a)*** child and ***b)*** adult head heights.

Data example.

Figure 5.1: Example of the aeroqual monitoring screen and histogram.

<u>Data processing</u>

Calculation of annual mean levels of PM10 and PM2.5 at each sampling location as the average value of the all the measurements done before and after of the interventions. Comparison of annual mean values for NBS intervention and control sample locations at each study site.

Calculations must be done using comparable periods of time before and after the interventions (i.e. if measurement period before of the intervention goes from nov18-oct19, measurement period must be from nov19-oct21 at least and processing can be done for either years or yearly).

Spatial Analysis software

QGIS is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

<u>Results</u>

The calculated values will be compared qualitatively and quantitatively for the periods before and after the interventions in the NBS and reference sections. Quantitative assessment will be done by using the following expression:

$$\boldsymbol{PM\ impact} = \left(\frac{NBS\ Measures\ average\ after\ intervent. - NBS\ Expected\ average\ after\ intervent.}{NBS\ Expected\ average\ after\ intervent.}\right) \times 100$$

Where *measures average after intervent.* is the average value of measurements after interventions and *Expected value after intervent.* (but supposing that interventions had not been done) is:

$$\boldsymbol{NBS\ Expected\ average\ after\ intervent.} \\ = \left(\frac{Ref.\,average\ after\ intervent.}{Ref.\,average\ before\ intervent.}\right) \times NBS\ Measures\ before\ intervent.$$

PM impact can be calculated both for PM2,5 and PM10. Positive or null PM impact values indicates negative or no impact of the NBS on PM concentration for that implementation. Negative values indicates a positive impact of that NBS on PM concentration.

References

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Mean levels of exposure to ambient air pollution

INTRODUCTION / rationale

Air pollution consists of many pollutants, among other particulate matter. These particles are able to penetrate deeply into the respiratory tract and therefore constitute a risk for health by increasing mortality from respiratory infections and diseases, lung cancer, and selected cardiovascular diseases. The mean annual concentration of fine suspended particles of less than 2.5 microns in diameters (PM2.5) is a common measure of air pollution. The mean is a population-weighted average for urban population in a country, and is expressed in micrograms per cubic meter [µg/m3]. Other important pollutants are ozone and NO_X. This indicator can be calculated using the different pollutants depending on the data availability and problems caused by each pollutant (according maximum levels reached in extreme events). This indicator has been defined using the SDG indicators numbers 3.9.1 and 11.6.2 as references but adapting it to be used at urban scale. This KPI is useful to assess the level of population exposed to low air quality levels in the city and the importance of this challenge for the city. Further analysis could be developed using public health or hospital admission data to correlate the importance or green infrastructure on air quality levels.

NBS Types

1. Urban Garden BioFilter	This NBS uses a special substrate (mixture of urban by – products) as filter media to capture pollutants (mainly NOx and PM) form the air of underground car parks without waste generation.
2. Urban Trees including: Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking and Arboreal areas around urban areas	This NBS includes individual large street trees, as well as the larger areas of woodland in the urban fringes. Trees perform multiple functions in urban areas. Urban trees are a vital element of our green infrastructure. Strategic positioning of large shade and cooling trees within urban areas can provide shade to buildings, reducing heat loading on building, provide islands of respite from high temperatures and capture some air pollutants (mainly PM) by dry deposition in our urban areas.
3. Green Façade	A green façade is a wall completely or partially covered with greenery. A green façade with climbing plants uses a trellis system to hold the vines of plants that are rooted in the ground or containers. Green façades offer economic, environmental, aesthetic and physiological benefits to the urban environment. Green façades are natural air-filters, creating a cleaner environment and provide high leaf surfaces.
4. Green shady structures	Pieces of stretched textile structure on which an inert substrate is installed. This inert substrate is covered with seeds, which germinate and grow on the textile structure. This NBS can be fixed to the facades of the buildings on the street or by posts fixed to the sidewalk. This green surfaces creates high leaf surfaces in pedestrian areas.
5. Green fences	This NBS is designed to reduce the traffic noise that arrives the pedestrian area and the homes on the street. On the one hand, the green noise barriers have a specific geometry that favors sound reflection and on the other hand, they have a vertical garden modules with a specific substrate that favors sound absorption.

Table 5.2: NBS Types that can be measurable with this KPI

Method

This KPIs is calculated from ground measurements by the official Air Quality monitoring networks in cities applying a methodology defined by URBAN GreenUP Project adapted from different sources. Additionally, information on the type of the zone (road traffic, city background, industrial, etc.) has been assigned to the different areas/streets of the city to weight population.

Sensor / software

Air Quality monitoring stations network in major urban agglomerations as Valladolid (Atmospheric Pollution Control Network of the City of Valladolid (RCCAVA)), Liverpool or Izmir.

Measurements

Concentrations of NO_2, O_3 and airborne particulate matter are measured by recording PM mass per cubic metre of air (PM2.5 and PM10).

Unit of measurement

PM - Micrograms (mcg) per cubic metre, µg/m^3. (Microgram (µg) One-millionth of a gram; a milligram (mg) = 1000 micrograms).

NO_2 – Micrograms (mcg) per cubic metre, µg/m^3. (Microgram (µg) One-millionth of a gram; a milligram (mg) = 1000 micrograms).

O_3 - Micrograms (mcg) per cubic metre, µg/m^3. (Microgram (µg) One-millionth of a gram; a milligram (mg) = 1000 micrograms).

Calibration / Verification

Municipal Air Quality networks have very reliable verification and calibration protocols.

Study sites

Data collection points are the locations of the stations of the Municipal Air Quality network and GIS model will extend the study sites to the whole city.

Number of study sites

City

Data sampling

Continuous monitoring in the selected points hourly.

Data example.

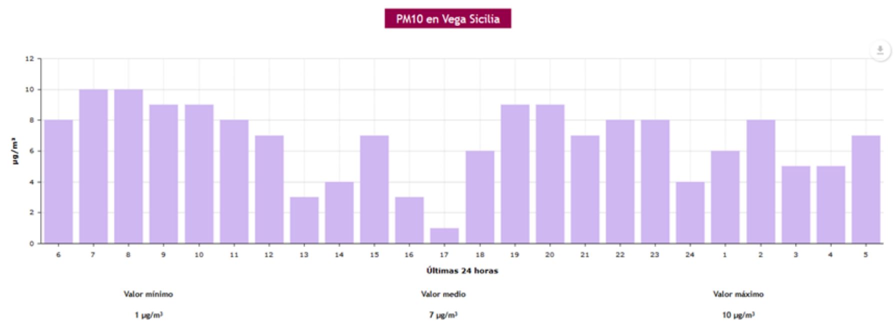


Figure 5.2: PM10 measurements in Vega Sicilia.

Data processing

Calculation of annual and monthly mean levels of NO_2, O_3, PM10 and PM2.5 at each station location.

There are three main types of stations for city domains (excepting industrial sites that are no considered for this KPI).

- Road traffic
- Urban background
- Peri-urban background

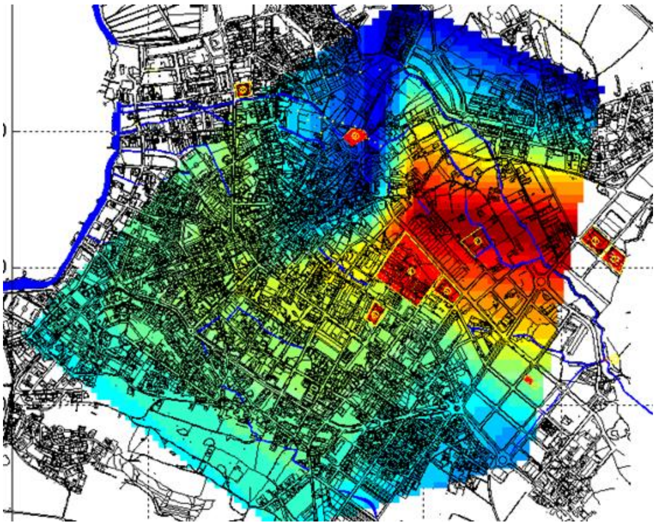
According to this classification, it can be obtained average values for road traffic areas, urban areas and peri-urban areas. Then, using a GIS software, a model of the city can be built that classifies all locations/streets/areas of the city in those categories.

Spatial Analysis software

QGIS is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

Results

The main result of this KPI is a city map where can be shown air quality average levels for the city. This outcome can be used to define population exposition levels and to highlight buildings used by vulnerable groups such as schools or residences for the elderly.



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https://www.valladolid.es/es/rccava/rccava

https://qgis.org/en/site/

5.2 Economic KPIs

Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. Use of GI val to calculate the value of air quality improvements

INTRODUCTION

This KPI, related to economic aspects measurements, evaluates how NBS interventions can increase the total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. use of GI val to calculate the value of air quality improvements. Supporting KPIs for Valladolid.

Valladolid plans to adapt the use GI-Val Toolkit. GI-Val Toolkit Model is The Mersey Forest's green infrastructure valuation toolkit. The current prototype is free and open source, and can be downloaded from http://www.merseyforest.org.uk/services/gi-val/. It takes the form of a spreadsheet calculator and a user manual. One of the tools, Tool 4.6, can estimate the impact of nature-based solutions on various air pollutants, in tonnes per year, and from those quantities it can estimate the avoided costs of other air pollution control measures. It uses a benefit transfer method, based upon the Chicago Urban Forest Climate Study by the USDA Forest Service (Nowak et al, 1994).

4.6 Avoided cost of air pollution control measures							
					This tool uses currency exchange rates. To update these, right-click the table at the bottom of this sheet and click refresh.		
What type of location is the project in?	*Sub-urban*	*Select*					
What is the existing land use type?	*Vacant*	*Select*					
Input existing area of tree cover (ha)	0	*Ha OR*	~~Number of trees~~	~~0~~	*Tool uses Ha as default, using values entered in the Project Data sheet. If using Number of Trees, reduce C22 and C23 to Zero.*		
Proposed increased tree cover (ha)	36.00391967	*Ha OR*	~~Number of trees~~	~~0~~			
CURRENT LAND COVER - POLLUTANT REMOVAL	**Tonnes/ha/yr**	**Tonnes/tree/yr**	**Gross removal (tonnes/yr)**	**Cost savings**			
Carbon Monoxide removed (tonnes / year)	0.0008	3.6E-05	0.00	£0.00			*Auto calculation cells*
Sulphur Dioxideremoved (tonnes / year)	0.0028	1.3E-04	0.00	£0.00			*Auto calculation cells*
Nitrogen Dioxide removed (tonnes / year)	0.0025	1.1E-04	0.00	£0.00			*Auto calculation cells*
PM10 particulates removed (tonnes / year)	0.0063	2.9E-04	0.00	£0.00			*Auto calculation cells*
Ozone removed (tonnes / year)	0.0071	3.2E-04	0.00	£0.00			*Auto calculation cells*
PROPOSED NEW ADDITIONAL LAND COVER - POLLUTANT REMOVAL				**Cost savings**	**Net impact of scheme on pollutants removal (tonnes/yr)**		
Carbon Monoxide removed (tonnes / year)	0.0008	3.6E-05	0.03	£36.49	*CO t/yr*	0.03	*Auto calculation cells*
Sulphur Dioxide removed (tonnes / year)	0.0028	1.3E-04	0.10	£226.84	*SO2 t/yr*	0.10	*Auto calculation cells*
Nitrogen Dioxide removed (tonnes / year)	0.0025	1.1E-04	0.09	£546.89	*NO2 t/yr*	0.09	*Auto calculation cells*
PM10 particulates removed (tonnes / year)	0.0063	2.9E-04	0.23	£408.37	*PM10 t/yr*	0.23	*Auto calculation cells*
Ozone removed (tonnes / year)	0.0071	3.2E-04	0.26	£172.47	*O3 t/yr*	0.26	*Auto calculation cells*
Tool 4.6 output	**33,770**	*£ NPV Discounting over 50 yrs already built in the worksheet below*					

Figure 5.3: Example of GI-Val toolkit

Improvements to or replacement of this tool is planned, as more robust methods are likely available.

RELATED NBS

This KPI is related to All NBS (Monetary issues)

Urban Garden BioFilter; Urban Trees including: Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking and Arboreal areas around urban areas, Green Façade; Green shady structures; Green fences

The use of GI-Val toolkit refers primarily trees, but also, to a lesser extent, other vegetation. The proposal on how to extend it below results paragraph.

METHOD

This KPI (coded: KPI-88) value comes from the measured data using a methodology defined by URBAN GreenUP Project.

The location type (urban) and the pre- and post-intervention tree canopy cover will be entered into GI-Val. In the case of Liverpool demo the tree canopy cover will be measured using the colour infrared imagery and height data available under the Aerial Photography for Great Britain agreement[3] and the landscape architects' drawings.

If the GI-Val tool is substantially changed, as planned, the method will also change somewhat.

SENSORS / SOFTWARE EXAMPLES:

[3] https://www.apgb.co.uk/

City official data, city platforms, questionnaires, small-medium enterprise accounts… (Related to de NBS investment zone)

UNIT OF MEASUREMENT

(€) (€/m3) (€/m2)

STUDY SITES (Position)

M U

DATA PROCESSING

Monitoring systems need to be improved with systematic quality checks in order to ensure that data collected are reliable and there needs to be effective coordination between regional/ area authorities, and measurement team generally, to ensure that the data reported are consistent and comparable. The guidelines, spelling out the frequency of checks, the concept used, the methods for carrying them out and so on should be provided for each NBS by specific region.

RESULTS

The use of GI-Val toolkit refers primarily trees, but also, to a lesser extent, other vegetation.

Value on emission (reduction) * value on fees (emissions)

This value extended, in reference to the other NBS, by considering the concept on gross value added KPIs. (Referenced in KPI 141)

Gross value added (GVA) + Monetary Value of Savings produced (if any)

Defined as the difference between the value of goods and services produced and the cost of raw materials and other non-labour inputs, which are used up in production. The research should conclude what is the total contribution of NBS in % of the total GVA to the region/area economy in Euro/ by year.

REFERENCES

- *Forestry Commission, Scotland, The economic an d social contribution of forestry for people in Scotland, David Edwards, Jake Morris, Liz O´Brien, Vadims Sarajevs and Gregory Valatin, September 2008*

5.3 Social KPIs

Air quality parameters

INTRODUCTION / rationale

This indicator is included in the list of indicators for *Challenge 5. Air Quality*. See table below with the total set of KPIs related to Air Quality (AQ) Challenge.

Other indicators are defined to assess a general impact of a NBS on AQ at building, district or city scale. However, this indicator is focused on the impact of specific NBS on a polluted gaseous stream before being released into the urban atmosphere.

This indicator has been mainly defined for **Urban Garden BioFilter** but in future can be used for other NBS to be installed in outdoor pipes to capture pollutants. At lab scale, the impact of this NBS has been measured by a setup with air characterization upstream and downstream of the filter. However at real scale measurements of AQ are more complicated. The system is going to be installed in the underground car park “Plaza Zorrilla”. Inlet air can be measured by installing a sensor in the area where air is going to be extracted or inside of the inlet pipe. However, outlet air cannot be capture directly, it is a very high surface to cover. Thus, it is going to be installed two measure points before and after the implementation of the BioFilter. One of them next to the outdoor area and the other one far away but in the Zorrilla Sq. too. **These three measure point will count with PM and NOx sensors**.

NBS Types

1. Urban Garden BioFilter	This NBS uses a special substrate (mixture of urban by – products) as filter media to capture pollutants (mainly NOx and PM) form the air of underground car parks without waste generation.

Table 5.3: NBS Types that can be measure with this KPI

Method

This KPIs is calculated from measured data using a methodology defined by URBAN GreenUP Project.

BACI (Before, After, Control, Impact)

Measure air concentrations of NO_2, PM2.5 and PM10 at sampling points at a range of radii from NBS location both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of street without NBS at a similar time of day on the same dates.

Null hypothesis

There is no difference in concentrations of NO_2, PM2.5 or PM10 between samples in stretches of road where street trees/green walls are present, and samples taken in stretches of road without street trees/green walls.

dSensor / software

EXAMPLES

AQMesh is a commercially available and proven low-cost system for monitoring air quality. The product combines a robust hardware platform with the latest sensor technology and GPRS communication, cloud-based data processing and secure online access. Gases are measured using the latest generation of electrochemical sensors, which allow compensation for environmental factors and sensitivity to 5ppb. Particles are measured using a light scattering optical particle counter. For NO, NO_2, O_3 and PM.

Data can be download from internet.

https://www.aqmesh.com/product/

Price around 10.000€ (three years) per unit.

The AQS 1 combines a robust light scattering particulate monitor, and Aeroqual's industry leading sensor-based gas analyser modules. The monitor performs to Near Reference levels yet costs much less than comparable analyzers; it is also lightweight and can be installed and moved with ease. For NO_2, O_3 and PM.

Data can be download from internet an IP accessible.

Price around 14.000€.

Measurements

Concentrations of NO_2 and airborne particulate matter are measured by recording PM mass per cubic metre of air (PM2,5 and PM10).

Unit of measurement

PM - Micrograms (mcg) per cubic metre, µg/m^3. (Microgram (µg) One-millionth of a gram; a milligram (mg) = 1000 micrograms).

NO_2 – ppb (parts per billion). Parts per billion (ppb) is the number of units of mass of a contaminant per 1000 million units of total mass.

Calibration / Verification

Comparison of the readings from the NO_2 and PM monitor against those from the static monitoring equipment in one station of the Atmospheric Pollution Control Network of the City of Valladolid (RCCAVA) to verify the tool.

Study sites

a) Stretches of road where street tree/green wall interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of road (road of similar width and with comparable building heights to intervention site) where street tree/green wall interventions are not proposed (control study sites). Control sites should be a sufficient distance away from street tree/green wall intervention sites for the observations made to be considered independent from the effects of street trees/green walls.

Number of study sites

tbc

Number of samples

Continuous monitoring in the selected points each ten minutes.

Data sampling

Continuous monitoring in the selected points each ten minutes.

Figure 5.4: Histogram example.

Data processing

Calculation of (weekly, monthly and/or yearly) mean levels of NO_2, PM10 and PM2.5 at each sampling location as the average value of the all the measurements done before and after of the interventions. Comparison of mean values for NBS intervention and control sample locations in the implementation area.

Data comparison before and after of the intervention using the reference to assess possible meteorological or other factors influence.

Calculations must be done using comparable periods of time before and after the interventions (i.e. if measurement period before of the intervention goes from nov18-oct19, measurement period must be from nov19-oct21 at least and processing can be done for either years or yearly).

For this KPI, continuous records of air quality are available and, therefore, a different processing of the information will be applied to evaluate the impact of the NBS.

Spatial Analysis software

QGIS is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

Results

The calculated values will be compared qualitatively and quantitatively for the periods before and after the interventions in the NBS and reference sections. Quantitative assessment will be done by using the following expression:

$$\boldsymbol{PM\ impact} = \left(\frac{NBS\ Measures\ average\ after\ intervent. - NBS\ Expected\ average\ after\ intervent.}{NBS\ Expected\ average\ after\ intervent.}\right) \times 100$$

Where *measures average after intervent.* is the average value of measurements after interventions and *Expected value after intervent.* (but supposing that interventions had not been done) is:

$$\boldsymbol{NBS\ Expected\ average\ after\ intervent.} = \left(\frac{Ref.average\ after\ intervent.}{Ref.average\ before\ intervent.}\right) \times NBS\ Measures\ before\ intervent.$$

Positive or null NO_2, PM10 and PM2.5 impact values indicates negative or no impact of the NBS on PM concentration for that implementation. Negative values indicates a positive impact of that NBS on NO_2, PM10 and PM2.5 concentration.

The additional methodology (using continuous data) aims to find significant differences by comparing the normalized distributions of the difference between the sections with NBS and the reference sections.

First, the normalized distribution of the difference of the hourly values of the NBS location and the reference location is calculated. Then, the distributions of data before and after of the interventions are compared. If significant differences are found between the distributions before and after the implementation, then the impact of the NBS can be assessed.

If the centers of the histograms of both distributions (before and after the implementation) are separated by more than the sum of the standard deviations, σ (ie 2σ), then they will be considered as significantly different (with a 95% probability). If the center of the histogram of the situation after the implementation is lower than that of the previous situation (and the differences are significant) then it will be concluded that the impact of the NBS is appreciable. As an equation, this statement could be presented as follows:

$$Absolut\ value(Aver._{before} - Aver._{after}) > \sigma_{before} + \sigma_{after} \quad Positive\ impact$$

$$Absolut\ value\ (Prom._{before} - Prom._{after}) < \sigma_{before} + \sigma_{after} \quad Neglective\ impact$$

This procedure is suitable for both PM and NO_2.

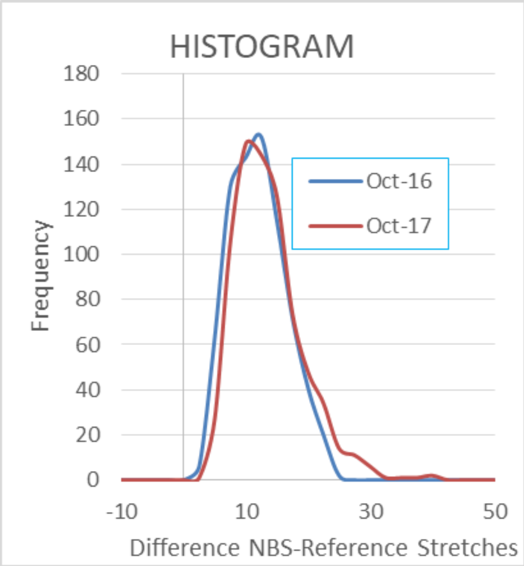

Figure 5.5: Example with no significant differences

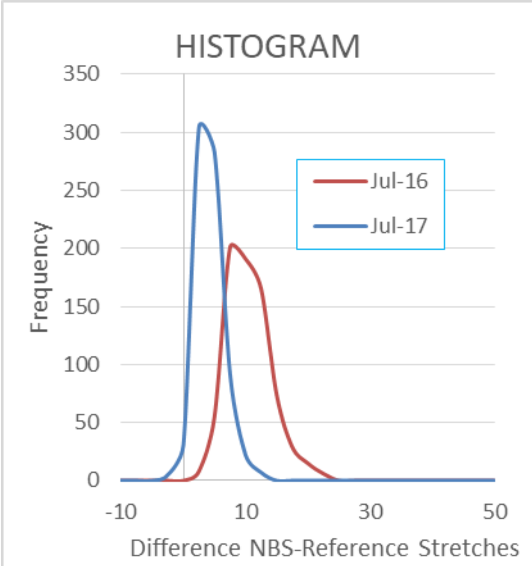

Figure 5.6: Example with Significant differences

	Oct-16	Oct-17		Oct-16	Oct-17
Average	10,8	12,4	**Average**	9,3	3,1
Stand. Desv.	4,5	5,4	**Stand. Desv.**	3,6	2,3

Table 5.4: Data example table.

References

http://life-equinox.eu/

6 CHALLENGE 6: URBAN REGENERATION MONITORING PROCEDURES

6.1 Socio-cultural KPIs

Assessment of typology, functionality and benefits provided pre and post interventions

INTRODUCTION

This is a global indicator which aims to analyze the urban regeneration (metropolitan or urban scale) taking into account the typology, functionality and benefits. The results will show the potential of a Nature Based solution to protect, improve, and regenerate the urban spaces.

This KPI called "Assessment of typology, functionality and benefits provided" is a complex indicator, which is compound by individual performance indicator (parameters). This KPI has multiple natures, composed, grouped and integrative. There have been defined a composed and weighted methodology to calculate this global KPI, through the addition of single KPI.

NBS TYPES

This KPI is a global indicator that can be applied to all technical interventions.

- Arboreal interventions: Urban carbon sink, planting trees, green areas, shady areas, green filter.
- Green corridor: green cycle lane, green resting areas, cycle-pedestrian green paths.
- Vertical and horizontal green infrastructures: green façade, shady areas, green roof, etc.
- Water interventions: floodable park, natural wastewater treatment plant, SUDs, rain garden.
- Singular interventions: electro-wetland, bio-filter.

METHODOLOGY

There have been defined a group of parameters that are the criteria to calculate the global indicator. These criteria are defined as single parameters, which are calculated departing from technical and statistical data collected or provided from other KPIs.

The parameters definition answers the following questions:

P1) Parameter: Typology. Question: What?

This parameter indicates the NBS improvement through the natural resources increase calculation. The definition of this parameter depends on the NBS type, so there are different ways to calculate this parameter, considering surface (m2), lineal (m) or single individuals (unit). In every case, the result is expressed in %.

- Green/Blue area increase (%): This method applies to all NBS that increase the green area, associated to a vegetation surface (trees, bushes, grass). This also applies to all NBS about water interventions that increase the water surface, associated to a blue area. This parameter can be calculated with mapping tools such as GIS (geographic information systems), My Maps, Google Earth and other.

$$\text{Green or Blue area increase (\%)} = \frac{\text{Increase green/blue area (m2)}}{\text{Green/blue area (m2)}} * 100$$

NBS - Green surface: Green resting areas, arboreal interventions, vertical green infrastructure, horizontal green infrastructure, urban orchard

NBS - Blue surface: Natural wastewater treatment plant will create a water ecosystem through a superficial lagoon; floodable park, although this NBS will not have a permanent water source; electro-wetland; SUDs, rain garden.

· Lineal NBS increase (%): This method applies to the NBS with lineal dimension, such as the green corridor with the cycle lane.

$$\text{Cycle lane increase (\%)} = \frac{\text{Increase cycle lane (km)}}{\text{Cycle lane (km)}} * 100$$

NBS: New green cycle lane and Renaturing existing cycle lane.

· Unit increase (%): This method applies to the NBS with unitary dimension, such as the green corridor with the cycle lane.

$$\text{Unit increase (\%)} = \frac{\text{New units (tree, recipient)}}{\text{Current units ex} - \text{ante (tree, recipient)}} * 100$$

NBS: Non-technical interventions (number of recipients); arboreal interventions (number of trees).

P2) Parameter: Functionality. Question: Where?

The functionality can be measured as the accessibility degree of the Nature-Based solution. It is related with the KPI 53 “Accessibility (measured as distance or time) of urban green spaces for population”. As it is defined, this social indicator evaluates the accessibility of urban green spaces for population in terms of total distance or time.

It is calculated as the shortest distance (linear) between the population in the NBS (line type), and the NBS location centroid (mean center). The result of KPI 53 is expressed in distance (m) or time (min), from an average velocity. This parameter can be measured throughout specific software, such as GIS software and spreadsheet software.

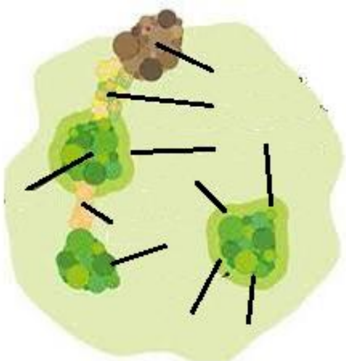

Figure 6.1: Accesibility of urban green spaces for population (Source: landscapeinstitute.org)

P3) Parameter: Sustainable benefits. Question: How?

This parameter shows the impact of the NBS taking into account economic, social and environmental aspects. It is related with the KPI 74 “Sustainability of green areas”. Sustainability has been also defined as a complex indicator, which is calculated through a check list with 30 items (requisites) that are classified into: Ecosystem items, Construction and operation items, and Social items.

The indicator will result in a Sustainability degree expression in 4 ranges, according to the score (rating): High (65-100 points), Medium high (40-65 points), Medium low (20-40 points) and Low level of sustainability (0-20 points).

RESULTS

The KPI “Assessment of typology, functionality and benefits provided” is a global indicator compound by three parameters. The result is calculated as the average of each parameter. It is expressed in %.

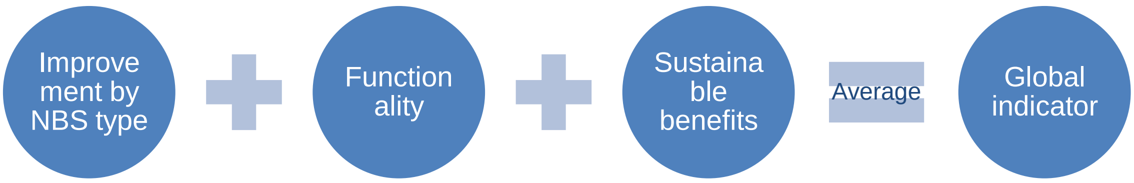

Figure 6.2: Results scheme.

DATA SAMPLING

This is an example of this KPI calculated to the NBS Arboreal interventions (*VAc5- Re-naturing parking trees (250)* in C1- Football Stadium Area (Parking).

$$\text{P1) Trees increase}_{\text{Footbal Std parking area}}\ (\%) = \frac{250\ (\text{tree})}{80\ (\text{tree})} * 100\ = 313\%$$

REFERENCES

“References for Urban Green Space Characteristics: A Comparative Study in Three Portuguese Cities”, Helena Madureira, Fernando Nunes, José Vidal Oliveira, and Teresa Madureira, 2018.

“Urban Green Spaces and an Integrative Approach to Sustainable Environment” Shah Md. Atiqul Haq, 2011

6.2 Economic

Savings in energy use due to improved GI

INTRODUCTION

The energy sector is the largest single source of global greenhouse gas emissions, and is responsible for over a quarter of all EU greenhouse gas emissions (European Comission). Green

Infrastructure can play a role in reducing the negative impacts of the energy sector, by: (1) reducing energy consumption; (2) providing bioenergy; and (3) providing carbon uptake and storage.

The KPI presented aims at quantifying both the energy savings and the bioenergy generated by all the NBS implemented in Valladolid. This KPI will be calculated converting into energy savings the benefits already considered by means of other KPIs. Therefore, in this KPI, all the NBS that provide an ecosystem service which has a direct link to an energy saving or the ones that generate electricity themselves will be considered.

NBS TYPES

CODE	ACTION	SUB-DEMO	CATHEGORY	SUB-CATHEGORY
VAc2	Planting 1,000 trees	A	Re-naturing Urbanization	Arboreal interventions
VAc3	Tree shady places (500 trees)	A	Re-naturing Urbanization	Arboreal interventions
VAc4	Shade and cooling trees (600 trees)	B	Re-naturing Urbanization	Arboreal interventions
VAc5	Re-naturing parking trees (250)	C1	Re-naturing Urbanization	Arboreal interventions
VAc7	Urban Carbon Sink	C3	Re-naturing Urbanization	Carbon capture
Vac11	Floodable park	C	Water Intervention	Flood actions
VAc13	Natural Wastewater Treatment Plant	C	Water intervention	Water treatment
VAc26	Electro wetland	B	Singular GI	Horizontal GI
VAc28	Green Roof	B	Singular GI	Horizontal GI
VAc29	Green Shady Structures.	B	Singular GI	Horizontal GI

Table 6.1: NBS Types that can be measured with this KPI

METHOD

This KPIs is calculated from measured data using a methodology defined by URBAN GreenUP Project.

Energy savings due to improved Green Infrastructure (ESGI) will be calculated by converting other KPIS (BASE KPIS, with other units of measurement) into its associated energy saving. Accordingly, from the complete list of KPIs measured at Valladolid DEMOSITE, the ones that imply an energy saving will be considered. Selected BASE KPIs and their corresponding units of measurement are defined in Table 1.

CODE	Key performance indicator	Primary units
1	Tons of carbon removed or stored per unit area per unit time	$tCO_2/m^2 \cdot y$
10	Energy savings from reduced building energy consumption	kWh/y
22	Temperature reduction in urban areas	% energy reduction
26	Intercepted rainfall per period of time	m^3/y
34	Water for irrigations purposes	$m^3/ha/y$
38	Volume of water removed from water treatment system	m^3/y

Table 6.2: BASE KPIs that can be converted into energy savings due to improved GI

Furthermore, there are NBS able to generate bioenergy themselves, such as Electrowetland. This bioenergy, which will be used to power temperature and humidity sensors, will be also considered as an energy saving and therefore added to the ESGI KPI.

BACI (Before, After, Control, Impact)

Energy savings will be calculated according to the KPIs established in Table 1. Each BASE KPI has its own control methods and baselines and therefore, no specific control is required for this KPI.

Null hypothesis

None of the KPI in which the ESGI KPI is based (Table 1) generate any quantifiable benefit.

Sensor / software

Due to the nature of this KPI which is calculated based on other BASE KPIs (Table 1) no sensor will be required.

Data processing

The initial step is the conversion of all the BASE KPIs considered in the Table 1 to the same timescale (referred to the same period of time). According to this factor, most of the BASE KPIs are quantified during yearly periods. However, if they are provided at other timescales values should be harmonized. This harmonization will be conducted considering constant values along the time (either if the time should be extended or reduced) as indicated in the Table 2.

	BASE KPI	CONVERSION	TIMESCALE CONVERTED KPI
EXTENSION	m^3/month	BASE KPI x 12 months	m^3/year

REDUCTION	m^3/5 years	BASE KPI/5	m^3/year

Table 6.3: Examples of timescale harmonization

Once all the BASE KPIs have the same timescale, the energy savings which they are linked to will be calculated. Each one of the BASE KPIs considered for this calculation is given in different primary units (Table 1). Therefore, for the calculation of their associated energy savings, when required they will be converted into energy units by means of specific conversion factors.

Accordingly, the factors required to convert the primary units into energy units are the ones stablished in Table 3.

$CODE_i$	**CONVERSION FACTOR**	**CF_i**	**Valor**	**Units CF_i**	**SOURCE**
1	Conversion factor from CO_2 to energy	CF_{CO2}	XXXXX	kWh/kgCO_2	????
22	XXXXXXX		XXXXX	XXXXXXX	Urban Green Up partner in charge of calculating the KPI
26	Energy consumption per cubic meter of wastewater transported and treated by the municipal wastewater treatment plant	CF_{WW}	XXXXX	KWh/m^3	Aquavall
27	Energy consumption per cubic meter of potable water (including transport)	CF_{PW}	XXXXX	KWh/m^3	Aquavall
	Energy consumption per cubic meter of irrigation water (including transport)	CF_{IW}	XXXXX	KWh/m^3	Parks and Gardens Department
38	Energy consumption per cubic meter of wastewater transported and treated by the municipal wastewater treatment plant	CF_{WW}	XXXXX	KWh/m^3	Aquavall

Table 6.4: conversion factors.

These conversion factors will be provided by the different stakeholders stablished in the last column of the Table 3.

Once the conversion factors are stablished, energy savings due to improved green infrastructure for each specific BASE KPI (KPI_i) will be calculated following these expression:

$$ESGI_{KPIi} = BASE\_KPI_i \cdot CF_i$$

RESULTS

To calculate the final value of the ESGI KPI ($ESGI_{tot}$), and only once all the BASE KPIs are converted into their associated energy savings per period of time ($ESGI_{KPIi}$), all the energy savings (including the bioenergy generated by the Electrowetland - BE) will be summed up according to the following expression:

$$ESGI_{tot} = \sum_{i} ESGI_i + BE$$

REFERENCES

European Commission. Green infrastructure in the Energy sector.

7 CHALLENGE 7: PARTICIPATORY PLANNING AND GOVERNANCE

7.1 Socio-Economic KPIs

Openness of participatory processes

Introduction

Nature-Based Solutions require planning approaches and governance architectures that support accessibility to green spaces, while maintaining their quality for the provision of ecosystem services. Urban environmental problems are often difficult to handle and successful solutions require combined efforts of different scientific disciplines but also an active dialogue between stakeholders from policy and society (Lemos and Morehouse, 2005).

In this context, transdisciplinary approaches for knowledge co-production provide insights about the ways and the rationale for engaging with multiple knowledge holders: experts and scientists as well as citizens and practitioners (Bergmann et al., 2012, Jahn et al., 2012). The scientific frameworks of urban ecosystem services were brought into the interface between policy and science to inform urban planning and governance (Frantzeskaki and Tilie, 2014).

The quality of the URBAN GreenUP project implementation depends on social learning and adequate technical solutions. This is possible through the support and cooperation between the involved parties and the resulting input of knowledge (Luyet, 2012).

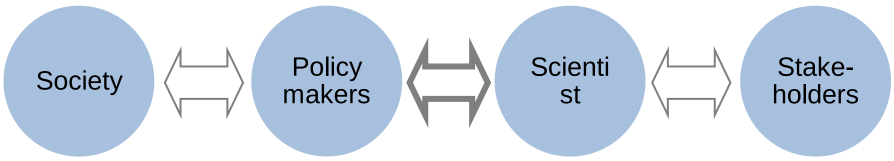

Figure 7.1: participatorie scheme

For this KPI definition "participation" is defined as "a process through which stakeholders influence and share control over development initiatives and the decision and resources which affect them" (World Bank definition, 1996). The stakeholder participation includes other stakeholders not mentioned in the other categories, such as civil society (individuals or organized society) and scientific community (the academia).

NBS TYPES

This KPI apply to all technical interventions of Valladolid Demo, in their designing, construction and monitoring processes, also knowledge co-production space.

METHODOLOGY

Participation is often reduced to the dissemination of information and the holding of workshops. These approaches generally do not take into account either the heterogeneity of stakeholders, or the complexity of the decision making process (Luyet, 2012).

The KPI "Openness of participatory processes" is based on the participation actions delivered in the city of Valladolid. There are defined two steps, data collection and data evaluation.

- Step 1. Data collection and characterization.

The data collection about the participatory processes would have the following items:

Participation techniques: Newsletter, Reports, Presentations, public hearings, Internet webpage, Interviews, questionnaires and surveys, Field visit and interactions, Workshop, Participatory mapping, Focus group, Citizen jury, Geospatial/ decision support system, Cognitive map, Role playing, Multicriteria analysis, Scenario analysis, Consensus conference.

Degrees of participation: The participation action is classified into the following types.

- Information: explanation of the project to the stakeholders.
- Consultation: presentation of the project to stakeholders, collection of their suggestions, and then decision making with or without taking into account stakeholders input.
- Collaboration: presentation of the project to stakeholders, collection of their suggestions, and then decision making, taking into account stakeholders input.
- Co-decision: cooperation with stakeholders towards an agreement for solution and implementation.
- Empowerment: delegation of decision-making over project development and implementation to the stakeholders.

Co-creation & Co-production agent: There are identified the following stakeholders groups:

- Policy makers: The Valladolid City Council Departments.
- Experts: Scientific community and consultants.
- Community representatives: Economic agents. Civil society such as civil associations and local communities.

		Openness to participatory processes			
Date	Communication model	Participation technique	Degree of participation	Co-creation & Co-production agent	Participation action
dd/mm /yyyy	Classify: In-person meeting. Video conference / Online meeting. Audio conference / Call.	Classify: Newsletter, Reports, Interviews, questionnaires, Workshop, others.	Classify: Information, Consultation, Collaboration, Co-decission, Empowerment	Policy maker, Scientific community, Civil society, Economic sector, Other stakeholder	Name of the participation action and short description

Table 7.1: Data collection record table for KPI 111 "Openness to participatory processes".

The following activities might be included to calculate this KPI: Single Desk actions, open days such as Mobility week or the Day of the Earth, conferences about Smart city, environmental awareness, etc.

- Step 2. Evaluation of participatory processes.

How do we evaluate the stakeholder participation? There are defined two techniques, quantitative and qualitative.

Quantitative evaluation: The “Openness of participatory processes” indicator is expressed through quantitative techniques such as (nº processess/year/participation technique/stakeholder) and population reached (number of attendees/agent type)

Qualitative evaluation: There is also calculated by qualitative technique. There will be assigned a final score from 1 to 5, depending on the following criteria:

- The quality of the process (conflict resolution, early involvement, transparency, equity, incluence, stakeholder representativeness, iontegration of all interests and definition of rules).
- The outcomes (capacity building, emergent knowledge, impacts and social learning)
- The political, social, cultural, historical and environmental context.

The qualitative score evaluates from 1-5 points, where 1-Low quality and 5-High quality.

		Evaluation of participatory processes	
Date	Participation action	Number of attendees	Qualitative score
dd/mm /yyyy	Name of the participation action and short description	Number of people that attend to the activity, for every stakeholder type (political, academia, citizens, etc.)	From 1-5 where 1-Low quality and 5-high quality.

Table 7.2: Evaluation record table for KPI 111 “Openness to participatory processes”.

- Note. Valladolid Participatory Budgeting Process.

It is worth mentioning the Valladolid Participatory Budgeting Process[4]. Since 2016 Valladolid City Council yearly opens to the citizens the investment decisions for the city. Participatory Budgeting is a mechanism by which citizens decide the assignment of a portion of municipal resources by establishing priorities in terms of municipal expenditures. Citizens over 16 years can choose how and where the City Council is spending municipal budget. Some examples of the investmen actions: Fix sidewalks, sewerage, pedestrian paths, cycle paths, public lighting, sports areas, parks and green areas, road signage, street furniture, improvement in urbanizations, small-scale equipment, improvement or conditioning of existing equipment (a public square, a school, a civic center, a library, etc).

- For the KPI “Openness of participatory processes” there will be identified if the citizens choose Nature-Based solutions actions as part of the participatory budgeting process. Some examples of these NBS are: Planting new trees, green areas, biodiversity actions, green infrastructure.

Sensor/Software

[4] Presupuestos participativos: https://www10.ava.es/presupuestosparticipativos

No sensor or software is used for calculate this KPI. There is used an Excel sheet and statistics software (such as SPSS).

Data sampling

Data is being collected from Valladolid City Council participatory actions yearly.

Data processing

Data is collected monthly. A global indicator is being calculated yearly. There will be included a statistic analysis of the participatory processes delivered.

- Internal meetings between Valladolid City Council Departments per year. Departments involved (#/month, #/year, n º attendees).
- Participatory actions with the scientific community per year (#/month, #/year, n º attendees).
- Participatory actions with civil society (individuals and organized citizenship such as civic center's board and neighborhoods' associations) per year (#/month, #/year, n º attendees).
- Participatory actions with economic agents per year. Economic agents involved (#/month, #/year, n º attendees).
- Participatory Budgets: Number of NBS projects requested by the citizens per year. There will be identifies the NBS type.

Results

(#Participatory actions/month) (#/year) (# attendees) (nº NBS requests in Participatory Budgeting) (qualitative evaluation score).

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Perceptions of citizens on urban nature

Introduction

Citizens' perceptions, both individuals and communities, are essential when evaluating the well-being benefits from urban green spaces (Kothencz et al, 2017). Public and stakeholder perceptions of urban nature, and specifically the quality or functionality of nature, are critical to our understanding of the "value" people place on local environments (Priego et al., 2008).

Exploring visitors' perceptions of green spaces is challenging as it depends on cognitive, affective and behavioural components and, therefore, sensory perceptions are individually different (Kothencz et al, 2017).

This KPI measures identified green space characteristics by the two following well-being variables and one geolocation variable:

- Green space visitors' level of satisfaction. Directly related with the urban green space (UGS) quality.
- Self-reported quality of life (QoL).
- Frequency of green space visitors' crowd-sourced geo-tagged data in NBS sites.

Visitors' level of satisfaction and perceived QoL contributions of UGS are key individual-level measures that are subjectively affected by area-based green space characteristics.

This KPI will reflect on how people assess change in their local environments in terms of satisfaction, quality of life and citizens' presence of urban green space (UGS) at a site (NBS), neighbourhood and city scale.

NBS Types

Green corridor (green cycle lane, resting areas, cycle-pedestrian green paths); Vertical and horizontal green infrastructure; Tree related actions; Natural Wastewater Treatment Plant, Rain gardens; Green Parking Pavements; Electro wetland. Non-technical interventions: Promotion of ecological reasoning and intelligence.

Methodology

The indicator is calculated from data captured by surveys and by the URBAN GreenUP mobile application (location data). The following diagram shows the calculation procedure.

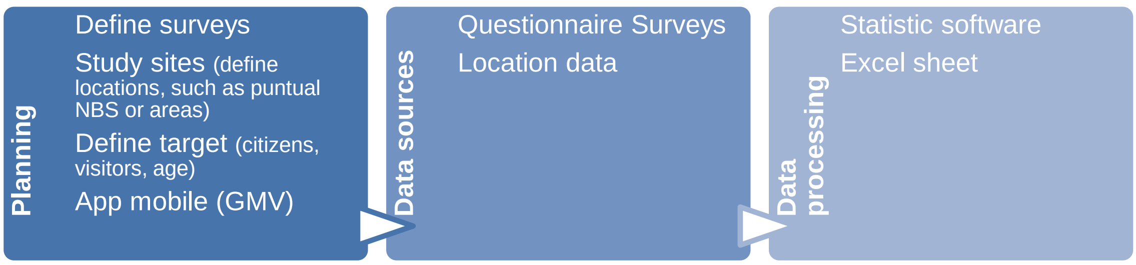

Figure 7.2: Workflow graphic example.

Surveys: On the one hand, Perceptions of citizens on urban nature applies questionnaire based-analytical methods. A social survey will ask individuals, communities and key stakeholders to rate the landscapes around the NBS in terms of their use/function, accessibility, and aesthetic quality.

Perceptions of citizens on urban nature will be measured as the use/function, accessibility, and aesthetic quality of the NBS in Valladolid

Currently, social surveys are conducted periodically by the Local Agenda 21 of Valladolid[5]. The questionnaire includes Sustainability Items such as the following. This LA21 Survey is the starting point for this URBAN GreenUP KPI: "Percentage of population satisfied or very satisfied with the quantity and quality of green spaces in the city". Results in 2014 were 68% and 65% respectively.

The perceived quality of green spaces will be assessed via a combination of qualitative questions reflecting on the composition, function and utility of green space and quantitative questions using a scaled responses and pre-determined asset/value lists to assess the perceived greenness and quality.

Design of the survey: The survey will contain a maximum of 30 questions that evaluate the perceived quality of life (QoL) contributions, and the answers are measured on a Likert scale (1-5; 1-very dissatisfied; 5-very satisfied). The items categories are: perception of nature, noise abatement, capacity for recreation, microclimate regulation, habitat, air purification and visual appearance, among others.

The survey will be launched *in situ*, person to person, close to the NBS locations (punctually and defining NBS areas). Surveys will be also send using randomly-distributed mail questionnaires to capture green space users and non-users' attitudes towards NBS and UGS in Valladolid.

Location data: On the other hand, crowd-sourcing data is being obtained from geospatial location of citizens in the NBS areas, as second data capture methodology. UGS visitors of recent years can use location-aware technologies to spatially log their activities; for example, UGS visitors can geo-tag their photographs that they take during theirs UGS visits, or log trajectories of their physical activities (Kothencz et al, 2017). This spatial data might be captured by position interaction between the Mobile App, QR codes and a beacons network strategically located in the NBS area.

There might be designed systems to capture data from geo-tagged photos downloaded from the sharing website Panoramio[6] (input to a GIS as point features). The photography taken in the Study sites can be classified into categories: Green space-with/without surroundings, vegetation-plant in detail, vegetation –larger habitat, water surface).

There are other systems to capture data from GPS track-logs downloaded from a social network sharing source (such as Nike+ run club and App).

[5] Local Agenda 21 of Valladolid - Sustainability indicators http://www.valladolidagendalocal21.es/

[6] Panoramio www.panoramio.com

Figure 7.3: Running trajectories touching or crossing the grounds of the study areas (Source: MDPI, Gyula Kothencz et al, 2017)

It is intend that surveys will be developed in the URBAN GreenUP Android mobile application (App) to identify social perception, wellbeing, and GPS location (beacons).

Sensor/Software

No sensor is needed for KPI 115. There might be installed beacons.

Data sampling

Measurements for social survey will be done in person (in situ surveys), via online platforms (on line surveys) and via the smartphone applications provided by the URBAN GreenUP Consortium members, such as GMV. There are identified the following two data sources:

- By surveys: The mobile application can show surveys, which ask simple questions to the population about issues of the social use of the NBS to evaluate aesthetic enjoyment and recreation: How many people are there in your environment? Do you feel better seeing this vertical façade?
- By mobile location: The volume of visits to NBS and the spatial patterns can indicate recreational capacity and aesthetic appreciation. In the URBAN GreenUP project the KPI could be calculated for these NBS:
    - Public transport use: GPS location + QR codes installed in the NBS location/areas.
    - Green corridor use: There is an Android API called *Activity*.
    - On foot movements: GPS location.

The KPI "Perceptions of citizens on urban nature" will be calculated with standard spreadsheet software (Excel or SPSS). The unit of measurement are: (% of satisfaction), (nº users).

Data processing

Survey data can be processed by using spreadsheet software by Excel or SPSS and spatial analysis software like ARCGIS or QGIS.

Results

Results can be displayed throughout maps and/or data tables.

References

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8 CHALLENGE 8: SOCIAL JUSTICE AND SOCIAL COHESION

8.1 Socio-Economic KPIs

Crime reduction through police reports and local authority data

INTRODUCTION

This indicator is included in the list of indicators *Challenge 8. Social Justice and Social Cohesion*.

According to Oxford dictionary, crime is an action or omission which constitutes an offence and is punishable by law.

The installation of urban furniture as a measure of protection against crime, vandalism and terrorist acts has been developing successfully since the 70s and it is called "Crime Prevention Through Environmental Design (CPTE)". The main technique is to reduce crime opportunities through modification and manipulation of the built environment that make it more difficult (Massoomeh et al, 2016).

Green Infrastructures can help to reduce the causes and opportunities crime and vandalism because the structures that look well cared for discourage crime and increase social justice and cohesion. It is a measure that through well planning, designing and managing of the built environment (Massoomeh et al, 2016).

NBS TYPES

This indicator affects all NBS which may suffer and/or prevent vandalism and /or crimes.

For example, a well design of a cycle lane can prevent collisions between cars and bikers and/or between bikers and pedestrian; and a well care green façade is more respected.

METHOD

This KPI can be assessed throughout specific software, such as GIS software and spreadsheet software. Results can be displayed throughout maps and/or tables.

This KPI can be considered for the entire municipality of Valladolid, giving a single resulting value for each study campaign. However, a street or neighbourhood level study is recommended since it can be useful for detecting the difference between areas and the influence of different NBS.

There is the possibility of combining the data of this KPI with those of the KPI 52 (Distribution of public green space - total surface or per capita), to determine if there is a correlation between crimes and green areas.

SENSOR/SOFTWARE

Data are acquired by statistic and external sources like: fire department, law enforcement information or City Council. So **no sensor is required**.

The criminality data will be compared before and after the installation of the NBS to know if this has influenced the study area.

Spreadsheet software can be required.

On the other hand, crime map for the area of the intervention produced by modelling software can be helpful but not necessary. For example, data is able to process by GIS with QGIS (is the GIS software)

Spatial Analysis software is required. **QGIS** is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

DATA SAMPLING

It is necessary to define the crimes that this KPI will be processed according to the definition of crime and the kind of data that it is possible to obtain.

Datasets are provided by **Valladolid City Council**. All Datasets need to follow INSPIRE principles. An appropriated Coordinate Reference Systems must be defined for each location (city). The image below shows the recommended CRS for Valladolid location.

Figure 8.1: coordinate system to use for Valladolid.

This is considered as a very stable KPI, so **frequency** could be the same as city council's demographic statistics, therefore, **annual**. In order to set the starting situation a preliminary study is also needed.

The data demanded to 010, Valladolid City council, police and fire department.

The required and recommended inputs for the calculation of this KPI are:

- Number of crimes (acts of vandalism or unintentional actions) around the location of the NBS
- Number of urban furniture damages around the location of the NBS
- Number of attestations around the location of the NBS
- Number of Written, complaints, suggestions related to actions

Ideally, the data should be provided each year with geographic coordinates or with the street where it is produced, or at least by postal code or district.

DATA PROCESSING

Data processing depends on the data provided.

If the data provided included the coordinates or the street and number street, it is possible to show the proportion of crimes near the NBS and its increase or decrease, that is to say, if the NBS has a direct influence in the crime level.

Thus, a simple geoprocessing analysis is proposed. Firstly, a **buffer** is established at a certain distance from green areas in order to obtain a relevant area of influence around them. Then, this dataset is evaluate with the dataset containing coordinates of the crimes throughout the tool **Count points in polygon**. Finally, using the **Fields calculator** and **Basic Statistics** tools, this KPI is shown as a percentage.

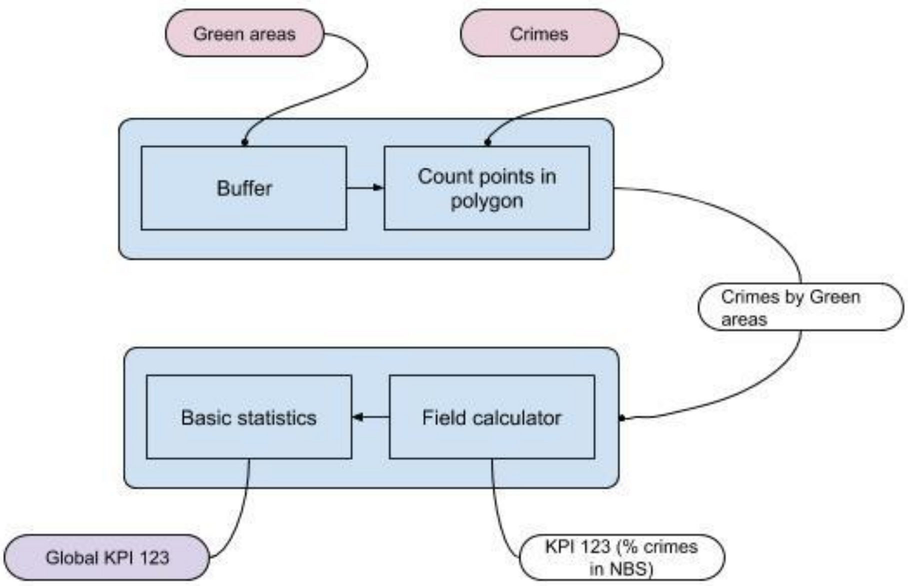

Figure 8.2: KPI algorithim dataflow scheme

RESULTS

Results depends on the data provided. Ideally, the data should be provided by streets and by date, in order to show the results in more detail. Like that, several figure are obtained for this KPI. For example, a figure will show the distribution of the crimes by zones or areas close to the actions before and after their installation (%) .

Two final figures are obtained at the end of the process for this KPI. One of them shows the distribution of green areas surface in terms of total surface (%), and the other shows the distribution of green areas surface in terms of inhabitants (m2/hab).

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Green intelligence awareness

Introduction

Changes in behavior and human attitudes are fundamental to achieve a more sustainable world, so that, it is very interesting to analyze the potential of an activity or intervention to increase the green intelligence awareness of a population.

There is enormous opportunity for nature based solutions to promote understanding of sustainability in ways that positively influence citizen behavior. There are many available resources to learn and understand the fragility of our environmental and the responsibility of humans to protect, preserve and respect the world. Therefore, this KPI aims to reflect how the intervention is used for educational purposes and enhancement of public awareness.

The Green intelligence awareness is opened to all educational and social groups, no matter what is the level of education (Post-graduate, university, school, basic education).

NBS Types

Non-technical interventions: Educational activities: Educational paths (A, C); Urban farming educational activities.

Methodology

The KPI 127 “Green intelligence awareness” is calculated as the

Quantify the number of activities, publications or campaigns focused on the enhancement of green intelligence awareness per year, related to a NBS. There are two different categories: Educational activities and Communication activities.

1) Educational activities:

The educational activities considered have to be directly or indirectly related with the URBAN GreenUP project. In the “Directly” category there are actions of the themes and NBS of the project, from Vac1 to VAc42in Valladolid, such as Vac1- New green cycle lane and re-naturing existing bike lanes, VAc3- Tree shady places, VAc14- Green Parking Pavements , VAc25- Green Façade, VAc20-21-22- Pollinator’s modules, VAc31- Urban orchard, and so on.

In this category there are included the URBAN GreenUP educational technical interventions:

- VAc36- Urban Farming Educational activities.
- VAc34- Educational path in Wastewater Treatment Plant area.
- VAc35- Educational path in floodable park area.

There are also included the URBAN GreenUP non-technical interventions

- VAc37- Engagement Portal for citizen
- VAc39- Promotion of ecological reasoning and intelligent
- VAc40- Single desk for RUP deployment
- VAc41- Support to citizen project of NBS
- VAc42- City mentoring strategy (Staff Exchange activities)

There can be also considered educational actions “Indirectly” related with the URBAN GreenUP project: These are activities organized by other entities and stakeholders different from the URBAN GreenUP Consortium, which are about the URBAN GreenUP general themes, such as climate change, green infrastructure, nature based solutions, sustainability, water management, resources efficiency, etc.

The measurement of the KPI 127 “Green intelligence awareness” by educational activities is expressed in the number of activities and number of recipient people (attendees):

a) Number of educational activities (nº activities/month). We differentiate among classes: courses, conferences/symposia, lectures, workshops, seminars, guided tours.
b) Number or people that attends to the educational activities (nº attendee/activity/class), for instance, number of people that attends to a Climate Change congress. This category could be characterized according to its characteristics: Educative level (University, school), average age, sector (architect, parks and gardens, industry, mobility, biomass).

There will be recorded a monthly record. There will be identified the NBS or related theme, such as climate change, Nature Based Solutions and others.

Date	Type	Activity name	NBS/Theme	Location	Nature	Attendes	Educative level
dd/mm /yyyy	Classify: Course, conference, lecture, workshop, seminar, guided tours	Name of the activity	NBS in URBAN GreenUP (VAcX) or Related theme.	Address, city	I = International N = National R = Regional U = Local (Valladolid)	Number of people that attend to the activity	Type of attendee (Proffesional, University, schools)

Table 8.1: Record table for KPI 127 "Green intelligence awareness" – Educational activities.

2) Communication activities.

This second group considers publications in different communication means such as written press (newspaper, magazines, articles, brouchers), television, radio and social media.

- Editorial actions:
  - Articles, texts, photographs or videos published in magazines, newspapers, books with technical and educational content.
  - Distribution of brochures, leaflets.
- Communication actions:
  - Online social networks campaigns (YouTube, Twitter, Facebook, other) with technical and educational content.

Partner	Type of Publication	Title	Date	Type of audience
Consortium partner or stakeholder	Type of publication (Newsletter, Articles, Press release, Interview, REport, Scientific paper, Video)	Name of the editorial	dd/mm/yyyy	Scientific community, industry, policy makers, civil society, investors, etc.

Table 8.2: Record table for KPI 127 "Green intelligence awareness" – Editorial.

Partner	Communication media	Title	Date	NBS/Theme	Impact
Consortium partner or stakeholder	YouTube, Twitter, Facebook	Name of the action, campaign	dd/mm/yyy	NBS in URBAN GreenUP (VAcX) or Related theme.	

Table 8.3: Record table for KPI 127 "Green intelligence awareness" – Communication.

The measurability of KPI 127 is also expressed as the size of the audience that is exposed to the communication activity impact (number of retweets and likes in Twitter, number of likes and shares in Facebook, number of plays in YouTube, etc)

It is important to consider that all educational activities must be developed in the municipality of Valladolid, or must be dedicated about Valladolid (for instance, a magazine from other Spanish region that talks about Valladolid interventions in the URBAN GreenUP project).

Sensor/Software

No sensor is needed.

Data processing

This KPI is expressed as the Sum of the educational activities per year, and sum of the publications with educational content per year (editorial). The register is recorded separately, because the concept and magnitude of each result are different.

Results

The KPI is calculated monthly. There will be calculated a total KPI yearly, with will generate at least three indicators (numbers): Number of activities per year, Number or people that attends to the educational activities and Number of publications per year.

The result could be expressed as ratios, for a similar period of time (month, year)

$$Green\ intelligence\ awareness\ = \frac{\text{Number of aeducational activities (nª)}}{\text{Number of publications (nº)}}$$

For instance, 12a/6p means 12 activities and 6 publications per year related to a NBS in particular.

References

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9 CHALLENGE 9: PUBLIC HEALTH AND WELL-BEING MONITORING PROCEDURES

9.1 Psychological indicators

Noise reduction rates applied to UGI within a defined road buffer dB (A) m^2 vegetation unit

INTRODUCTION / rationale

This indicator is included in the list of indicators for *Challenge 9. Public Health and Well-Being*. See table below with the total set of KPIs related to Public Health and Well-Being (PH&WB) Challenge.

Noise pollution by traffic, construction works, etc. is a common city problem. Nuisance from noise is detrimental to neighbourhood liveability, living comfort and work environments, and can increase risk of serious health problems such as hearing loss and cardiovascular disease.

Urban ecosystems provide noise reduction services by serving as a natural sound buffer. Vegetation provides both a direct and an indirect barrier to environmental noise. Starting with its direct functions, green belts attenuate noise by absorption, dispersal, and destructive interference of sound waves, though sound levels can intensify locally if measured right below tree crowns. Indirect noise reduction effects are generated by lessened wind speeds and the absorptive capacity of pervious soils.

UGS also proved to offer noise reducing services via psychological effects: just observing the presence of a green wall can lead people to perceive less noise nuisance or alter the perception of noise as sounds such as flowing water, bird singing, and leaves rustling in the wind mask disturbing background noise.

It is defined the Ecosystem Service noise reduction as the physical capacity of vegetation to attenuate environmental noise.

On the other hand, the methodology proposed for this KPI is based and uses the methodology and tools proposed by the European Commission Working Group Assessment of Exposure to Noise (WG-AEN).

The Environmental Noise Directive (END) requires two main indicators to be applied in the assessment and management of environmental noise. The first indicator (Lden) is the noise level for the day, evening and night periods and is designed to measure ‘annoyance’. The END defines an Lden threshold of 55 dB. The second indicator (Lnight) is the noise level for night-time periods and is designed to assess sleep disturbance. The END defines an Lnight threshold of 50 dB. Member States must report the numbers of people who are exposed to noise levels above both thresholds for each noise source (e.g. roads, railways, airports, industry).

NBS TYPES

1. Green Noise Barriers	This NBS is designed to reduce the traffic noise that arrives the homes on the street. On the one hand, the green noise

	barriers have a specific geometry that favors sound reflection and on the other hand, they have a vertical garden modules with a specific substrate that favors sound absorption.
2. Green Façade	A green façade is a wall completely or partially covered with greenery. A green façade with climbing plants uses a trellis system to hold the vines of plants that are rooted in the ground or containers. Green façades offer economic, environmental, aesthetic and physiological benefits to the urban environment. Green façades can be designed for *sound* absorption.
3. Green shady structures	Pieces of stretched textile structure on which an inert substrate is installed. This inert substrate is covered with seeds, which germinate and grow on the textile structure. This NBS can be fixed to the facades of the buildings on the street or by posts fixed to the sidewalk. These green surfaces can absorb or reflect partially the sound.
4. Green fences	The main objectives are to provide a green separation between river and pedestrians and create little habitats for wildlife. It is built as a part of river and riverbank re-naturing. This NBS can be designed for *sound* absorption.
5. Urban Trees including: Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking and Arboreal areas around urban areas	This NBS includes individual large street trees, as well as the larger areas of woodland in the urban fringes. Trees perform multiple functions in urban areas. Urban trees are a vital element of our green infrastructure. Strategic positioning of large shade and cooling trees within urban areas can provide shade to buildings, reducing heat loading on building, provide islands of respite from high temperatures and capture some air pollutants (mainly PM) by dry deposition in our urban areas.
6. Green roof	The external upper covering of a building which the main objective is to favour the growth of vegetation keeping the habitability conditions in the rooms below. The inclination of the roof must be between 0 and 45º. The green roofs have a waterproofing resistant to the penetration of roots and several additional layers that allow the correct development of the vegetation.
7. Green covering shelters	This NBS is a specific type of green roof. This GI integrates specific vegetation in curve or flat surfaces with a minimum maintenance. This type of green roof is very light and we can use it in structures that do not support much weight. It could be installed in small or big coverage infrastructures, like bus shelter or existing covering shelters.

Table 9.1: NBS Types that can be measured with this KPI

Method

This KPIs is calculated from measured data using a methodology defined by URBAN GreenUP Project.

It is accounted for two factors that influence noise reduction services: vegetation (NBS) characteristics and distance to the noise source. The analysis is focused on road traffic noise as this is a constant source and most disturbing to people.

BACI (Before, After, Control, Impact)

Measure noise levels at sampling points at a range of radii from NBS street tree/green wall locations both pre- and post-intervention (with or without) to serve as input to model simulations and to create a noise map. The measurements before and after the intervention have to be made on similar dates, same day of the week and hour. Simulations with and without NBS will be assessed to define the impact of the NBS.

A strategic noise map[7] is the presentation of data on one of the following aspects:

- A noise situation in terms of the noise indicators L_{den} and L_{night};

- The exceeding of a limit value;

- The estimated number of dwellings that are exposed to specific values of a noise indicator;

- The estimated number of people exposed to noise.

Values of L_{den} and L_{night} can be determined either by computation or by measurement (at the assessment positions) and that for prediction, only computation is applicable.

Sensor / software

Monitoring equipment

A portable sound level meter designed to measure sounds. This KPI requires a portable monitor because some data is required to complete model simulation.

EXAMPLE

The SC-15c is a type 2 integrating averaging sound level meter that includes many features and it is very easy to operate. It has a single range, and so it is not necessary to pre-set the measurement range in terms of the signal level to be measured.

[7] 'strategic noise map' shall mean a map designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area;

Software

Predictor Type 7810 de Brüel & Kjaer,

WG-AEN recommends that for the purposes of strategic noise mapping for the END, the tools that are commonly available in GIS (and available is some noise mapping software) that facilitate the simplification of building shapes, and the shape of other objects that can influence sound propagation e.g. noise barriers, are used to simplify their outlines. For example, such functions could be used to remove any elements of a building envelope that are less than 1 metre in length. It is recommended that prior to the selection of the final model test areas are used to assess the impact of the available simplification options upon the final calculated noise levels.

Measurements

L_{den} and L_{night}. (in situ measurements and modelled values by software assistance)

Unit of measurement

L_{den} and L_{night} in decibel (dB).

Calibration / Verification

Calibration of the sound level meter used for in situ measurements following standard procedures (EN 61672-2:2013/A1:2017, EN 61672-2:2013, EN 61672-1:2013, EN 61672-3:2013).

Study sites

a) Stretches of road where noise barriers or other interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of road (road of similar width and with comparable building heights to intervention site) where NBS interventions are not proposed (control study sites). Control sites should be a sufficient distance away from street tree/green wall intervention sites for the observations made to be considered independent from the effects of street trees/green walls.

Number of study sites

tbc

Number of samples

tbc

DATA SAMPLING

Both intervention and matched control study sites should be sampled on the same occasion during each round of samples (i.e. an intervention site and matched control should be sampled on the same date and at as close a time of day as possible). Each fixed sampling location at a study site should be sampled every weeks for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022). At each sampling point two readings should be taken: at heights estimated to represent ***a)*** child and ***b)*** adult head heights.

DATA PROCESSING

Noise map for the area of the intervention produced by modelling software.

Spatial Analysis software

QGIS is the GIS software proposed to be used.

RESULTS

Figure 9.1: Example of data visualization.

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NMPB-Routes-96 (SETRA-CERTULCPC-CSTB), encionado en el "Arreté du mai 195 relatif au bruit des infrastructures routières, Journal officiel du 10 mai 1995, article 6" y en la norma francesa "XPS 31-133". http://sicaweb.cedex.es/docs/mapas/fase1/aglomeracion/Valladolid/resumen.pdf pag. 13

WHO (2014) WHO | 7 million premature deaths annually linked to air pollution, http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/

WHO (2011) Burden of Disease from Environmental Noise. Quantification of Healthy Life Years Lost in Europe. WHO Regional Office for Europe, Copenhagen.

9.2 Health KPIs

Increase in walking and cycling in and around areas of interventions

INTRODUCTION

This indicator is included in the list of indicators for **Challenge 9. Public health and Well-being**. This is a health indicator, related to ecosystem service provision. This one evaluates how NBS intervention can increase the attraction of citizens to walking and cycling inside the NBS and also around them.

Urban green infrastructures are key part of the sustainable development in our cities. They can provide important Ecosystem Services in them, including provisioning, regulating, supporting and cultural services. They have an important impact in human's health (Bowler, Buyung, Knight Pullin, 2010).

Accessibility to green areas is a determining factor in the availability of citizens to make use of them. So for further information, KPI 53 (Accessibility to green areas) can be consulted. Boths KPIs are closely related. In fact, it is expected that an improvement of accessibility to green areas will result in an increasing of walking and cycling.

NBS TYPES

This indicator is related to NBS involving **green infrastructures**, either horizontal or vertical, such as green corridor, urban carbon sink, etc.

A complete list of NBS Types that can be measurable with this KPI is shown below.

CODE	ACTION	SUB-DEMO	CATHEGORY	SUB-CATHEGORY
VAc1	New green cycle lane and re-naturing existing bike lanes	A	Re-naturing Urbanization	Green route
VAc2	Planting 1,000 trees	A	Re-naturing Urbanization	Arboreal interventions
VAc3	Tree shady places (500 trees)	A	Re-naturing Urbanization	Arboreal interventions
VAc4	Shade and cooling trees (600 trees)	B	Re-naturing Urbanization	Arboreal interventions
VAc5	Re-naturing parking trees (250)	C1	Re-naturing Urbanization	Arboreal interventions
VAc6	Installation of 3 Green Resting Areas	A	Re-naturing Urbanization	Resting areas
VAc7	Urban Carbon Sink	C3	Re-naturing Urbanization	Carbon capture
VAc15	Cycle-pedestrian green paths	A	Singular GI	Cycle-pedestrian infrastructure
VAc22	Green noise barriers	A	Singular GI	Vertical GI

VAc23	Green noise barriers	B	Singular GI	Vertical GI
VAc24	Green Vertical mobile garden	B	Singular GI	Vertical GI
VAc25	Green Façade	B	Singular GI	Vertical GI
VAc26	Electro wetland	B	Singular GI	Horizontal GI
VAc27	Green Covering Shelter	B	Singular GI	Horizontal GI
VAc28	Green Roof	B	Singular GI	Horizontal GI
VAc29	Green Shady Structures	B	Singular GI	Horizontal GI

Table 9.2: NBS Types that can be measured with this KPI

METHOD

This KPI can be measured throughout specific software, such as spreadsheet software. Results can be displayed throughout maps and/or tables. This KPI can be considered for the entire municipality of Valladolid, giving a single resulting value for each study campaign. However, a neighborhood level study is recommended since it can be useful for detecting deficitary areas.

This KPI can be measured based on statistical data. This data can be from:

- Using the smartphone application we can promote walking and cycling at the intervention sites, and also measure its use by using the GPS or other types of validation (QR code reading).
- Subscriptions to the bicycle loan system of Valladolid (Vallabici)
- Calculation of the number of users of the bike lane.
- Survey of local residents, users and businesses of their perceived and actual use of NBS for walking, cycling and other activities pre and post-investment.

SENSOR/SOFTWARE

Data are acquired by surveying and statistical data from bicycle loan system of Valladolid (Vallabici). Statistical data processing is also required throughout **Spreadsheet software.**

Spatial Analysis software can be required for results display. **QGIS** is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

DATA SAMPLING

Datasets are provided by **Valladolid City Council**.

This is considered as a very stable KPI, so **frequency** could be the same as city council's demographic statistics, therefore, **annual**. In order to set the starting situation a preliminary study is also needed.

The required and recommended inputs for the calculation of this KPI are shown in the following table.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Cycling users	Number of Subscriptions to ValláBici	num	Data number	Required study data for this KPI. This data could be done by neighborhood.
Walking users	Number of walking users of green areas (survey)	num	Data number	Required study data for this KPI. This data could be done by neighborhood.
Neighborhood location	Official Neighborhood Boundaries cartography	-	Shapefile – Polygon	Optional data for this KPI. This dataset can also require an ID value.

Table 9.3: Properties of the new variables obtained

DATA PROCESSING

Overall statistics can be calculated in order to obtain the total number of walking and cycling users. This number can also be referred to the amount of hours (approximately) per user, but that would require further surveys.

RESULTS

Two final figures are obtained at the end of the process for this KPI. One of them shows the total number of walking users, and the other shows the the total number of cycling users.

Obtained value can be compared to previous value, with a formula:

$$Walking\ (\%) = (-1) \cdot \frac{U_j - U_i}{U_i} \cdot 100$$

$$Cycling\ (\%) = (-1) \cdot \frac{U_j - U_i}{U_i} \cdot 100$$

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
KPI 139 (w)	Increase in walking in and around areas of interventions	%	table	Derived variable obtained by statistical processing. Positive value means users has increased, negative value means users has decreased.
KPI 139 (c)	Increase in cycling in and around areas of interventions	%	table	Derived variable obtained by statistical processing. Positive value means users has increased, negative value means users has decreased.

Table 9.4: Properties of the new variables obtained

REFERENCES

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10 CHALLENGE 10: POTENTIAL OF ECONOMIC OPPORTUNITIES AND GREEN JOBS MONITORING PROCEDURES

10.1 Socio-Economic KPIs

Number of subsidies or tax reductions applied for (private) NBS measures

INTRODUCTION

This KPI, related to economic aspects measurements, evaluates how NBS interventions can influence private sector.

When a positive externality on consumption is present in a market, the government can actually increase the value that the market creates for society by providing a subsidy equal to the benefit of the externality. (Such subsidies are sometimes referred to as Pigouvian subsidies or corrective subsidies.) This subsidy moves the market to the socially optimal outcome because it makes the benefit that the market confers on society explicit to producers and consumers, giving producers and consumers the incentive to factor the benefit of the externality into their decisions.

RELATED NBS

This KPI is related to NBS involving: Vertical green interventions, Horizontal green interventions, Urban farming promotion: Urban orchard; Community composting; Small-scale urban livestock, Sponsoring activities; Support to citizen project of NBS, Non-technical actions, Natural waste water treatment

METHOD

The KPI-140 value comes from the measured data using a methodology defined by URBAN GreenUP Project.

Application of subsidies and reduction of fees by the NBS (for example, El Campillo market). Subisidia for houses that put a green roof, pots on the balconies (to be determined). Analysis of the economic savings in moving from having less cars to the battery. Other actions to promote the BSS.

BACI (Before, After, Control, Impact)

To be defined depending on case.

MEASUREMENT INSTRUMENTS

SENSORS / SOFTWARE EXAMPLES:

City official data, city platforms, questionnaires, small-medium enterprise account (Related to de NBS investment zone)

UNIT OF MEASUREMENT

(nº subsidies) (€/m2)

(nº subsidies or nº private) (nº /year) (€/year)

CALIBRATION / VERIFICATION (Standards)

To be defined depending on case.

STUDY SITES (Position)

R/ M/ U

DATA PROCESSING

Monitoring systems need to be improved with systematic quality checks in order to ensure that data collected are reliable and there needs to be effective coordination between regional/ area authorities, and measurement team generally, to ensure that the data reported are consistent and comparable. The guidelines, spelling out the frequency of checks, the concept used, the methods for carrying them out and so on should be provided for each NBS by specific region.

RESULTS

- **Number of subsides implemented (by zone affected)**

Data Dept. Finance and Patrimony

Direct value on subsides (by zone), before and after implementation, during the established period.

Number of subsides implemented = n * Z [(nº subsides) (€/m2)]

Where n is referring to the subsides total number multiplied by its value by zone Z (directly related to the each particular NBS)

REFERENCES

- *An impact evaluation framework to support planning and evaluation of nature-based solutions rojects; An EKLIPSE Expert Working Group report, 2017*

- *"The Model of the Environmental Sustainability Matrix" ("El Modelo de la matriz de Sostenibilidad Ambiental"); La ordenación Urbana y el Desarrollo Sostenible, Angel Ibañez Ceba, Fermín Cerezo Rubio, August 2009*

- *"A Positive Externality on Consumption" (Science, Tech, Math, Social Sciences); https://www.thoughtco.com/positive-externality-on-consumption-overview-1147392*

- *"Understanding Subsidy Benefits, Costs and Market Effect" (Science, Tech, Math, Social Sciences); https://www.thoughtco.com/analysis-of-a-subsidy-1147899*

Number of jobs created; gross value added

INTRODUCTION

This KPI, related to economic aspects measurements, evaluates how NBS interventions can increase the attraction of businesses, or how to increase the value of the existing ones. This value, evaluated through the measurements of number of jobs created and the percentage of the gross value added, will reflect the economic opportunities and potential of NBS solutions.

RELATED NBS

This KPI is related to NBS involving: Vertical green interventions, Horizontal green interventions, Urban farming promotion: Urban orchard; Community composting; Small-scale urban livestock, Sponsoring activities; Support to citizen project of NBS, Non-technical actions, Natural waste water treatment

METHOD

The KPI-141 value comes from the measured data using a methodology defined by URBAN GreenUP Project.

BACI (Before, After, Control, Impact)

Essentially a 'before-after' indicator which captures the part of the employment increase that is (a) direct consequence of NBS implementation (workers employed to implement the NBS project should not be directly counted). The positions needs to be filled (vacant posts are not counted) and increase the total number of jobs in the enterprise. If total employment in the enterprise does not increase, the value is zero – it is regarded as realignment, not increase. Safeguarded etc. jobs are not included.

Gross: Not counting the origin of the jobholder as long as it directly contributes to the increase of total jobs in the organisation. The indicator should be used if the employment increase can plausibly be attributed to the support.

Full-time equivalent: Jobs can be full time, part time or seasonal. Seasonal and part time jobs are to be converted to FTE using ILO/statistical/other standards.

Durability: Jobs are expected to be permanent, i.e. last for a reasonably long period depending on industrial-technological characteristics; seasonal jobs should be recurring. Figures of enterprises that went bankrupt are registered as a zero employment increase.

Timing: Data is collected before the project starts and after it finishes; the NBS holders are free to specify the exact timing (depending on the NBS time needed to get the profit). Using average employment, based on 6 months or a year, is preferred to employment figures on certain dates.

MEASUREMENT INSTRUMENTS

SENSORS / SOFTWARE EXAMPLES:

City official data, city platforms, questionnaires, small-medium enterprise accounts… (Related to de NBS investment zone)

UNIT OF MEASUREMENT

(nº jobs) (€/m2)

(nº jobs or nº users) (kg/year) (€/year)

CONSIDERATIONS

The following factors should be considered:

- Each climate resilience challenge area can be addressed by multiple individual actions, and indicators can be used to assess the effectiveness of individual actions in addressing each climate resilience challenge
- Indicators for assessing specific types of NBS impacts of NBS across aspects of multiple systems, including socio-economic, socio-cultural and ecosystems, although geographic and temporal scale may be relevant to the interactions
- The applicability of indicators can vary across geographic scales, highlighting of considering regional, metropolitan, urban, street/neighbourhood and building impacts separately
- There is a need for assessing the impacts of NBS over the short, medium and long-term, and thus mechanisms are needed for monitoring NBS effectiveness beyond the end of the project
- Synergies and trade-offs can be associated with NBS impacts, including across elements of the ecosystem and socio-cultural system. NBS impacts are, therefore, likely to be multi-directional and complex
- Investment in NBS can maximize the benefits for provision of environmental, socio-cultural and economic services if multiple challenge areas are considered concurrently and the different stakeholder are involved in the planning and implementation process.

STUDY SITES (Position)

R/ M/ U

DATA PROCESSING

Monitoring systems need to be improved with systematic quality checks in order to ensure that data collected are reliable and there needs to be effective coordination between regional/ area authorities, and measurement team generally, to ensure that the data reported are consistent and comparable. The guidelines, spelling out the frequency of checks, the concept used, the methods for carrying them out and so on should be provided for each NBS by specific region.

RESULTS

- **Number of jobs created (Direct employment)**

Direct value on employment by zone, before and after implementation, during the established period.

Number of jobs created= n * Z [(nº jobs) (€/m2)]

Where n is referring to the direct full time employment in during the time defined (directly related to the each particular NBS); Z- affected zone/area in reference to the NBS (should depend on NBS the definition of the area)

- **Gross value added (GVA)**

Defined as the difference between the value of goods and services produced and the cost of raw materials and other non-labour inputs, which are used up in production. The research should conclude what is the total contribution of NBS in % of the total GVA to the region/area economy in Euro/ by year.

REFERENCES

- An impact evaluation framework to support planning and evaluation of nature-based solutions rojects; An EKLIPSE Expert Working Group report, 2017

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- Forestry Commission, Scotland, The economic an d social contribution of forestry for people in Scotland, David Edwards, Jake Morris, Liz O´Brien, Vadims Sarajevs and Gregory Valatin, September 2008

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- Draft to the deliverable D1.2 "Challenge cathalogue" Urban GreenUP, June 2018

New businesses attracted and additional business rates

INTRODUCTION

This KPI, related to economic aspects measurements, evaluates how NBS interventions can increase the attraction of businesses, or how to increase the value of the existing ones. This value, evaluated through the measurements of number of new business created and the percentage of the gross value added, will reflect the economic opportunities and potential of NBS solutions.

RELATED NBS

This KPI is related to NBS involving: Vertical green interventions, Horizontal green interventions, Urban farming promotion: Urban orchard; Community composting; Small-scale urban livestock, Sponsoring activities; Support to citizen project of NBS, Non-technical actions, Natural waste water treatment

METHOD

The KPI-143 value comes from the measured data using a methodology defined by URBAN GreenUP Project.

BACI (Before, After, Control, Impact)

To be defined depending on case.

MEASUREMENT INSTRUMENTS

SENSORS / SOFTWARE EXAMPLES:

City official data, city platforms, questionnaires, small-medium enterprise account (Related to de NBS investment zone)

UNIT OF MEASUREMENT

(nº business) (€/m2)

(nº business or nº users) (kg/year) (€/year)

CALIBRATION / VERIFICATION (Standards)

To be defined depending on case.

STUDY SITES (Position)

R/ M/ U

DATA PROCESSING

Monitoring systems need to be improved with systematic quality checks in order to ensure that data collected are reliable and there needs to be effective coordination between regional/ area authorities, and measurement team generally, to ensure that the data reported are consistent and comparable. The guidelines, spelling out the frequency of checks, the concept used, the methods for carrying them out and so on should be provided for each NBS by specific region.

RESULTS

- **Number of business created (direct value buss related NBS by zone)**

Direct value on business created by zone NBS affected, before and after implementation, during the established period.

Number of business created= n * Z [(nº business) (€/m2)]

Where n is referring to the number of business and Z to its increased value (NBS related by zone), during the established period of implementation (directly related to the each particular NBS)

- **Gross value added (GVA)**

Defined as the difference between the value of goods and services produced and the cost of raw materials and other non-labour inputs, which are used up in production. The research should conclude what is the total contribution of NBS in % of the total GVA to the region/area economy in Euro/ by year.

REFERENCES

- An impact evaluation framework to support planning and evaluation of nature-based solutions rojects; An EKLIPSE Expert Working Group report, 2017

- "The Model of the Environmental Sustainability Matrix" ("El Modelo de la matriz de Sostenibilidad Ambiental"); La ordenación Urbana y el Desarrollo Sostenible, Angel Ibañez Ceba, Fermín Cerezo Rubio, August 2009

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Consumption benefits: property betterment and visual amenity enhancement

INTRODUCTION

This KPI, related to economic aspects measurements, evaluates how NBS interventions can increase consumption benefits, property betterment and visual amenity enhancement resulting from NBS.

Benefits of Consumption versus Benefits to Society. A positive externality on consumption occurs when the consumption of a good or service confers a benefit on third parties who are not involved in the production or consumption of the product.

RELATED NBS

This KPI is related to NBS involving: Vertical green interventions, Horizontal green interventions, Urban farming promotion: Urban orchard; Community composting; Small-scale urban livestock, Sponsoring activities; Support to citizen project of NBS, Non-technical actions, Natural waste water treatment

METHOD

The KPI-150 value comes from the measured data using a methodology defined by URBAN GreenUP Project.

BACI (Before, After, Control, Impact)

To be defined depending on case.

MEASUREMENT INSTRUMENTS

SENSORS / SOFTWARE EXAMPLES:

City official data, city platforms, questionnaires, small-medium enterprise accounts… (Related to de NBS investment zone)

UNIT OF MEASUREMENT

(nº improvements) (€/m2)

(nº improvements or nº users) (€/year)

CALIBRATION / VERIFICATION (Standards)

To be defined depending on case.

STUDY SITES (Position)

R/ M/ U

DATA PROCESSING

Monitoring systems need to be improved with systematic quality checks in order to ensure that data collected are reliable and there needs to be effective coordination between regional/ area authorities, and measurement team generally, to ensure that the data reported are consistent and comparable. The guidelines, spelling out the frequency of checks, the concept used, the methods for carrying them out and so on should be provided for each NBS by specific region.

RESULTS

- **Consumption benefits (Direct property betterment)**

Direct value on consumption benefits by zone, before and after implementation, during the established period.

To be based on analysis of the cadastral value of the properties according to the availability of green areas. It requires a zone analysis, since it depends on the location of the house and its relation with the NBS.

Consumption benefits= n * Z [(value of improvements vs value of investment) (€/m2)]

Where n is referring to the number of units with benefit by its direct value (directly related to the each particular NBS)

Gross value added (GVA)

Defined as the difference between the value of goods and services produced and the cost of raw materials and other non-labour inputs, which are used up in production. The research should conclude what is the total contribution of NBS in % of the total GVA to the region/area economy in Euro/ by year.

REFERENCES

- An impact evaluation framework to support planning and evaluation of nature-based solutions rojects; An EKLIPSE Expert Working Group report, 2017

- "The Model of the Environmental Sustainability Matrix" ("El Modelo de la matriz de Sostenibilidad Ambiental"); La ordenación Urbana y el Desarrollo Sostenible, Angel Ibañez Ceba, Fermín Cerezo Rubio, August 2009

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- "A Positive Externality on Consumption" (Science, Tech, Math, Social Sciences); https://www.thoughtco.com/positive-externality-on-consumption-overview-1147392

11 Quality assurance

The aim of this section is to describe the methodology that will be followed in the Urban Green Up project to assess the validity of the set of indicators selected for each of the intervention sites in order to evaluate the performance of the Nature Based Solutions deployed in the scope of the project.

If the previous sections of the document work on top of the impact assessment framework of the EKLIPSE Expert Working Group Report of the EC to select a set of indicators and describe the implementation of the indicators themselves, this section aims to define a set of tests to study the relevance, cross interference and sensitivity of the indicators as defined in previous sections, trying to provide insight on the usefulness of these indicators both to measure the cost-effectiveness of NBS individually, but also to compare across different NBS projects.

Different tests will be carried out to understand if the indexes are well designed and respond to changes as expected and also to compare the proposed methodologies for the construction of the indexes (particularly where the implementation between different sites is different). These tests should lead to the selection of the most suitable calculation and aggregation methods and also highlight areas for improvement in the selected indicators.

11.1 Validation of the evaluation strategy

Given that NBS seek to address societal challenges, they need, by definition, to address economic, environmental and social challenges. There are a range of potential actions that can be taken and indicators are an important means of assessing the potential performance and the actual effectiveness of particular NBS actions (European Commission, 2016).

Each climate resilience challenge area can be addressed by multiple individual actions, and indicators can be used to assess the effectiveness of individual actions in addressing each climate resilience challenge. However, there is potential for interactions between NBS actions which require consideration in NBS assessments.

Indicators for assessing specific types of NBS impacts can be relevant to multiple climate resilience challenges. It is, therefore, important to assess the impacts of NBS across aspects of multiple systems, including socio-economic, socio-cultural and ecosystems, although geographic and temporal scale may be relevant to the interactions.

The selection of appropriate indicator(s) will depend on a number of factors including:

- Objective of the action — which challenge(s) it is seeking to address;
- Type of action — all NBS will involve some element of biodiversity, but will differ in their attributes and thus appropriate methods for measurement;
- Potential expected impacts, both direct and indirect, and both positive (synergies) and negative (trade-offs or disservices);
- Resources and skills available for measurement of the impacts;
- Scale of analysis, which influences the availability and relevance of data for specific indicators

The objective of the evaluation strategy is to determine the robustness and sensitivity of the selected indicators to changes and assure that the impact of the Nature based Solutions adopted in the scope of the project is correctly reflected in the changes of the different KPIs.

The evaluation strategy should assess the methodology selected to calculate the different indicators: aggregation (or single impacts), thresholds, baseline definition, stipulations, models, calculation formulas, statistical data sources, robustness against missing data, etc.

Finally, the evaluation strategy will try to provide insight on the cross-effects between NBS actions, synergies and interactions among the different indicators (although issues of scale, implementation and local context may hide said synergies or trade-offs).

11.2 Indicators tests

The purpose of the indicators tests is to check if the calculated indicators respond to changes as it is expected to happen with the variations introduced in the value of the actual measurements and to compare the methodologies proposed. Thus, the following indicators tests are defined:

- Extreme values. Minimum and maximum values.
- Variation of values. Minimum and significant variations.
- Missing values. Minimum, maximum and mean values.

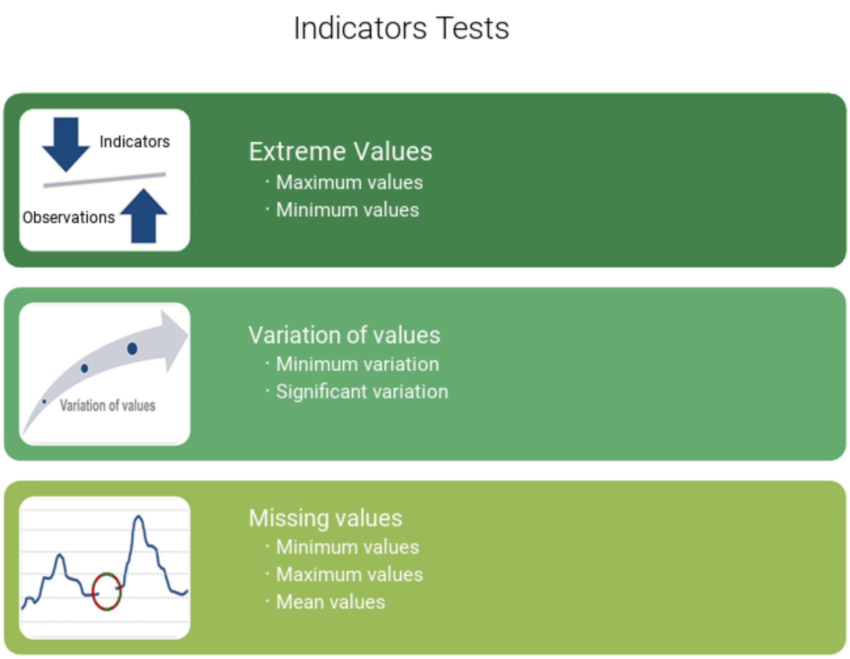

Figure 11.1: Indicators examples

11.2.1 Reference scenarios

11.2.2 Behaviour under extreme values. Minimum and maximum values

The purpose of these tests is to check that the indicators can reach the expected minimum and maximum values, that is, if the KPI is calculated by transforming an observation of a physical magnitude (in time or multiple locations) or a combination of observations of multiple magnitudes, or replies to surveys, when all the observations take the minimum value or all the observations take the maximum value (limited by the sensitivity of the measurement equipment /sample limitations).

This means that the indicators can reach their maximum value when all the observations have maximum values, and likewise will reach the lowest possible value when the observations have minimum values. This means that the calculation formulas will be evaluated when:

- All the observations take the maximum value.
- All the observations take the minimum value.

Inability to reach said values may indicate that it is necessary to normalize the indicator or modify the calculation procedure so that it reaches the expected values.

11.2.3 Variation of values. Minimum and significant values

The purpose of these tests is to understand the sensitivity of the indicators to minimum and significant variations of the value of the measured observations in the final value of the indicators. Since there are different proposed methodologies for weighting and aggregation, these tests are also defined to compare the sensitivities of the different methods to these variations in the final indicator values. Thus, the following variations are defined to test the indicator behaviour:

- Variation of 5% of the value of all the observations (multiple spatial/time samples or multiple observations if they are combined for a single indicator) at the same time.
- Variation of 50% of the value of all the observation at the same time.
- Variation of 5% of the value of all the magnitudes, one at the time.

Variation of 50% of the value of all the magnitudes one at the time.

11.2.4 Resilience to missing values, minimum and mean values

Due to multiple reasons, such as malfunction of a sensor, impossibility to perform a field survey, lack of samples in a particular area, or lack of statistical information from a particular source, it is likely to have missing values for some of the observations used for the indicator calculation.

The purpose of these tests is to determinate the sensitivity of the indicators to missing observations in order to compare which method is the most appropriate to use in the final configuration of the indicators. Thus, the following tests are defined:

- Variation of the value of each magnitude to the mean value of the interval
- Variation of the value of each magnitude to the minimum value of the interval
- Variation of the value of each observation to the maximum of the interval

This should allow determining which the most suitable substitution value is for each of the indicators.

11.3 Data sources validation

The basis for all observational studies is the availability of appropriate data of high quality. Data may be collected specifically for the research purpose in question (what is often referred as “primary data”), but data collected for other purposes (so-called “secondary data”) is also useful in research. Data validation is intended to provide certain well-defined guarantees for fitness, accuracy, and consistency for any of various kinds of input data.

Although high accuracy and precision are desirable, a high degree of trust and knowledge about their maximum and minimum level and additional metadata of the data sources (collection method, availability, transformations, etc.) is often as much or even more valuable to achieve correct and unbiased results.

Primary data is mostly validated through proper screening, by using various descriptive statistical methods. Secondary data validation is more complex, and often relies on trust in the sources, combining data from multiple sources, two-stage sampling and aggregated methods.

11.4 Reference data sets

Reference datasets provide statistically accurate data that can be used to evaluate the measurements (primary source data) performed on the NBS sites and other datasets used for the calculation of the KPI. Such data may come from statistics institutes, public administrations, or previous similar studies. In any case, it is necessary to validate the data to a degree according to the rest of the project (usually by comparing to real data or previous publications).

It may also be necessary to convert the datasource information due to differences in representation, sampling, units or accuracy. Thus, not only the reference data source needs to be validated but also the transformation applied to the reference data.

All datasources used for the calculation of the indicators need to be listed and validated, on one hand, to verify that the data is applicable, and also to prepare a dataset for further studies that will allow to evaluate the methodology and as a future reference for additional research and to compare between different NBS and demonstration sites.

Reference datasets can also be used to evaluate the calculation methods for the indicators. By entering the reference dataset in the KPI calculation algorithms, we should obtain the range of typical values for the indicator, to compare the results with the expected scenarios.

Finally, having a reference data set to compare with allows detecting deviation or malfunction in primary data collection during operation (e.g. a sensor malfunctioning or an error in data transmission/encoding) by comparison with the expected range of values.

12 Smartphone monitoring application

Within the scope of the monitoring program of the actions implemented in Valladolid, a smartphone application will be developed to fulfil three purposes; namely:

- Raising awareness of the NBS implemented in the city of Valladolid
- Distributing surveys (and gathering their responses) to measure several of the core KPIs, using the users as a "crowdsourced" sensor to measure the impact of the NBS developed in the project
- Measuring the activity of users in the green corridor area and near other intervention sites.

Given the high penetration rate and ubiquity of smartphones in the population, a smartphone application constitutes an ideal channel to interact with end users, since it establishes a bidirectional and permanently available bidirectional channel of communication with them.

Although web pages do have several advantages against mobile applications (they are compatible with all operating systems, can be easily updated, do not need a download or installation) mobile applications do offer a greater interaction with the users, and once installed, the number of reiterated interactions is greatly above of that of a web page. Smartphones also integrate a relevant number of sensors that can be used to provide more advanced interactions, retrieve notifications, communicate with external devices, etc.

In order to foster its adoption by the end-users and promote the participation of those users that have already installed the application, some kind of gamification mechanisms need to be implemented in the application. The exact details of the gamification process are still being determined with the Valladolid Municipality in order to better integrate with their digital development plans (which already include gamification mechanisms).

The smartphone application will rely on a backend server in order to store all the information about the usage of the green corridor, to retrieve new survey campaigns, store the user responses and also store the scoring information for gamification purposes.

This platform will also provide a unified interface and manage all communications with the project's ITS platform (thus isolating the smartphones from all the details of the ITS platform implementation and giving a greater degree of freedom for their implementation).

The functionalities of this platform will be a simple data storage accessible by the mobile applications through REST web services using HTTPS and JSON encoding, in order to store the user scoring/observation/KPIs in a database and to retrieve the configuration concerning scoreboards, new surveys and system settings.

The server will also offer the interfaces for the ITS platform to retrieve the relevant KPI information as required (similar web services could be a solution, although the particular details can be tailored to the ITS platform needs).

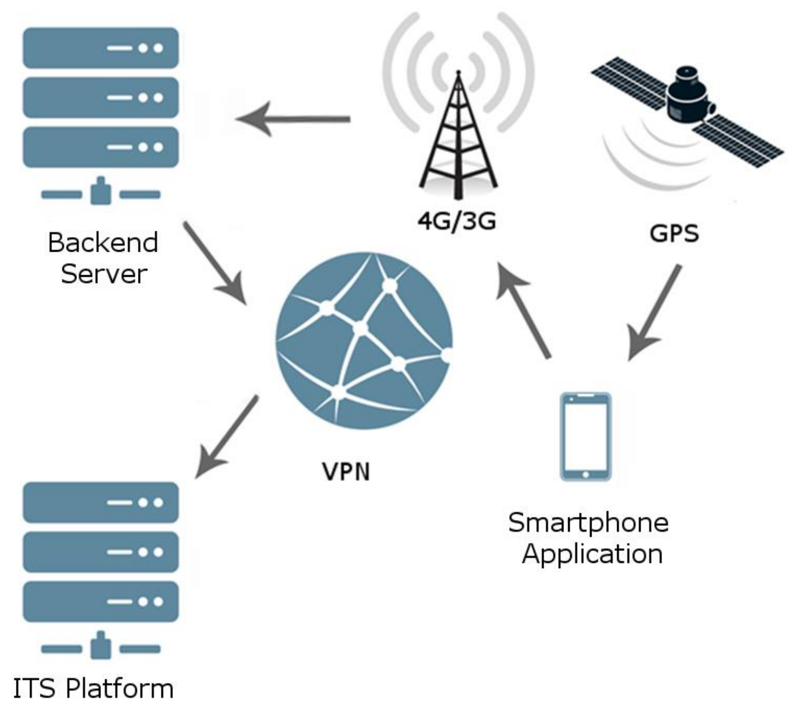

Figure 12.1: High level system architecture

This intermediate platform may have some basic intelligence, so that aggregated information can be provided to the ITS platform as a single sensor, providing the combined score of the user base rather than individual devices (which would further enhance the anonymity of the users).

The KPI calculation, however, will be performed outside the mobile devices themselves. Although the smartphone application will provide an "engine" to present anonymous surveys to end users. The specific contents of the survey and the aggregation process are transparent to the mobile application, and thus, the analysis of the responses is left for the ITS platform (or third parties that operate on the survey responses).

12.1 Mobile application design

The Urban GreenUP application for the Valladolid demonstration site will follow a MVP design pattern and the *Clean Architecture* concept. Although there are multiple implementations of *Clean Architecture*, given that it is more of a philosophy or set of best practices than a design tool, all of them aim to achieve the same objective, that is, the separation of concerns.

The core idea is that it allows defining what the application will do independently of the tools and frameworks used to implement it, by isolating the business rules from the domain model and the databases or web services it interacts with.

This modular approach has multiple advantages in terms of code verification, development and maintenance, but also allows customizing the application with relatively little effort, given that the interface and external services which the application interacts with can be completely replaced without affecting the internal core logic. Additionally, the user interface is also independent from the application core, so it can also be modified without further effect in the rest of the application.

The application design, functionality and architecture are further explained in the Annex A and Annex B, covering the functional design and architecture in detail. It should be noted that these annexes describe the core design and architectural principles, but they may be subject to further modification and refinement in order to align the specifics of the mobile application to the requirements of the Valladolid Municipality and possible opportunities to integrate it with the Municipality's digital services.

12.2 Mobile application requirements

The application will initially be developed as a native application for Android smartphones (with a market share of almost 80% in Spain) in versions 4.4 or higher, with no special hardware or performance requirements, although GPS, communications and a camera may be required for some of the functionalities (which will not be available in devices lacking said features, such as QR code scanning or location tracking).

Regarding requirements for the urban data framework, the platform should access the intermediate gamification server through the corresponding web services and through a secure endpoint (ideally within a secured VPN, although it is not indispensable).

12.3 Mobile application security

Mobile applications will use secure communications in order to ensure the privacy of all the information exchanged with the servers and the platform. The first consideration is to keep the anonymity of the users.

the application will not gather personal information apart from a minimum set of information required to segregate groups of interest (mostly age groups, according to transportation habits or people living near intervention sites), and only a random and unique identifier will be generated, without any need to log into the application or provide any more identity information. Given that the application is not authenticated, only the random identifier is used to group together the responses coming from the same smartphone, and no credentials are exchanged. Also, since the token only resides in the smartphone, if the application is uninstalled and reinstalled at a later stage, there will be no way to relate newer responses with the older responses, and it will behave towards the system as a new user.

All messages will be ciphered using HTTPS with a server-side certificate (so that the client devices can verify the destination server). Given that the information handled at the device is not privacy or safety critical and will not leave the terminal, it is not deemed necessary to perform client-side encryption (information will still be encoded in binary format, so that it is not readily accessible and modifiable).

13 Data management and data privacy (CAR)

13.1 Introduction

Data Management Plans (DMPs) have been introduced in the Horizon2020 Work Programme for 2014-15. Since the main purpose of the DMP is to provide an analysis of the main elements of the data management policy that will be used in the scope of the project with regard to all the datasets that will be managed to carry out the related activities. The scope of the DMP is not only the development of the project, but also after it is completed.

A DMP has to describe the data management life cycle for the data sets that will be collected, processed and/or generated in the scope of the project, and even after it is completed. Processes regarding data collection, processing and generation should be outlined, including methodologies, standards, data access and how this data will be curated and preserved.

According to the EC guideline, the DMP needs to be updated at least by the mid-term and final review of the project, it is not a fixed document; it evolves and will be updated during the lifespan of the project. In this case, updates of the DMP will be developed in M24 and at the end of the project.

13.2 Data Management Plan in the scope of the URBAN GreenUP project

Once the purpose of a DMP has been described, the main elements of the DMP of the URBAN GreenUP project have to be detailed.

Confidentiality issues must be taken into account, but also the dissemination ones, because it is in the interest of some partners to disseminate the results achieved in the scope of the project. As a result, it is important to take into account that the DMP is closely related to the Dissemination Plan, so a compromise must be found between confidentiality and dissemination of the achieved results.

As detailed in picture below, two different types of datasets will be created: the ones containing gathered data and the ones containing the Key Performance Indicators (KPIs) calculated using the aforementioned data. Restricted access will be given to raw data sets, and the calculated KPIs will be free to access and use. The data gathered will be available by ftp (secured using login/password), and the KPIs will be published in the project website[8].

[8] http://www.urbangreenup.eu/

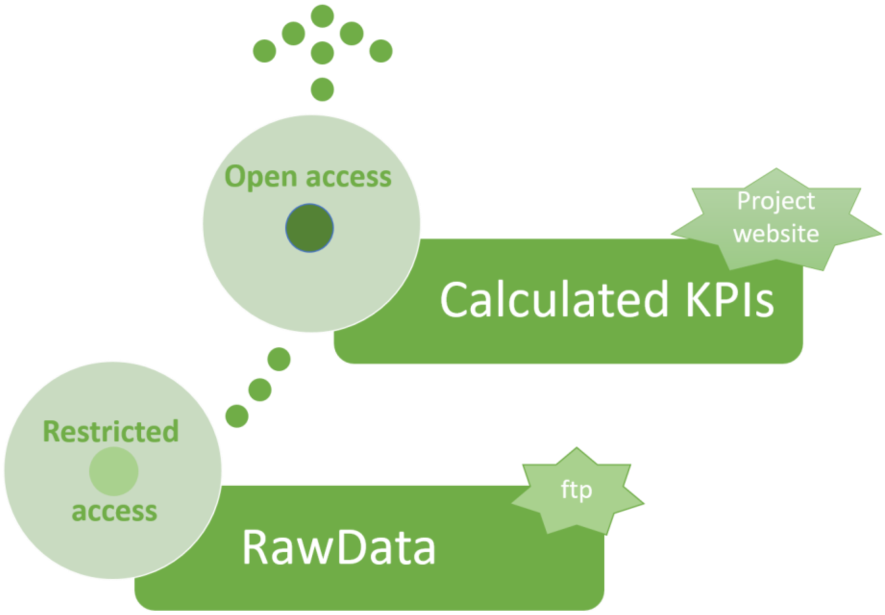

Figure 13.1: Data relation

Concerning the data gathering, and if needed (if personal data will be gathered/processed), all the issues related to the GDPR (General Data Protection Regulation) will be implemented.

As the GDPR is a new regulation, the main differences with the previous directive 95/46/EC regarding the data subject rights are pointed below:

- The conditions for consent have been reinforced for the sake of clarity and intelligibility of the legal terms and conditions, and also making easy the processes of withdraw.
- Breach notification that should be done within 72 hours after the notification.
- Right to access. The data subjects now have the right to get, from the data controller, confirmation that the data is being processed and the purpose of that process.
- Right to be forgotten. The data subject has de right to oblige the data controller to erase the data, cease dissemination and halt processing of the data from third parties.
- Data portability. The data user, once he has received its personal data in a legible digital format from one controller, can send them to another one.
- The territorial scope has been increased, and now the regulation applies to all companies processing data of subjects residing in the EU, independently from the location of the company.

14 References

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15 ANNEX A. Application design: functionality

The application has been designed following Google's Android design application guidelines both from a technical and User Interface points of view.

https://material.io

https://developer.android.com

15.1 Main menu

The application menu allows accessing all the functionality of the application in a simple and quick manner. It also provides useful information that may save useless navigation to some of the options (such as the surveys or the scoreboard). If there are no surveys available to the user (whether it is because there are no active surveys in the system, or the user is not suitable due to the segmentation information), the option is disabled, grayed out and informs the user of the situation. Also, since the scoreboard is mostly intended to keep track of the current ranking of the user, a quick overview of the latest period (week/month) would save him the need to visit the specific functionality for that purpose.

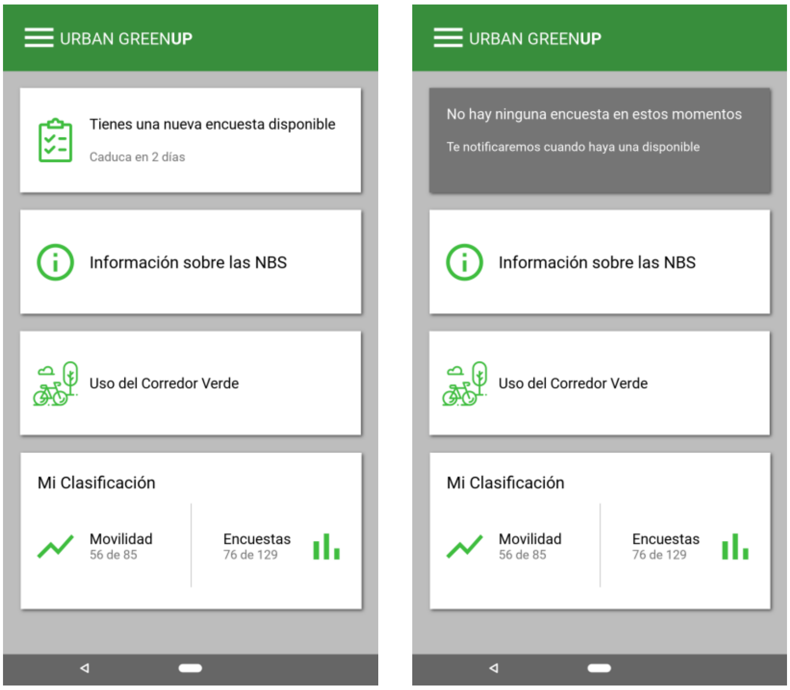

Figure 15.1 Application Main Menu

The current iteration of the design (shown above) is based on material design "cards".

15.2 Survey functionality

The survey functionality is the most flexible way of retrieving feedback from the end-users. Given that the questionnaires may cover a broad range of topics, it is possible to contribute to a wide range of KPIs measurement with a single, common tool. The greatest obstacle when using an online survey tool is getting the user to participate, hence why a gamification mechanism is being studied to include it in the application.

The mobile application will offer a survey "engine" that can render surveys as defined in the backend. This allows defining different survey "campaigns" that will be shown to the user (if he belongs to the target population). All surveys will be setup on the server, so that new surveys can be defined and downloaded on the future. All responses will also be stored on the server, so that no sensible information can be stolen from the application.

The application will provide support for a set of response types:

- Open question
- Numeric values
- Multiple Choice
- Single Choice
- Stars /rating

The question description in itself will may include a shorter text, a longer description and images, if required. This provides a flexible toolset that can be leveraged when defining questions in order to obtain valuable feedback from the users.

Questions will be presented one by one to the user until he finishes the survey. Once all questions have been replied, responses are sent to the server and the user is presented a score associated with his replies.

The application itself will not analyse the responses of the user, it is only responsible for delivering them to the server. The analysis is to be performed at the backend side.

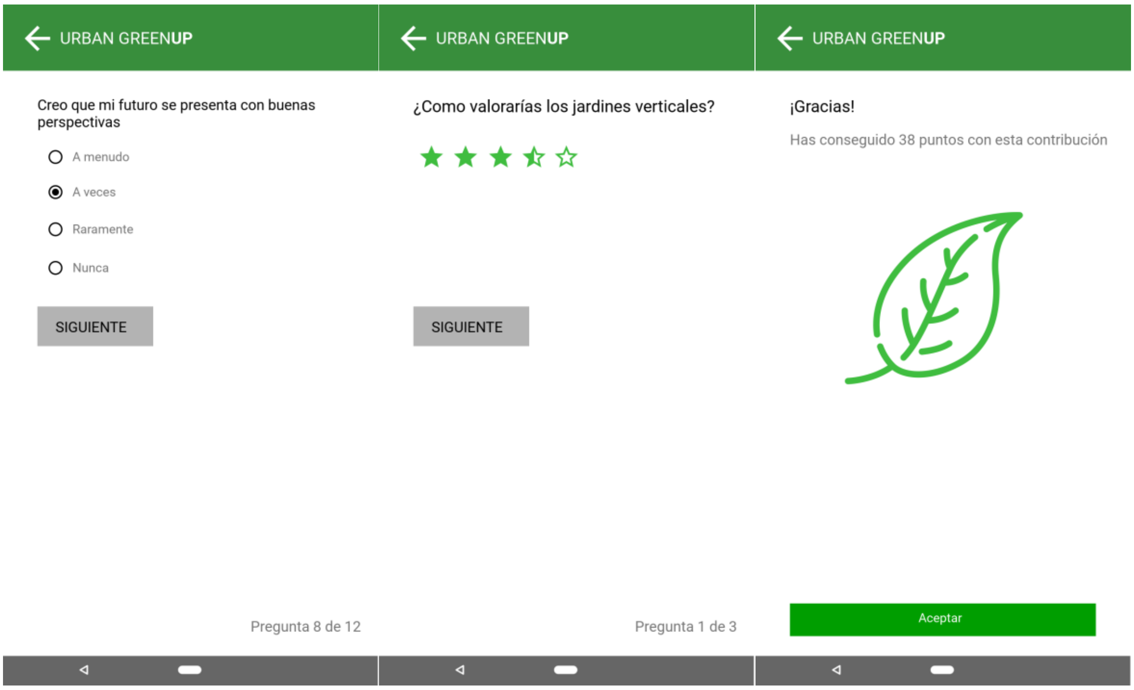

Figure 15.2 Survey initial design

15.2.1 Segmentation survey (first start)

When the application starts for the first time, a special survey will be presented to the user. This survey is the only one that will be hardcoded in the application itself, and it will allow deciding (anonymously) which surveys to present to the user. The survey will request the user to provide some basic information such as age range, region of the city where he lives (postal code) or usual transportation modes (car, walking, public transport, etc.). Once all the questions of the segmentation survey have been provided, a unique ID is generated in the phone and stored internally. This allows correlating the responses of the surveys to a single user and providing him with the corresponding scores without getting any personal information.

When the application detects that the unique ID is already present, the initial survey is not requested anymore.

The specific questions of the segmentation survey are not closed yet, although they should be broad enough to keep users anonymous while allowing gathering relevant information (e.g. only presenting surveys about the well-being of elderly people to people of that age range).

15.3 Green corridor functionality

The green corridor functionality will measure the activity of users within the area of the intervention. Although it would be possible to use the phone's GPS to determine when he approaches the area, continuous tracking of the user would be controversial, at best, and would certainly cause rejection from the users. Therefore, we will leverage the gamification mechanisms to promote the usage of the functionality, and only monitor their activity when explicitly requested by the user (which would be necessary to achieve rewards).

The application will offer the users the possibility to start the tracking of their activity in the green corridor, and they will raise their score on the mobility axis the longer the time they remain and move within the area. When enabled, a persistent notification will remind the user that the function is active. Once the user leaves the area for more than a time threshold (10 seconds by default) or turns it off manually, the tracking stops and a score is calculated according to the time spent and distance travelled within the corridor. The time threshold is necessary since the position may drift significantly in urban areas and moreso when there is foliage in the area (as is expected in the green corridor). The value can be tuned afterwards, but a too low value may be unable to cope with position "bounces" caused by GPS interference and multipath, whereas a too long value would also be undesirable since it would introduce a delay in the detection of the user leaving the area.

The tracking will continue even if the application is in the background, although a notification will be displayed in the system, reminding the user that the application is running and allowing him to turn it off any moment.

15.4 NBS information functionality

The mobile application will also provide information about the nature based solutions deployed in Valladolid. To simplify the access to the information, a split view with a list of interventions and a map of the city will be displayed (with the current location of the user) will be shown. In there, the user can access further details on the nature based solutions deployed in the city either by clicking on the icons of the map, or in the elements of the list. A set of category toggles will allow quickly filtering among the available NBS.

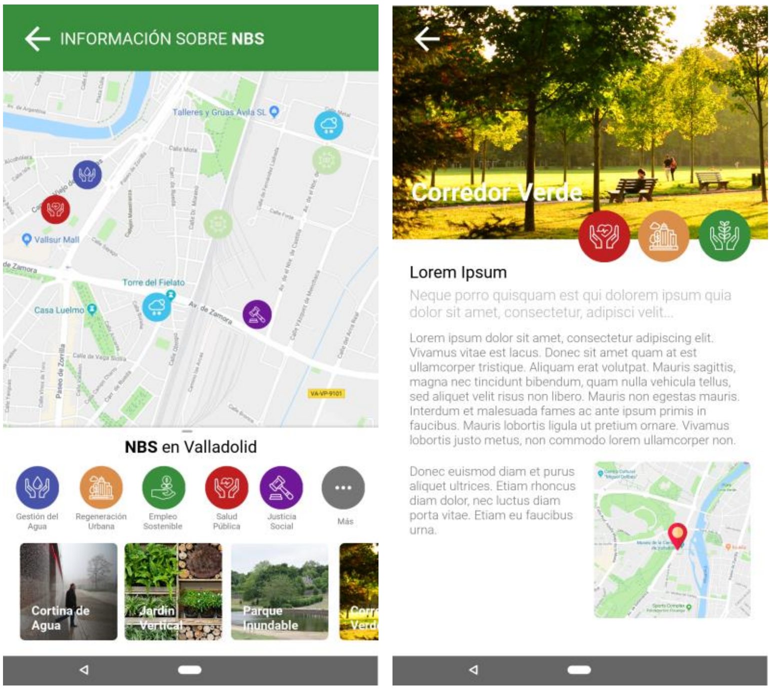

Figure 15.3 NBS Information screens design

Once the user selects a particular element, a detail view is shown with more information about the NBS, such as location, expected impact, additional pictures, etc. At the moment it is not closed whether the information will come from the backend, to simplify the update process or it will be already pre-loaded on the application itself, since it is not expected that the NBS will change, and it would allow for more custom formatting, whereas loading the information from the server would limit the information to follow a pre-set template (or a set of templates).

15.5 Scoreboard functionality

The final functionality of the application is the scoreboard. The application needs a mechanism to motivate the users to interact with it, learn more about nature based solutions, monitor their activity in the green corridor and participate in the surveys. At the current moment, the functionality's scope is limited to displaying the current user score along two axis, mobility and participation in surveys.

The scoreboard functionality and periodical reset of the scores (weekly/monthly/yearly) is meant to motivate the users to reach a high score and beat other users of the application. Some kind of rewards, either in-app, digital rewards such as trophies or badges or physical/real world ones, such as free trips on public transport based on the user scores would certainly increase the user interest, but in order to provide such rewards, further interaction with the municipality is required (since it would be them who provided the prizes).

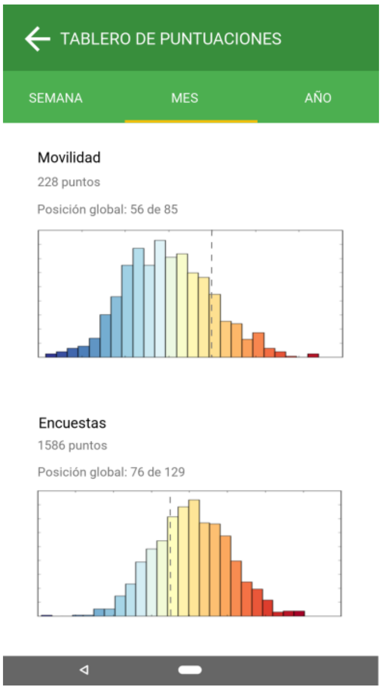

Figure 15.4 Scoreboard preliminary design

For the moment, a token functionality is foreseen showing the current classification of the user along the two axis in the current period, and any rewarding scheme could be built on top of the basic rating functionality according to the user ranking per period of time.

15.6 Conclusions

This annex summarizes the design of the mobile application that will be developed as part of the monitoring activities of the Urban GreenUP European project. It described the application functionality and included some mock-up pictures of a possible user interface design. The application as described will support the monitoring of the deployed Nature Based Solutions and provide valuable information coming from the end-users, the citizens, in order to calculate several of the core KPI of the project.

The positioning capabilities (and activity tracking) of modern smartphones should prove a valuable tool to monitor the use of the green corridor developed in Valladolid, whereas the survey engine designed in the application should provide a flexible tool allowing direct interaction with the citizens to gather information on several topics, from air quality, to noise levels or general health and well-being.

The multimedia capabilities of the devices are also an ideal vessel to provide information about the NBS, which will be made accessible through the mobile application to the users, particularly if they want to read further information at the NBS site.

Finally, the gamification element, although basic, can promote the usage of the application, and sets the basis for further improvements and future developments.

This design covers the core functionality which is necessary in the scope of the project. However, it remains open to modifications, since further iterations with the Valladolid Municipality are required in order to integrate this application with the digital development strategy of the municipality, and also in order to close several details (such as the rewards of the participation) that depend on their specification and policies.

16 ANNEX B. Application architecture

The architecture proposed for the Urban GreenUP mobile application follows a MVP (Model - View - Presenter) desing pattern, and also the Clean Architecture design principles. Although there are several Clean Architecture implementations, given that it is not a tool or framework, but rather a design philosophy, they all seek the same purpose, which is to ensure the separation of concerns in the designed application. Code is organized in modules, which are also organized in several layers, each of which takes care of a particular functionality, that is, the model of a particular use case of the business logic, or to present information to the user or how to interact with a particular data source. The key of this approach is that it focuses on defining what the application itself does, irrespectively of the actual underlying technologies and tools used to develop it. Also, it divides the business model domain from the databases or web services that hold/provide the actual data.

A clean application is characterized by the following properties:

- **Framework independent:** The architecture itself does not depend on any library or tool that may limit the design with its features and requirements. This allows using frameworks as tools, rather than constraint our system to restrictions imposed by the tools used to develop them.
- **Testable:** The business logic can be tested without user interface, database, web server or other external elements
- **UI independent:** The graphical user interface can easily be replaced without further impact in the rest of the application, business logic or data layers.
- **Database independent:** The business rules are not bound by any DBMS used to hold application information
- **External factor independent:** Using the clean architecture, the business logic should not be affected by any change on the surrounding external elements, or whether a domain object has changed due to interaction with external systems.

This approach allows for a more independent code and splitting/parallelization of work, providing verifiable and easy to maintain modules. An example of the proposed layer approach to the architecture is included below:

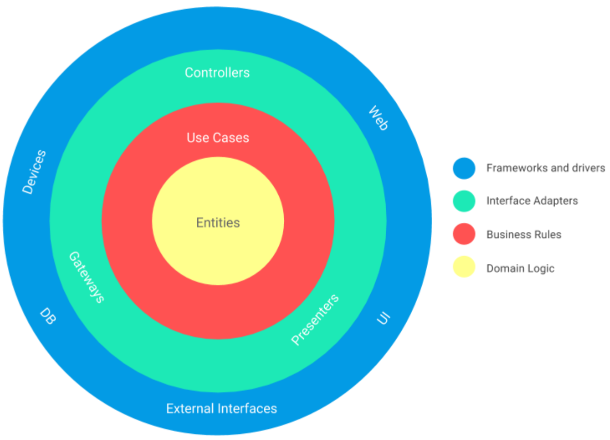

Figure 16.1 Clean application layer approach

Concentric circles represent different software areas. In general terms, the further we are from the center, the higher the software level is. Inner circles represent the business logic, and external circles represent the outside world, be it the user interface or external systems and data repositories.

The key rule to follow during desing is that code dependencies are only allowed in one direction, that is from outside to the inside. The entities of our system cannot depend on any element on an outer layer, as it may be a database, web service, etc. That is how separation of concerns is achieved.

The proposed structure includes:

- **Entities:** They represent the high level business rules. These entities should never be affected by changes in external elements.
- **Use cases:** They contain the business rules specific to the application. These use cases direct the flow of information from and to the entities and uses the business rules to achieve the use case objectives. They may also be called interactions.
- **Interface adapters:** It's a set of adapters that convert data between the format required in the use cases and the format used by external sources, such as the database or the web. Presenters, views and controllers of the MVP architecture often belong to this layer. Models are only structures that are exchanged between controllers and use cases back and forth, and forwarded to the views. Likewise, information coming from the user is converted to the format which is most convenient to the use case and then to whatever the persistence framework chosen to store information requires.
- **Frameworks and drivers:** The most external layer is composed by frameworks and tools like the database, the user interface, etc.

The figure below shows how the clean architecture principles can be applied to a MVP application:

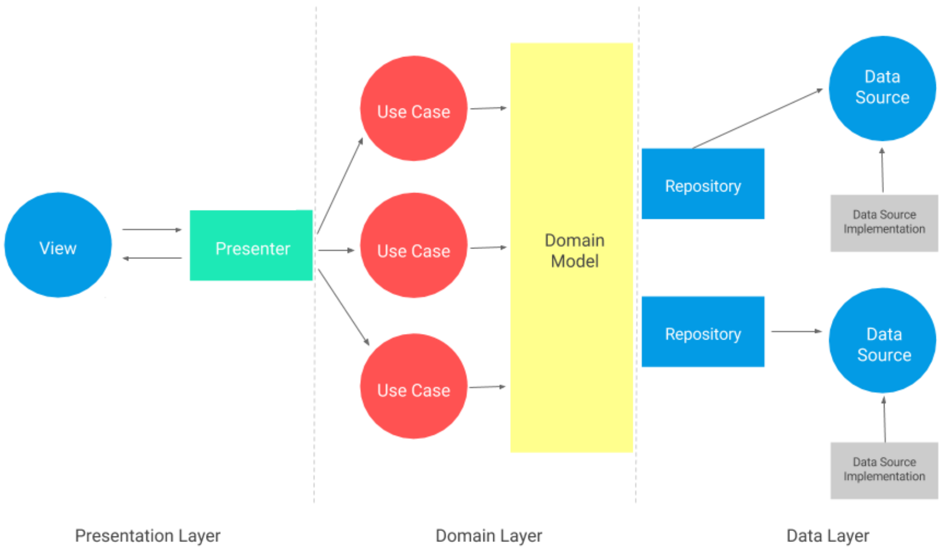

Figure 16.2 Clean application principles applied to a MVP application schema

The colours of the image represent to which of the Clean Architecture layers that particular element belongs.

Presentation Layer

This layer is where everything related to views takes place and it manages the interaction with the user. It may have logic components but only presentation-related logic, that is, deciding what and when is shown to the user.

Domain Layer

This layer contains all the business logic. The domain layer defines what the application itself does, and includes all entities and use cases. The domain layer should be pure code, that is:

- it doesn't cause collateral effects
- it doesn't depend on the status of an element external to the application itself
- the same inputs always produce the same outputs

Data Layer

This layer is where all the information required by the application to work is gathered. The information may come from the database, an external sensor or a web service.

16.1 Functionality and SW modules

The core objective of this design is to build a mobile application to monitor the effectiveness of the deployed NBS, for which it will gather data to assess several of the core KPIs defined in the project, either through surveys presented to the user or leveraging on the sensors available on the smartphone itself. In general, to monitor the usage of the green corridor, it is enough to use the sensors of the smartphone to determine the location of the user. Furthermore, modern smartphones integrate "activity" or "health/lifestyle" APIs, which provide information on the current activity and transportation mode of the user (whether he is driving, cycling, stationary or walking).

As for the surveys functionality, the mobile application will communicate with a backend that provides information about currently available surveys, and store the responses once completed.

The application needs for very little persistent data stored in the device, namely the unique identifier generated when the user logs in for the first time. Everything else is sent to the backend, and only stored temporarily on the application itself. Although it is not needed, it may be possible to store some information on the device to show cached data in the application screens while it is updated with information coming from the server.

16.1.1 User information management

The application will limit the amount of information gathered from end-users. A minimum of questions regarding the user age, mobility habits and area of residence will be requested in order to be more accurate with the surveys interpretation.

No user login will be required, although a unique ID will be generated in the phone and sent along with the requests to be able to group all requests coming from the same user and to allocate the corresponding score to the user.

16.1.2 Backend communications

Mobile applications will use secure communications in order to ensure the privacy of all the information exchanged with the servers and the platform. There is no point in user authentication, but all messages will be ciphered using HTTPS with a server-side certificate (so that the client devices can verify the destination server). Given that the information handled at the device is not privacy or safety critical and will not leave the terminal, it is not deemed necessary to perform client-side encryption (information will still be encoded in binary format, so that it is not readily accessible and modifiable).

16.1.3 Architecture overview

The following figure describes a possible implementation of the clean architecture to address all the functionality required by the design:

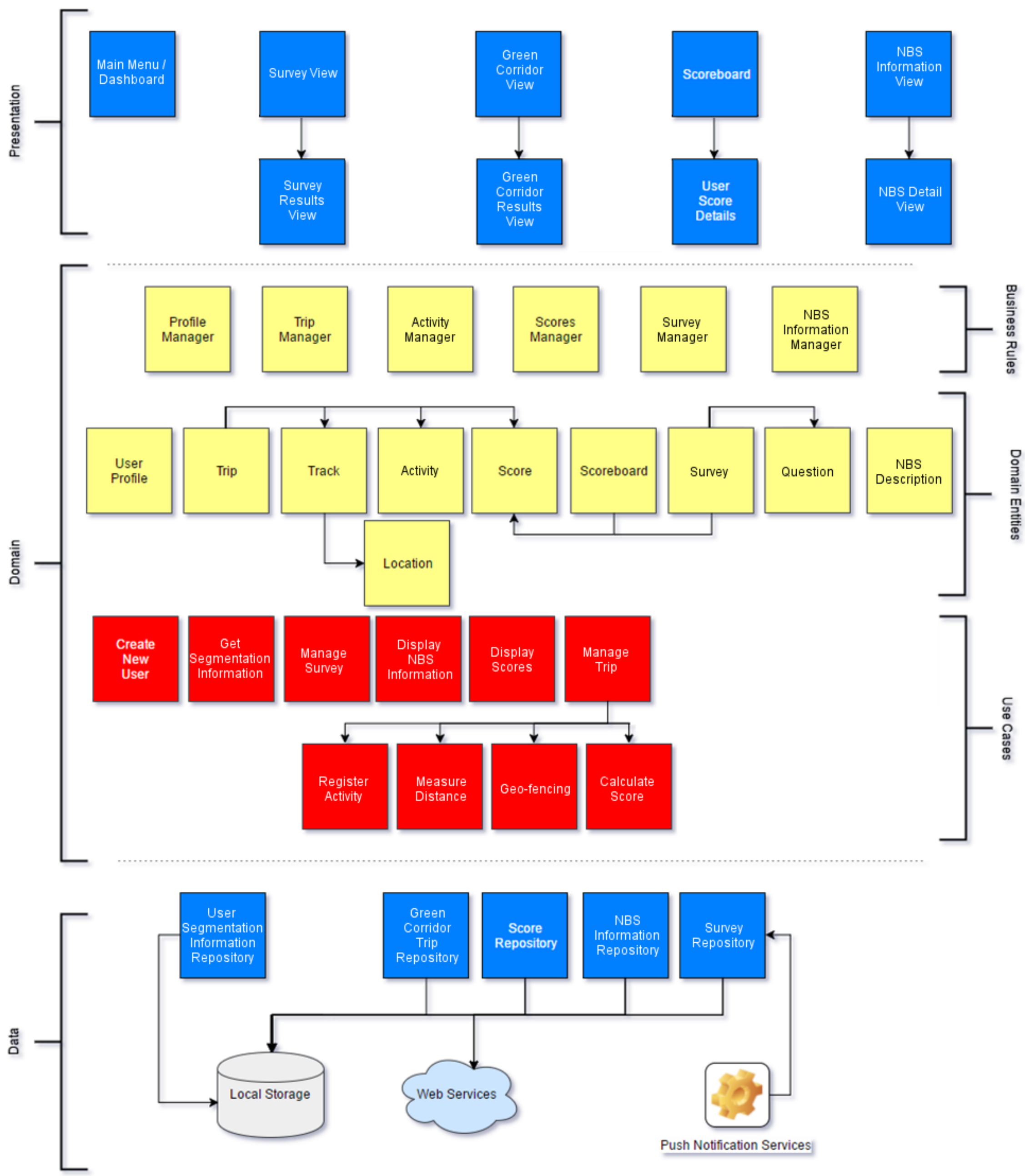

Figure 16.3 Valladolid demosite mobile app architecture

16.2 Conclusions

Given the high penetration rate and ubiquity of smartphones in the population, a smartphone application constitutes an ideal channel to interact with end users, since it establishes a bidirectional and permanently available bidirectional channel of communication with them. This document summarizes the architecture of the mobile application that will be developed as part of the monitoring activities of the Urban GreenUP European project.

The described architecture follows the clean architecture design principles to keep the separation of concerns and improve the overall application modularity, simplifying the testing and maintenance of the application in the long term.

This architecture covers the core functionality which is necessary in the scope of the project. However, it remains open to modifications, since further iterations with the Valladolid Municipality are required in order to integrate this application with the digital development strategy of the municipality, and also in order to close several details (such as the rewards of the participation) that depend on their specification and policies.